УДК 65.012.123

MODERN OF CALENDAR PLANS TECHNIQUE COMPOSITION FOR CONSTRUCTION OF BUILDING COMPLEX

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Abstract. The main tasks at the stage of project implementation for the on-line production of works are the operational planning of construction and installation works and their management, which ensures the prevention of organizational and technological failures, as well as the elimination of failures and their consequences. For this purpose, the development of organizational and technological solutions to improve the reliability of their adoption at the stage of production work project is actual today. One of the models for reflecting probabilistic production processes is the network model. In this paper, the Monte Carlo method was used to analyze the network model, solving the problem of stability of the critical path under a probability network. Its essence lies in the multiple realization of the probabilistic process on the model. For each work of the network schedule, the interval of work time values was determined, assuming the occurrence of any value of the duration in the range of limit values is equally probable. Next, we mathematically simulated the probable value of the duration by generating random numbers. Then, the network schedule was calculated as deterministic and the empirical distribution of process parameters was obtained and analyzed. We came to the conclusion that such an approach is advisable in practical activities and can be recommended to the contractor to improve organizational and technological reliability in the design of the PPR, as well as to solve the reliability problems of organizational management systems (investigation of the impact on the reliability of their organization systems, management structure, etc.).

Keywords: organizational and technological reliability, project of production, organizational failure, technological failure, network model, critical path, probabilistic network.

СОВРЕМЕННАЯ МЕТОДИКА СОСТАВЛЕНИЯ КАЛЕНДАРНЫХ ПЛАНОВ ПРИ СТРОИТЕЛЬСТВЕ КОМПЛЕКСА ЗДАНИЙ

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Аннотация. Основными задачами на этапе реализации проектов при поточном производстве работ являются оперативное планирование строительно-монтажных работ и управление ими, обеспечивающее предупреждение возникновения организационных и технологических отказов. Одной из моделей отражения вероятностных производственных процессов является сетевая модель. В данной статье для анализа сетевой модели применили метод Монте-Карло, решая задачу устойчивости критического пути при вероятностной сети.

Пришли к выводу, что такой подход целесообразен в практической деятельности для повышения организационно-технологической надежности при проектировании ППР.

Ключевые слова: организационно-технологическая надежность, проект производства работ, организационный отказ, технологический отказ, сетевая модель, критический путь, вероятностная сеть.

СУЧАСНА МЕТОДИКА СКЛАДАННЯ КАЛЕНДАРНИХ ПЛАНІВ ПРИ БУДІВНИЦТВІ КОМПЛЕКСУ БУДІВЕЛЬ

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Анотація. Основними завданнями на етапі реалізації проектів при поточному виробництві робіт є оперативне планування будівельно-монтажних робіт і управління ними, що забезпечує попередження виникнення організаційних і технологічних відмов. Однією з моделей відображення імовірнісних виробничих процесів є мережева модель. У даній статті для аналізу мережевої моделі застосували метод Монте-Карло, вирішуючи завдання стійкості критичного шляху при ймовірнісній мережі. Прийшли до висновку, що такий підхід доцільний в практичній діяльності для підвищення організаційно-технологічної надійності при проектуванні ПВР.

Ключові слова: організаційно-технологічна надійність, проект виконання робіт, організаційна відмова, технологічна відмова, мережева модель, критичний шлях, імовірнісна мережа.

Introduction. The development of the methodological foundations of the organizational and technological reliability (OTR) of construction projects has been devoted to a significant number of works of the Gusakovs' and A.V. Ginzburgs' scientific school [1, 2].

For the first time the term «organizational and technological reliability» was introduced by A.A. Gusakov, as the ability of organizational, technological, economic decisions to ensure the achievement of a given result of construction production in the conditions of random perturbations inherent in construction as a complex stochastic system.

Reliability is a component of the object quality. The requirements for the quality system are established by international standards ISO 9000 series (9001-9003) and are sufficiently comprehensive proof of effective procedures existence for ensuring reliability. Despite this, the analysis of reliability at different stages of the construction object life cycle showed a graph of errors distribution leading to accidents, that most of them are at the stage of SMR [3].

