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World Conference on Engineering and Technological Sciences
Hosted Online from Rome, Italy
Date: 8th April, 2026
Website: https://econferencia.com

ANALYSIS OF METHODS FOR CALCULATING TECHNICAL AND ECONOMIC INDICATORS OF MACHINE SYSTEMS

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Abstract:
This scientific study analyzes the methods for calculating the technical and economic indicators of machine systems, their theoretical foundations, and practical application possibilities. The research examines deterministic and stochastic approaches, as well as life cycle cost (LCC)-based evaluation methods, highlighting their advantages and limitations. In addition, the study considers issues of technical justification of machine complexes used in construction processes, particularly in earthworks during the construction of residential buildings. Based on the analysis of scientific literature, the limitations of existing approaches are identified, and the necessity of an integrated assessment of machine systems is substantiated. The results of the study contribute to improving the efficiency of machine systems, reducing costs, and optimizing production processes.

Keywords: Machine systems, technical and economic indicators, efficiency, operating costs, reliability, productivity, deterministic approach, stochastic

approach, life cycle cost (LCC), construction technology, earthworks, mechanization, optimization, digital modeling, resource utilization.

Introduction

In modern production and construction industries, machine systems constitute a key component of technological processes, and their efficiency has a direct impact on the overall economic performance of enterprises. Therefore, the accurate calculation and analysis of the technical and economic indicators (TEI) of machine systems is considered one of the important directions of engineering economics. Technical and economic indicators include a set of parameters such as operational efficiency, reliability, energy consumption, productivity, and operating costs of machines and mechanisms. According to scientific literature, the economic efficiency of machine systems is determined not only by their technical capabilities but also by operating conditions, the quality of maintenance services, and the level of operational management. Methods for calculating TEI are generally based on deterministic and stochastic approaches. Deterministic methods rely on precise values of machine parameters, whereas stochastic methods take into account their random variability. In addition, modern approaches widely apply discounting methods and Life Cycle Cost (LCC) analysis. These methods enable a comprehensive assessment of all costs incurred over the entire service life of a machine. Technical and economic analysis of machine systems is important not only for their selection but also for developing optimal operational strategies. Therefore, research in this field contributes to improving production efficiency, rational use of resources, and enhancing the competitiveness of technical systems. Overall, a deep analysis of methods for calculating technical and economic indicators of machine systems represents one

of the urgent scientific and practical problems of modern engineering economics and production management.

In the global practice of residential building construction, optimization of earthwork processes is of particular importance. Considering that earthworks account for approximately 15–25% of total construction works, the technical justification of machine complexes used in these processes is highly relevant. Currently, in developed countries, earthworks in residential construction are increasingly performed using modern universal construction machinery, which significantly enhances construction efficiency. In this context, the introduction of modern technologies into excavation and site preparation processes, automation and monitoring of operations, as well as the optimal selection and utilization of machine systems, are of great importance. Such approaches allow for reducing construction costs, saving time, and increasing labor productivity, thereby enabling a deeper technical justification of machine systems used in earthworks and their role in residential construction processes. Consequently, advanced solutions and innovative technologies are aimed at improving quality and efficiency in the construction sector.

International experience shows that the technical justification of machine systems for earthworks plays a crucial role in ensuring the safety and reliability of buildings and structures, increasing labor productivity in construction processes, and rationally reducing costs without compromising quality. In residential construction, the mechanization of earthworks is essential. To ensure quality, effectively reduce manual labor, and improve the efficiency of machinery use, there is a need for modern technologies and equipment. Compliance with regulatory requirements during earthwork operations helps shorten construction timelines and reduce project costs. For these purposes, the development of scheduling plans, reduction of labor costs, and ensuring the safety and reliability

of structures are the focus of ongoing scientific research aimed at increasing labor productivity and reducing construction costs.

Analysis and Main Results. The calculation of technical and economic indicators (TEI) of machine systems plays an important methodological role in construction production planning, the efficient use of resources, and the scientific justification of design and technological decisions. Existing scientific studies mainly address this issue within the framework of normative calculations or empirical observations. However, they insufficiently consider the multi-factor and dynamic conditions of real construction sites. As a result, the obtained calculation outcomes often correspond to idealized conditions and do not fully ensure the expected technical and economic efficiency in practice.

