The principle of determining the values of building system’s organizational and technological reliability

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Abstract. Over the past few decades, a new scientific direction has been formed, connected with the concept of organizational and technological reliability (OTR) of construction. Domestic scientific school of research, evaluation, design and management of OTP construction activities uses a variety of methods and models (analytical, graphical, statistical, imitation, etc.) in solving the problem of increasing the reliability of building production systems. This article's goal is to get acquainted with the basic concepts and problems of the scientific direction of the organization and management of construction, as well as the principles of determining organizational and technological reliability.

Introduction
In modern conditions, when a large number of participants, technical facilities, human and other types of resources are employed in the construction industry, technological, organizational, economic, and managerial decisions become much more complicated. The strategic objectives of the investment and construction complex are to improve the quality of construction products, ensure reliability and safety, the profitability of real estate, sustainable development of enterprises and organizations of the construction industry. Construction companies are constantly faced with the need to meet the requirements of quality standards, since the quality of construction products is the health, comfort and mood of citizens, safety, reliability and durability of the objects being built. The quality of construction and installation works at the enterprises of the construction complex is ensured by proper control of their quality at each stage of their production, compliance of the technological parameters of the production process with the requirements of technical regulations [3]. Quality is formed at all stages of construction: in the design, in the production of construction and installation works, during operation. In addition, a large number of random factors of external and internal environment, both production and non-production, affect the organizational and technological reliability of construction production. Accounting for their impact on construction production is possible on the basis of the creation of probabilistic statistical models and methods for studying them. Such factors can be economic, climatic, technical social factors that, as a rule, act not separately, but jointly, which leads to the emergence of a synergistic effect on the construction industry. Recently, from economic factors, destructive impact is noted. For this reason, the problem of ensuring the reliability and stability of the functioning of production building systems is becoming ever more important [6].

Main part
One of the main directions of improving the quality and competitiveness of products, the effective organization of production in construction is the performance of work in the shortest possible time with minimal losses of the required quality. Ensuring reliable performance of work in the planned time plays a significant role in the overall reliability and stability of the construction complex. Meanwhile, raising the level of quality and organization of production during construction is the main strategic task of Russian enterprises, as evidenced by the annual statistical data from the state construction supervision and examination service of defects and irregularities identified during construction and operation. The analysis of the activities of enterprises engaged in construction allows us to single out the following problems: an increase in the construction period as compared to the calendar plan; low quality of design solutions and construction works. In this regard, the task appears to assess the degree of influence of violations on the functioning efficiency and quality of organization of production processes. To manage the work organization process, it is proposed to use such a criterion as organizational and technological reliability (OTR).

By A.A. Gusakov’s definition [1]:

Organizational and technological reliability (OTR) is an ability of organizational, technological, managerial economic decisions to ensure the achievement of a given result of the construction industry in the conditions of random perturbations inherent in construction as a complex probabilistic system.

The reliability of the system (of an object) is a property of the system to achieve a given result in the process of functioning for a specified time; property of the system, allowing it to steadily perform its functions in the event of failures, failures and errors in its individual parts. Reliability is one of the essential aspects of the quality of the system, its reliability and performance. Under the reliability means the ability of the system to maintain a stable working condition (not to have failures) during the considered period of time. Disruption, reducing the quality, but not determining the work stoppage, is called a failure. A partial or complete loss of performance is called a failure. Causes of failures can occur suddenly or be determined by a gradual change in parameters. In this case, it is possible to predict the loss of system performance. Thus, the development of an effective way to prevent the occurrence of factors that adversely affect the timing, cost and quality of the construction of the object is the most important element in reducing the risks of construction and increasing its organizational and technological reliability.

The quantitative characteristics of the reliability of the construction process are determined by the reliability of the joint functioning of the constituent elements [4]: the scope of work (SW), hardware (HW), material elements (ME), labor resources (LR), construction process (CP). The combination of the construction process' elements in the sense of reliability is assumed to be consistent, the absence or failure of one of the elements leads to a halt or failure in the process (Figure 1).

![Figure 1. Reliability scheme of the construction process: the scope of work (SW), hardware (HW), material elements (ME), labor resources (LR), construction process (CP).](image)

In production systems consisting of series-connected n security elements, $R_{posl}$ is expressed by the formula:

$$R_{posl} = R_1 R_2 R_3 \ldots R_n = \prod_{i=1}^{N} R_i ,$$

(1)

In which $R_i$ is an reliability of the i-th element of the production system.

This formula is often called the law of reliability's production[1, 3].
The reliability of the construction process is characterized by the availability factor (Kg.pr), determined by the formula:

\[ KG.pr = KG.sw \times KG.hw \times KG.me \times KG lr, \]  

where KG.sw, KG.hw, KG.me, KG.lr are respectively the readiness coefficients of the front of work, technical equipment, material elements, labor resources.