In construction practice, the project for the production of work (PPW) refers to the organizational and technological documentation, and there are no other documents regulating the decisions on construction and assembly work (CMR) and production organization. While in the United Kingdom, Finland, the United States, Canada and other countries there are national standards (Building Information Modeling), which foresee the development of a PPR by the general contractor with their use [4]. For example, the CM Standards of Practice (developed by the American Building Management Association) is a set of rules for the management of construction projects and includes the following sections – project management, contract administration, cost management, safety and risk management, quality management, cost analysis, time management.

Formulation of the problem. The object – organizational and technological documents, in particular, a calendar plan. The higher the reliability of the object, the higher its quality (relevance and efficiency over time, the predictive value of the results, etc.). When analyzing the functioning of a construction stream, there are deviations in the actual parameters of its operation from the values established in the technological maps or work schedules. Full or partial termination of the functioning of the construction stream or process, which causes deviation from the specified parameters, is a technological failure. They arise as a result of the various organizational and technological factors impact that destabilize the production of works. Technological failure is not necessarily associated with a complete shutdown of the process. The most frequent are partial failures, which are eliminated in the production process [5, 6].

For construction, it seems expedient to consider reliability from the point of completion of construction in a timely manner. If the deadlines for the construction of significant milestones are broken (the latter are considered as failures), the value of the planned efficiency index is reduced. Refusal is an event that marks the impossibility of further use of the plan (for example, a breakdown in terms and amounts of investment, an accident when installing building structures, etc.).

Given the high degree of uncertainty and risk in the planning and management of complex technical systems projects, the task of time management under such conditions is topical.

In most of the work on organizational and technological reliability, the theoretical basis is the probability theory in application to network planning and management methods, but the flow organization has its own characteristics that must be taken into account when assessing the level of reliability of the developed schedules for the construction of situational specialized, object and complex flows (situational task will predict the possibility of failures and an expanded opportunity to compensate for delays due to failures in the current the implementation of other work flow and specific recommendations for this flow on the possibility of using time reserves and shortening the work period).

To solve this type of problems, methods of probabilistic network planning are used. At the moment, the most common methods of probabilistic network planning include the method of evaluation and analysis of programs (PERT), the method of statistical tests, or the Monte Carlo method, the method of graphical evaluation and program analysis (GERT) [7].

Analysis of recent research and publications. The main tasks at the stage of project implementation for the on-line production of works are the operational planning of construction and installation works and their management, ensuring the prevention of organizational and technological failures, as well as the elimination of failures and their consequences.

The main task in assessing the distribution of failure probabilities for calculating the level of reliability of SMR is to determine the functions characterizing the probabilistic properties of the construction process under consideration. The following laws of probability distribution of failures have become most widespread: normal, Poisson, exponential, gamma and beta distributions [8, 9].

To date, the distribution patterns of failures have been fairly well studied (in the manufacture of SMR, a uniform distribution of failures is considered when a random event is in a certain time interval and its occurrence is equally probable), and other methods for increasing the organizational and technological reliability of construction production (for example, oriented to territorial and proprietary standardization). Variant design of organizational and technological solutions remains relevant. Methods for eliminating the causes of failures include the use of logistics methods, the introduction of a quality management system based on international standards, the reservation of material and technical and other resources, as well as risk management [10].

The solution of network planning tasks in probabilistic indicators requires a large amount of statistical data, in connection with their absence, the article presents a numerical experiment on an abstract model.

Statement of the main material. To analyze the network model, we apply the method of statistical tests (the Monte Carlo method) [11]. This method is the most accurate method for realizing probabilistic network models, and the simplest from the point of view of computer implementation. Its essence lies in the multiple realization of the probabilistic process on the model.

