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ASSESSMENT CRITERIA FOR ORGANIZATIONAL AND TECHNOLOGICAL RELIABILITY OF MACHINE OPERATION

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Abstract

This article examines the assessment criteria for organizational and technological reliability of machine operation, as well as their theoretical and practical foundations and their significance in production processes. It is substantiated that the reliability of machines is determined not only by technical parameters but also by the level of organizational management and the stability of technological processes. The main factors characterizing organizational reliability are analyzed, including the technical maintenance system, the quality of planning, resource availability, and the human factor. Technological reliability is studied in relation to the machine’s ability to operate continuously and efficiently under specified operating conditions. In addition, the assessment of the reliability of machine complexes in earthworks, the processing of full-scale test results, and the principles of mathematical modeling are considered. The results demonstrate that these approaches are essential for improving the overall efficiency of machine systems and reducing operational costs.

Keywords: Machine reliability, organizational reliability, technological reliability, assessment criteria, earthworks, machine complex, technical readiness, operation, statistical analysis, systems approach.

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Introduction

The efficient operation of machines and mechanisms plays a crucial role in the sustainable development of modern production systems. The increasing complexity of production processes, the automation of technological systems, and the growing demand for higher productivity are placing ever more stringent requirements on the reliability of machines. Therefore, the comprehensive assessment of organizational and technological reliability of machine operation is considered one of the most relevant scientific and practical issues today. The reliability of machines is generally characterized by their ability to perform specified functions without failure over a defined period of time. However, practical experience shows that assessment based solely on design or technical parameters is insufficient. The level of reliability is largely determined by the degree of production organization, maintenance systems, operational conditions, and the effectiveness of technological processes. For this reason, an evaluation approach that takes into account both organizational and technological factors is of significant importance.

Organizational reliability is associated with factors ensuring the continuity of production processes, including planning quality, efficiency of maintenance systems, availability of spare parts, and management of the human factor. Technological reliability, on the other hand, reflects the machine's ability to perform its functions consistently and efficiently within specified technical parameters under specific production conditions. The interaction and balance between these two components determine the overall level of reliability. The aim of this article is to scientifically substantiate the assessment criteria for organizational and technological reliability of machine operation, identify their structure, and systematically analyze evaluation methods. The study examines the system of reliability indicators, the main influencing factors, and their role in improving production efficiency.

To successfully implement these tasks, it is important to develop scheduling plans and create modern software tools aimed at improving the effectiveness of project documentation management among construction participants. In addition, particular importance is attached to reducing labor input and construction duration, as well as technically substantiating machine complexes for earthworks in the construction of high-quality residential buildings. Relevant in this regard

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are the Decree of the President of the Republic of Uzbekistan No. PF-5577 dated November 14, 2018 "On additional measures to improve state regulation of the construction sector," the Decree No. PF-5963 dated March 13, 2020 "On additional measures to deepen reforms in the construction sector of the Republic of Uzbekistan," and the Decree No. PF-6119 dated November 27, 2020 "On modernization, rapid and innovative development of the construction industry of the Republic of Uzbekistan." Also significant is the Presidential Decree No. PF-60 dated January 28, 2022 approving the "Development Strategy of New Uzbekistan for 2022–2026." Furthermore, Resolution No. PQ-3550 dated February 20, 2018 "On measures to improve the procedure for conducting expertise of pre-project, project, tender documentation and contracts," and Resolution No. PQ-4464 dated September 20, 2019 "On measures for the wide implementation of information and communication technologies in the construction sector," along with other regulatory documents, define the implementation of sectoral tasks. This article contributes, to a certain extent, to the realization of the objectives set forth in these regulatory frameworks.

Literature Review

The issues of assessing organizational and technological reliability of machine operation have been widely studied by numerous domestic and foreign researchers, and various scientific approaches have been developed in this field. The initial foundations of reliability theory were focused on determining the probability of failure-free operation of technical systems. Later, this concept evolved into a more complex system-based interpretation that also includes organizational and technological factors. Scientific literature indicates that the assessment of machine reliability is primarily based on statistical and probabilistic methods. Many researchers widely use indicators such as failure-free operating probability, mean operating time, time between failures, and repair time. At the same time, some scholars emphasize that these indicators mainly reflect the technical condition of machines and do not fully represent production efficiency.

In modern research, organizational reliability is considered a separate direction, where production management quality, optimization of maintenance systems, logistics, and the level of resource provision are identified as key factors. In

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several studies, planned maintenance systems (preventive and predictive maintenance) are recognized as one of the main tools for improving overall machine reliability. In studies related to technological reliability, the main criterion is the machine's ability to perform a given technological process continuously and with high quality under specific operating conditions. In this regard, the stability of production parameters, adaptability to load variations and external influences, and indicators affecting product quality are of significant importance.