In the works of V.A. Afanasyev, a normative approach is used as the basis for evaluating TEI of machine systems. Although this approach simplifies the calculation process and facilitates planning activities, it does not adequately reflect technological disruptions, organizational constraints, and variability of working conditions that occur in real construction environments. Therefore, normatively based calculations cannot fully represent the actual performance of machine systems. A.V. Repin applies deterministic models in which the production process is assumed to be stable and predictable. However, in earthwork conditions, variability of soil properties, interruptions in transportation processes, and organizational factors violate these assumptions. Consequently, the applicability of Repin's models is limited in real construction practice.

V.B. Smirnov proposed integral technical and economic indicators that allow a generalized evaluation of machine systems. Nevertheless, the insufficient differentiation of quality and reliability factors within these indicators complicates the identification of clear technological priorities in decision-making processes. In the research of S.A. Barkalov, the adaptation of technical-economic

models to production environments is addressed. However, the proposed models are mainly oriented toward large-scale industrial facilities and do not fully correspond to the conditions of residential construction, which are characterized by limited working space and short-duration work phases. A.L. Mailian investigated the relationship between production efficiency and TEI, focusing mainly on individual technological operations. However, the system-level evaluation of machine complexes as unified technological entities remains insufficiently developed, limiting the effectiveness of a systemic approach.

A.V. Skvortsov introduced a multi-criteria evaluation method for comparing machine systems. Nevertheless, the subjectivity in determining weighting coefficients reduces the accuracy of decision-making results. In the studies of V.G. Fedorov, the concept of hidden losses in evaluating economic efficiency is highlighted. However, the lack of a well-developed mechanism for identifying and quantifying these losses limits their practical application. In recent years, foreign research based on BIM and digital modeling technologies has significantly expanded simulation capabilities of machine systems. However, these models are mostly limited to technical parameters and do not comprehensively integrate economic and organizational factors, which restricts their applicability under real construction conditions. Studies conducted by researchers from CIS countries often evaluate machine system efficiency based on time norms. While this approach is useful for planning purposes, it does not sufficiently capture technological mismatches between machines or identify bottlenecks in production systems. As a result, overall system efficiency is often constrained by the slowest operational element without adequate analytical justification.

Economic evaluation approaches commonly consider only direct costs such as fuel consumption, depreciation, and maintenance expenses. However, hidden

losses associated with technical failures, downtime, organizational disruptions, and deviations from planned schedules are often neglected, leading to an underestimation of the real cost of machine systems. In some studies, machine system efficiency is treated as a simple sum of individual machine indicators. Such an approach contradicts system engineering principles, as it ignores functional and technological interdependencies between machines. In practice, the performance of one machine directly affects the working conditions and productivity of others, requiring a comprehensive system-level evaluation.

Stochastic models provide high accuracy in assessing reliability and operational probability of machine systems. However, due to their mathematical complexity, their practical implementation in everyday construction management remains limited. The conducted analysis shows that although existing approaches to TEI calculation have addressed certain aspects of the problem, they have not yet been unified into a comprehensive, multi-criteria, and scenario-based methodological system adapted to real construction conditions. Therefore, this dissertation proposes the development of an integrated methodological approach that treats machine systems as a unified technical-economic object and combines normative, modeling, and integral evaluation methods into a single coherent framework.

Conclusions and Recommendations

The analysis of methods for calculating technical and economic indicators (TEI) of machine systems shows that their efficiency is closely related not only to technical parameters but also to economic indicators. In modern production conditions, a comprehensive assessment of machine productivity, energy consumption, reliability, and operating costs is of great importance. Such an integrated approach enables a more accurate evaluation of real system performance and supports rational decision-making in engineering practice.

According to the research results, deterministic and stochastic methods are the main approaches used for evaluating machine systems, and they produce different outcomes under different operational conditions. Deterministic methods are relatively simple and convenient; however, they do not fully reflect the variability of real production environments. Stochastic methods, on the other hand, account for uncertainty and random factors, although their practical application is often limited by mathematical complexity.

Furthermore, Life Cycle Cost (LCC) analysis has been identified as one of the most effective methods for determining the real economic efficiency of machines over their entire service life. This approach provides a reliable basis for equipment selection and operational decision-making. In general, the correct calculation of technical and economic indicators plays a crucial role in improving production efficiency, reducing costs, and ensuring the stable operation of technical systems.

Recommendations

It is advisable to introduce a life cycle cost (LCC)-based evaluation approach in machine selection processes instead of relying solely on initial purchase cost.

- the use of modern software tools and digital modeling methods should be widely implemented in technical and economic analysis processes.
- monitoring systems for machine reliability and operational efficiency should be introduced at enterprise level.
- continuous professional development courses on technical and economic calculation methods should be organized for engineering and technical staff.
- priority should be given to energy-efficient and high-performance machine systems in order to reduce overall production costs.

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