For each work of the network schedule, we determine the limiting values of the parameters (work durations) and the distribution law, the probabilities of the parameters value, on the range of the limiting values. Then, we perform mathematical modeling of the parameter probable value by generating random numbers. Next, we calculate the network graph as deterministic. As a result, an empirical distribution of process parameters is obtained, which can be subjected to any targeted analysis, if necessary.

Using the Monte Carlo method, we solve the problem of stability of the critical path under a probability network.

Duration of work is determined by:

$$t_1 = M(t_1) + \alpha_1 \cdot S(t_{iJ}),, \tag{1}$$

where α_1 – random number, taken from tab. 1 random numbers.

Table 1 – Method of static tests (calculation of work durations)

Code of work	M(t)	S(t)	A						***t_{ij}***					
			a_1	a_2	a_3	a_4	a_5	a_6	t_1	t_2	t_3	t_4	t_5	t_6
1-2	2	2	-0,5863	0,8115	0,5125	1,7981	1,4943	-0,3934	0,83	3,62	3.,3	5,59	4,99	1,21
1-3	4	3	1,1572	0,5405	0,2119	0,4270	1,1123	-0,7867	7,47	5,62	4,64	5,28	7,34	1,64
2-3	4	3	-0,4428	-1,1929	-0,1557	-0,7679	-0,7165	0,9780	2,67	0,42	3,53	1,67	1,85	6,93
2-4	8	4	-0,3934	-1,3596	-0,2030	-0,5557	-1,2496	0,8574	6,43	2,56	7,19	5,78	3	11,43
3-4	0	-	0,8319	0,4167	1,2237	-0,1032	0,0099	0,999	0	0	0	0	0	0
3-5	4	2	0,9780	0,5674	0,9765	-0,5098	-0,5061	-0,5564	5,96	5,13	5,95	2,98	2,99	2,89
4-5	6	2	0,8574	-0,2666	-0,5063	0,6141	-0,7891	0,9087	7,71	5,47	4,99	7,23	4,42	7,82
4-6	4	3	0,9990	-0,0622	1,1572	-0,888	1,1054	0,4270	7	3,81	7,47	1,34	7,32	5,28
5-6	6	3	-0,5564	-0,0572	0,4428	0,8960	0,8563	-0,7679	4,33	5,83	7,33	8,69	8,57	3,7

Table 2 – Calculation of the network model from a numerical experiment

The code of the initial event	work	t_{ij}	Early start of work t_{ij}^{rn}	Early termination of work t_{ij}^{ro}	Late start of work t_{ij}^{pn}	Late completion of work t_{ij}^{po}	R_{ij}	r_{ij}
-	1-2	0,83	0	0,83	0	1,04	0,21	0
-	1-3	7,47	0	7,47	0	7,47	0	0
1	2-3	2,67	0,83	7,47	1,04	7,47	3,97	3,97
1	2-4	6,43	0,83	7,47	1,04	7,47	0,21	0,21
1,2	3-4	0	7,47	7,47	7,47	7,47	-	-
1,2	3-5	5,96	7,47	15,18	7,47	15,18	1,75	1,75
2,3	4-5	7,71	7,47	15,18	7,47	15,18	0	0
2,3	4-6	7	7,47	19,51	7,47	19,51	5,04	5,04
3,4	5-6	4,33	15,18	19,51	15,18	19,51	0	0

From the calculation (tab. 2) the critical path:1-3-4-5-6; T_{kr1} = 19,51.

The initial data for calculating the durations of network models work (2, 3, 4, 5, 6) are given in Tab. 1.

Below are shown the results of calculations (similar to the calculations in Tab. 2) of network models (2, 3, 4, 5, 6).

Accordingly, critical paths (1-2-4-5-6): T_{kr2} = 17,48; T_{kr3} =22,54; $T_{kr.4}$ =27,29; $T_{kr.5}$ =23,76; $T_{kr.6}$ =24,16.

For the normal probability distribution law, the required minimum sample size is calculated depending on the sufficient confidence probability and relative measurement error [12].