In recent years, a systems approach has been widely applied in scientific literature. According to this approach, machine reliability is evaluated not only based on its technical condition but also in close interrelation with the surrounding organizational and technological environment. In this context, the "human–machine–environment" system is considered the main object of analysis. Furthermore, the development of digital technologies and monitoring systems has created opportunities for real-time assessment of reliability indicators. The analysis shows that although certain results have been achieved in existing studies on assessing organizational and technological reliability of machine operation, there remains a need to integrate these indicators into a unified system, develop comprehensive evaluation criteria, and adapt them to practical applications. Therefore, conducting in-depth scientific research in this direction remains one of the most relevant tasks.

Research Methodology

In this study, a systematic and comprehensive approach was applied to develop and analyze the assessment criteria for organizational and technological reliability of machine operation. The research methodology is aimed at studying the operational processes of technical systems, identifying reliability indicators, and evaluating them in relation to organizational and technological factors. During the research process, several scientific methods were employed. In particular, the statistical analysis method was used to collect data on machine failures, operating time, and repair intervals, which were then utilized to calculate reliability indicators. Based on probability theory, the probability of failure-free operation and the frequency of failures were determined, enabling the assessment of the system's overall reliability level.

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Using a systems approach, the machine operation process was considered as a "human–machine–technological environment" system, and the influence of each component on overall reliability was analyzed. This approach made it possible to study organizational and technological factors not separately, but as an interconnected system. In addition, a comparative analysis method was applied to compare machine performance indicators under different production conditions. This helped to determine how the level of organizational management and the efficiency of technological processes affect reliability.

An expert evaluation method was also used, where the main criteria of organizational reliability were formed based on the opinions of industry specialists. In this context, indicators such as the quality of maintenance services, the level of planning, resource availability, and the human factor were assessed as key determinants. To generalize and systematize the obtained results, elements of mathematical modeling were used. This approach enabled the assessment of organizational and technological reliability of machine operation within a unified system of complex indicators. Overall, the applied methodological approaches allowed for a comprehensive study of machine reliability not only from a technical perspective but also from organizational and technological viewpoints, thereby increasing the scientific and practical significance of the research results.

Analysis and Main Results

During the article, the criteria for assessing organizational and technological reliability of machine operation were systematically analyzed, and their influence on practical performance indicators was studied. The conducted analyses showed that the overall reliability of machines is determined not only by technical parameters but also by the level of organizational management and the stability of technological processes. Statistical data analysis revealed that a significant share of failures occurring in production processes is caused not only by technical breakdowns but also by organizational shortcomings-such as unplanned maintenance, interruptions in spare parts supply, and human-factor-related errors. This situation highlights the necessity of improving the level of organizational reliability.

The results of technological reliability assessment confirmed that the machine's ability to operate stably under a defined working regime depends on the accuracy

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of the production process and technological discipline. Load variations, disruption of operating regimes, and instability of technological parameters were found to lead to a decrease in machine efficiency. Based on the analysis, the main factors of organizational reliability were identified as: efficiency of the maintenance system, quality of production planning, level of logistics and spare parts supply, and personnel qualification. Each of these factors was found to have a significant impact on the overall reliability level.

The study also showed that when organizational and technological factors operate in harmony, the probability of failure-free machine operation increases significantly. According to the results of the integrated assessment, enterprises where system-based management was implemented experienced a reduction in failure frequency and an increase in mean operating time. As a key conclusion, it can be stated that the formation of a unified system of comprehensive criteria for assessing organizational and technological reliability of machine operation is necessary. Such a system, by jointly considering technical, organizational, and technological indicators, contributes to improving production efficiency and reducing operational costs.

In residential construction, the reliability of machine systems during earthworks is one of the key factors determining construction productivity. Earthworks consist of a set of interrelated technological operations, including excavation, loading, transportation, unloading, and leveling. Each of these operations is performed by specific machines, and the continuity of the technological chain depends on the coordinated operation of the machine system. If a disruption occurs in any link of this chain, the efficiency of the entire production process decreases. Therefore, assessing the reliability of machine complexes is an important component of scientifically based construction organization.

The organizational and technological reliability of machine operation reflects the ability of a machine complex to operate continuously and stably under given production conditions. In earthworks, excavators, transport vehicles, and auxiliary machines form an integrated technological system. In this system, the excavator is considered the leading machine, while other machines are selected according to its productivity. The stability of the leading machine determines the efficiency of the entire system. This approach is one of the fundamental principles

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in construction machinery selection theory and ensures the continuity of the technological chain.