Construction systems are much more complex than technical systems. The scientific discipline that studies the general patterns of failure, malfunction, system recovery, examining the impact of external and internal impacts on the processes occurring in the system, creating the basis for calculating reliability and predicting failures and failures, is called the theory of reliability [8]. Within the framework of this theory, ways are being sought to improve reliability when designing systems using various forms of redundancy (introducing redundant components into the system) to perform certain functions. The method of collecting, recording and analyzing static information characterizing reliability is determined. In the theory of reliability, quantitative characteristics (criteria) of assessing reliability are considered, a link is established between economic efficiency and these characteristics, methods for monitoring and testing reliability, as well as methods for processing and evaluating the results of these tests are developed. The theory of reliability is based on the methods of mathematical statistics, probability theory and queuing theory. From the standpoint of these methods, it is important to analyze the structure of the system, the reliability of which needs to be determined. Any system can consist of independent elements, of dependent elements interacting with each other, as well as of various combinations of those and others. Obviously, building production systems are complex and diverse combinations of dependent and independent elements, characterized by heterogeneity.

Materials and methods

The main quantitative characteristic of the reliability of the system is the probability of failure-free operation (p) is a probability that an object failure does not occur within a given operating time or a given time interval [5]. The probability of failure-free operation is inverse to the probability of failure and, together with the failure rate, determines the reliability of the object. The probability of failure-free operation is determined by the formula:

\[ p(t) = \frac{N - n(t)}{N}, \]

where \( N \) is the number of homogeneous elements at the beginning of work; \( n(t) \) is the number of failed (partially or completely out of order) elements during operation \( t \).

The probability of failure-free operation is a decreasing function of time and has the properties [2]:

- at the initial moment of time (at \( t = 0 \)) \( p(0) = 1 \),
- as \( t \to \infty \), the function \( p(t) \) tends to zero (Figure 2).

Figure 2. Probability of no-failure operation: \( p(t) \) - reliability function; \( t \) - is the time during which the probability of failure-free operation is determined.

In practice, sometimes a more convenient characteristic is the probability of failure \( Q(t) \) (Figure 3).
Figure 3. Probability of failure: $q(t)$ is a function of unreliability; $t \leftarrow$ is the time during which the probability of failure is determined.

The failure-free operation of the system and the appearance of a failure are incompatible and opposite events, therefore the sum of their probabilities is equal to 1. Consequently,

$$Q(t) = 1 - p(t).$$

(4)

For systems of construction production, not complete failures are typical, but partial ones, i.e., malfunctions in work, which self-eliminate during the continuous operation of the system [7]. Therefore, in majority of works on the organizational and technological reliability of construction, the availability $K_g$ factor is used as the main indicator of system reliability. The reliability of a separate element of the construction process according to the time criterion is characterized by the availability factor ($K_{g.e}$), which is determined by the ratio of the time of failure-free operation of the element to the time of the process execution using the formula:

$$K_{g.e} = \frac{T_{o}}{T_{o} + \sum_{i=1}^{n} t_{oi}},$$

(5)

In which $T_o$ – time between failures, $T_r$ – recovery time.

That means, for systems of construction production, $K_g$ is the ratio of the system uptime for the given period of its operation to the amount of uptime and failures (failures or downtime) over the same period of time:

$$K_r = \frac{T}{T + \sum_{i=1}^{n} t_{oi}},$$

(6)

where $T$ is the duration of non-failure work; $t_{oi}$ – duration of failures of the $i$-th element of the system.

Results

The basis for the development of the principle of determining OTS in the first place should be based on the probabilistic-statistical approach. The probability of failure-free operation is the probability that a failure in the operation of the system does not occur within the given time limits. Evaluation of the OTP is formulated as the probability of the implementation of the entire project or certain works by the deadline [3]. Therefore, the assessment of the reliability of building systems should be understood as the assessment of the probability of achieving the goal.

As a basis for quantifying OTR, the average system uptime of the system is used without making changes in the structure and nature of this system. Knowing the average actual time of the system’s trouble-free operation and the planned time of its operation, it is possible, using the laws of probability theory, to determine the probability of the system’s failure-free operation during the entire specified time (probability of failure-free operation is $p$). This probability, that is, the reliability of the system, is expressed as a percentage or numerically in the range of 0 ... 1: 0 < $p$ 1.
The system in the process of operation may be in a state of failure or in a state of reliability. As a result, a relationship is established between the planned $T_p$ and the actual $T_f$ work duration. Therefore, the conditions of failure and reliability can be written as:

- failure $T_f > T_p$;
- reliability $T_f \leq T_p$.

For calculating reliability, the probability theory apparatus is used, since $p$ is a function of the distribution of a random variable $T_p$. The larger the $p$, the more reliable the system, so the reliability criterion of the production system can be represented as:

$$p(T_f < T_p) \rightarrow \max.$$  \hspace{1cm} (7)

**Summary**

So, to determine the OTR system, the methods of the theory of reliability are used, based on the analysis of the distributions of aggregates of random variables - the reliability of individual elements of the complex. The main difficulty in determining an OTR system object is that it usually consists of a large number of parts, elements, relatively isolated subsystems, and a rich variety of different connections and relationships. The human-machine (organizational-technological, managerial, etc.) elements included in the main system and including, in addition to technological, economic and social aspects, are also characterized by a certain level of reliability, which significantly decreases as the system becomes more complex. Determining the value and increasing the OTR is reduced to identifying, integrating and, as a result, reducing the number of factors affecting the reliability violation of the building system.

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