Calculation of work durations and calculation of network models (numerical experiments 7-18) are carried out similarly to the calculations of Tab. 1 and Tab. 2. and the values of the critical paths are shown in Fig. 1.

The stability of the critical path as the probability of its passage through certain events for a given probability p = 0.98, λ = 3.02, respectively, are determined by the following formulas:

$$T_{kr}^{med} \approx M[T_{kr}] = \sum T_{kr} / N . \quad (2)$$

Accordingly: $M[T_{kr}] = 22{,}36$,

$$D[X] = M[X^2] - (M[X])^2 . \quad (3)$$

Accordingly: $D[X] = 13{,}54$,

$$S^2[T_{kr}] = D[X] . \quad (4)$$

Accordingly: $S\ [T_{kr}] = 3{,}68$.

We find the maximum and minimum values of the critical path for a given probability p = 0.98, λ = 3.02.

$$\max T_{kr} = M[T_{kr}] + \lambda \cdot S[T_{kr}]. \quad (5)$$

Accordingly: $\max T_{kr} = 33{,}47$.

$$\min T_{kr} = M[T_{kr}] - \lambda \cdot S[T_{kr}]. \quad (6)$$

Accordingly: $\min T_{kr} = 11{,}25$.

In this article, for assessing the reliability of calendar plans, the critical path was estimated as determining the overall construction period, stability problem of the critical path under a probabilistic network was solved (the model was realized and calculated 18 times with the help of generating random numbers, the result of one embodiment of the model is shown in Tab. 1 and its calculation in Tab. 2).

The histogram shows the values of the computed critical paths and their maximum and minimum probabilistic values (fig. 1).

The values of the critical paths fall within the range between the minimum and maximum probabilistic values of the critical paths, pass through the same events, hence the critical path is stable, the model is reliable and can be the main decision in the organization of SMR production.

Such approaches can be recommended for use in practical activities when designing the PPR and will give good predictions for a particular construction organization with the growing information volumes of the «plan-fact».

Accumulation of data significant amounts from the work of a specialized flow over a long time interval for a specific technology will enable to make the forecasting of failures and compensation of delays due to failures occurring during other workflows and specific recommendations for this flow on the possibility of using time reserves and shortening work periods.

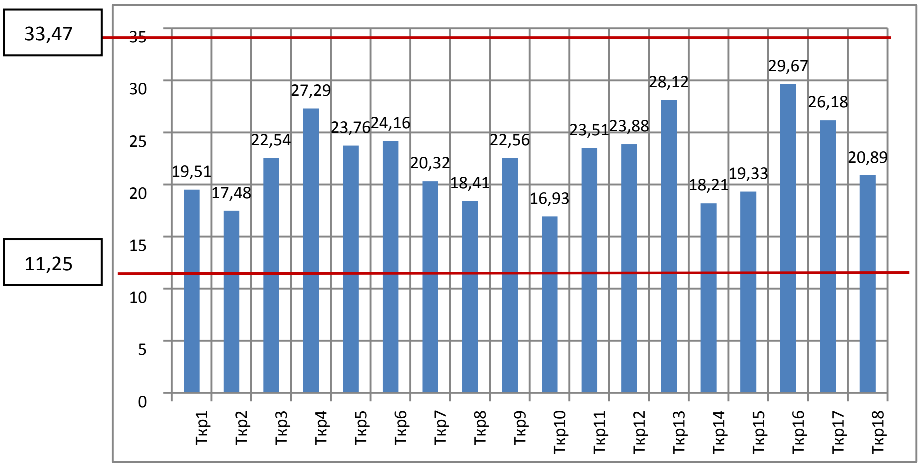

Fig. 1. Histogram of critical paths

Conclusions. The general contractor, using arrays of its own statistical information and based on the principles of limiting the costs and duration of work, determined at the pre-project level of business justifications of construction projects, can develop a methodical approach to managing the projects that it implements. The essence of this approach seems to us to recommend the principle of integrating investment and engineering solutions into the process of organizational and technological design.

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Стаття надійшла 5.02.2018