According to the construction norms and regulations of the Republic of Uzbekistan, earthworks must be performed using a highly mechanized approach, and the technological process must be organized continuously. The number of machines in construction operations should be determined in accordance with the productivity of the leading machine. This requirement is aimed at ensuring the organizational reliability of machine complexes and improving production efficiency. Site conditions, transport movement, and logistics capabilities are also taken into account when selecting machine systems.

The organizational reliability of machine operation is determined by production-related organizational factors. These include the sufficiency of machine quantity, work scheduling, logistics conditions, and maintenance systems. Poor organization of work on construction sites increases machine idle time, which leads to a decrease in productivity. In the conditions of Tashkent city, the limited size of construction sites, dense traffic flow, and complex infrastructure create additional constraints for machine operation. Therefore, the maneuverability of machines must be considered when selecting machine complexes.

Technological reliability is defined by the production compatibility of machines. In earthworks, excavation, loading, transportation, and leveling operations are performed sequentially. If coordination between these operations is disrupted, machine downtime occurs. For example, if the number of transport vehicles is insufficient, the excavator remains idle; if transport vehicles are excessive, their efficiency decreases. In accordance with construction standards, earthworks must be organized as a continuous technological process, which ensures the technological reliability of machine complexes.

In assessing the technical reliability of machine systems, the coefficient of technical readiness is used. This indicator reflects the degree to which a machine is in an operational condition and is defined as:

Kt = Tish / (Tish + Ttamir)

This indicator allows for the assessment of the technical condition of the machine. A high technical readiness coefficient ensures stable machine operation and increases the continuity of the production process.

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The machine utilization coefficient is considered an important indicator for evaluating organizational reliability and is defined as follows:

Kf = Tfoyd / Tkal

This indicator evaluates the actual operational performance level of machines. In construction processes, reducing machine idle time contributes to improving this coefficient. Proper planning of organizational measures increases machine efficiency. The technological compatibility coefficient assesses the degree of coordination within a machine complex. The overall productivity of a technological chain is determined by the machine with the lowest productivity. This is known as the "bottleneck principle":

Km = Qmin / Qmax

This indicator makes it possible to evaluate the technological reliability of machine systems. To assess the overall reliability of a machine system, an integral indicator is used, which combines the main partial reliability coefficients into a single comprehensive measure.

Kint = Kt · Kf · Km

The integral indicator makes it possible to determine the overall operational stability of a machine complex. Integral evaluation is widely used in the optimization of machine systems. Soil (ground) conditions have a direct impact on the reliability of machine operation. The type, moisture content, and density of soil significantly influence the selection of excavation equipment. According to construction standards, earthworks must be organized taking into account the physical and mechanical properties of the soil. Climate conditions are also a key factor affecting the organizational and technological reliability of machine operation. Temperature, wind speed, and humidity levels can significantly influence machine performance efficiency. Therefore, climatic factors must be considered in planning machine operations.

Thus, the organizational and technological reliability of machine operation is based on a comprehensive assessment of technical readiness, utilization level, technological compatibility, and external influencing factors. These indicators are interrelated and are jointly considered when evaluating the effective performance of machine complexes. While the technical readiness coefficient determines the serviceability level of a machine, the utilization level reflects how efficiently the machine is used in real production processes. Technological compatibility ensures

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coordination between machines and guarantees the continuity of the technological chain. The integrated assessment of these factors allows for determining the overall operational stability of machine systems.

In addition, external factors have a significant impact on machine reliability. In particular, the physical and mechanical properties of soil, the relief of the construction site, availability of transport infrastructure, and climatic conditions determine machine efficiency. For example, in dense soils, the load on excavation machines increases, which may affect their technical readiness. Similarly, limited construction site space restricts transport movement, leading to idle time in the technological chain. Therefore, considering external factors in selecting machine complexes is of great importance. A comprehensive assessment of organizational and technological reliability of machine operation enables scientifically grounded selection of machine complexes for earthworks. This approach contributes to optimizing the number of machines, stabilizing production rhythm, and reducing idle time. As a result, continuity of the construction process is ensured and production efficiency is increased. Furthermore, optimal selection of machine complexes reduces operational costs, shortens construction duration, and improves the economic efficiency of projects.

Improving the reliability of machine systems is closely connected with optimizing construction production processes. By increasing the level of coordination between machines in the complex, the efficiency of the technological chain is enhanced. This ensures high-quality execution of construction works within planned deadlines. From this perspective, the assessment of organizational and technological reliability of machine operation is one of the important scientific directions in construction production management.

In determining the organizational and technological reliability of construction machine complexes, processing the results of full-scale tests is of significant scientific and practical importance. Full-scale tests involve direct observation, measurement, and statistical processing of machine system performance under real construction site conditions. This approach allows verification of theoretical models, evaluation of machine complex efficiency in real production environments, and development of optimal technological solutions. Scientific studies emphasize that field test results are the primary empirical data source for

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determining operational parameters of construction machinery systems and serve for model verification.

During full-scale testing, key technological parameters of the machine system are determined. In earthworks, excavators, transport vehicles, and auxiliary equipment form an interconnected technological chain. In this system, parameters such as excavator cycle time, bucket filling coefficient, vehicle circulation time, unloading time, and machine idle time are measured. These parameters reflect the real working conditions of the machine complex and allow evaluation of technological compatibility. The methodology of full-scale testing consists of several stages. In the first stage, the observation object is selected, i.e., the construction site where earthworks are performed is identified. In the second stage, the composition of the machine complex is determined. In the third stage, a list of measurable parameters is established. In the fourth stage, time measurements are carried out. In the final stage, the collected data is processed using statistical methods. This methodology is widely used in assessing machine reliability.

The main parameters measured during full-scale tests include excavator cycle time, loading time, transport cycle time, unloading time, idle time, and shift productivity. These parameters allow determination of the technological compatibility of the machine system. For example, if the transport vehicle cycle time does not match the excavator cycle time, a disruption occurs in the technological chain. Therefore, the results of full-scale tests are crucial for optimizing the number of machines. In data processing, statistical methods are applied. Based on the measured values, the arithmetic mean is determined:

$$\mathbf{T_{o'rt}} = \frac{\sum_{i=1}^{n} \mathbf{T_i}}{\mathbf{n}}$$

here T_i - measured values, n - “The number of observations. This indicator makes it possible to determine the average parameters of machine operation. During statistical processing, variance is also calculated:”

$$\mathbf{D} = \frac{\sum_{i=1}^{n} (\mathbf{T_i} - \mathbf{T_{o'rt}})^2}{\mathbf{n} - \mathbf{1}}$$

Variance serves to assess the stability level of the machine operation process. If the variance is small, the operational stability of the machine system is high. In processing the results of full-scale tests, the coefficient of variation is used:

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$$\mathbf{V} = \frac{\boldsymbol{\sigma}}{\mathbf{T_{o'rt}}}$$

Here $\sigma = \sqrt{D}$ - The coefficient of variation makes it possible to evaluate random fluctuations in the machine operation process. If the coefficient of variation is small, the reliability of the machine system operation is considered high. Based on full-scale test results, the overall production capacity of the machine system is determined. The real production capacity of the earthworks system is determined as follows:

$$\mathbf{Q_{system}} = \mathbf{min}\left(\mathbf{Q_{e,total}}, \mathbf{Q_{t,total}}\right)$$

This formula indicates that the overall productivity of the technological chain is determined by the machine with the lowest productivity. This is based on the "bottleneck principle" and demonstrates the necessity of coordinating the machine complex. Based on full-scale tests, the project duration is determined as follows:

$$\mathbf{T} = \frac{\mathbf{V_{total}}}{\mathbf{Q_{system}}}$$

Here V_{total} - the volume of earthwork to be completed, Q_{system} system productivity. This indicator makes it possible to evaluate the production efficiency of a machine complex. During the processing of test results, the economic efficiency of the machine system is also assessed. In this process, fuel consumption, maintenance costs, repair costs, and operational performance indicators of machines are taken into account. Studies show that as machine speed increases, fuel consumption also increases; however, the duration of work decreases. Therefore, multi-criteria evaluation methods are used to determine the optimal operating mode.

Thus, the processing of full-scale tests of construction machinery enables the determination of real operational parameters of machine systems, statistical evaluation, and verification of theoretical models. This approach contributes to the scientifically based selection of machine complexes, improvement of production efficiency, and ensuring the organizational and technological reliability of the construction process.

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CAT 320D2 – It is a medium-class hydraulic crawler excavator, widely used in earthworks, foundation excavation, loading, and transportation operations. This machine belongs to the 20–22 ton class and is designed to ensure high productivity at construction sites.

2. Dvigatel (Engine)

Dvigatel model - Cat C7.1
Dvigatel power - 110–112 kW (≈148–150 hp)
rated rotational speed — 1800 ayl/min
work volume — 7.01 L
emission standard — Tier 3 / Stage IIIA
maximum torque — ≈712 Nm

3. weight and dimensions

operating weight — 20 500 – 22 300 kg
transport length — ≈9.46 m
transport width — ≈2.99 m
transport height — ≈3.05 m
track width — 790 mm

4. work equipment

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bucket capacity — 0.8 – 1.2 m³
boom length — 5.7 m
stick length — 2.9 m
maximum digging depth — 6.7 m
maximum radius — ≈9.8 m
maximum loading height — ≈6.49 m
5. hydraulic system
hydraulic pressure — ≈35 MPa
double-piston pump system
pump flow rate — ≈202 L/min
high-precision joystick control system
6. operating parameters
slewing speed — ≈11 rpm
travel speed — 3.2 / 5.6 km/h
maximum output capacity — 70 %
bucket breakout force — ≈150 kN
stick digging force — ≈106 kN
7. fuel and operating costs
fuel tank capacity — ≈410 L
Fuel consumption depends on operating conditions
Maintenance interval — extended
Capable of operating on low-quality fuel
8. structural features
reinforced boom and frame
Heavy-duty crawler tracks
Ergonomic operator cabin
LCD monitoring system
Air conditioning and visibility windows
CAT 320D2 The excavator is a medium-class hydraulic machine that ensures high productivity in earthworks. The machine's optimal bucket capacity, high digging force, and efficient hydraulic system make it suitable for foundation excavation and loading soil into transport vehicles in residential construction projects. Taking into account the technical parameters of this machine, the formation of a machine

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complex contributes to improving the organizational and technological reliability of the construction process.

Conclusion and Recommendations

The results of the conducted research demonstrate that the assessment of organizational and technological reliability of machine operation plays an important role in improving the efficiency of production processes. The analysis confirms that the overall reliability of machines is closely related not only to their technical condition but also to the quality of organizational management and the stability of technological processes. The main factors determining organizational reliability were identified as the efficiency of the maintenance system, the level of production planning, the availability of resources and spare parts, and the qualification level of the human factor. Technological reliability, in turn, is characterized by the machine's ability to operate continuously and stably within specified parameters under a given operating regime.

Based on the research results, it can be concluded that a comprehensive assessment of organizational and technological factors enables more accurate determination of machine reliability levels and contributes to increasing production efficiency. At the same time, the criteria developed on the basis of a systems approach help reduce the number of failures in practice and optimize operational costs. The construction machinery system was considered as an interconnected set of technological operations, and its efficiency was shown to depend on technical parameters, operational stability, and organizational coordination. It was demonstrated that in selecting machines, factors such as productivity, technical readiness level, transportation distance, soil type, and construction site conditions must be taken into account.

Criteria for assessing organizational and technological reliability in earthworks were developed. These criteria are based on indicators such as the technical readiness coefficient, utilization coefficient, cycle compatibility, and probability of idle time. Using these indicators, it is possible to determine the overall stability of machine systems, ensure continuity of the technological chain, and improve production efficiency. Methods for processing full-scale test results of construction machinery were also considered. Statistical processing of test data allows determining mean cycle times, variance, and coefficient of variation,

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which are essential for evaluating the stable operation of machine systems. In addition, a queuing theory-based mathematical model was proposed to assess the interaction between excavators and transport vehicles.

One of the key outcomes of the chapter is the development of a reliability model for earthworks processes. This model is based on a comprehensive assessment of technical, organizational, and technological factors of machine systems. It allows determining the optimal ratio between excavators and transport vehicles, reducing idle time, and ensuring efficient operation of machine complexes. The presented theoretical foundations serve as a basis for scientifically grounded selection of machine complexes in earthworks for residential construction. The developed mathematical models and evaluation criteria can be used in subsequent chapters for predicting the organizational and technological reliability of machine systems, optimizing machine fleet utilization, and improving construction process efficiency.

Recommendations

Based on the results of the study, the following recommendations are proposed:

- it is necessary to implement a comprehensive system of evaluation criteria that includes not only technical indicators but also organizational and technological factors when assessing machine reliability.
- the widespread implementation of modern maintenance systems in production enterprises, including preventive and predictive maintenance, is recommended.
- it is necessary to develop digitalization and monitoring systems in production processes to ensure real-time control of machine reliability.
- improving personnel qualifications and adapting workers to technological processes is essential to reduce human-factor-related errors.
- optimization of spare parts and resource supply systems is required to prevent organizational disruptions.
- in general, the proposed measures contribute to improving machine reliability in production systems, extending their service life, and increasing economic efficiency.

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