doi: 10.18720/MCE.77.6

Organizational and technological reliability of the construction process

Организационно-технологическая надежность строительного процесса

V.N. Kabanov,
National Research Moscow State Civil Engineering University, Moscow, Russia

Д-р экон. наук, профессор В.Н. Кабанов,
Национальный исследовательский Московский государственный строительный университет, г. Москва, Россия

Key words: organizational and technological reliability of construction; organizational-technological solutions of construction; duration of construction; cost of construction products; organizational and technological design of construction processes

Ключевые слова: организационно-технологическая надежность; строительный процесс; организационно-технологическое решение строительства; продолжительность строительства; стоимость строительной продукции; организационно-технологическое проектирование строительных процессов

Abstract. Construction projects of buildings and structures, as well as plans of construction and installation works are often subjected to fair criticism from the Pro-producers of the work. Such criticism is that the calculated cost value and long lasting-STI CMP does not take into account the specificity of real contractors. To address these criticisms and proposals were developed for the assessment of such intensity values of SMR production, which most realistically take into account the actual conditions of construction and Contracting organization. The application of the classical methods of probability theory simplifies the procedure of collecting background information and in some cases allows you to use the results of the numerical experiment. Computational procedures require special training and is easily amenable to automation (programming). The result of the research represents the author's method of estimating the quantitative strength value of organizational and technological reliability with regard to construction, manual processes, and technological solutions providing leading mechanization, subject to the calculation of the intensity of works as the sum of labor productivity of employed workers.

Аннотация. Проекты возведения зданий и сооружений, а также планы производства строительно-монтажных работ весьма часто подвергаются справедливой критике со стороны производителей работ. Такая критика состоит в том, что расчетные значения стоимости и продолжительности СМР не учитывают специфику реальных подрядных организаций. Для устранения этих критических замечаний разработаны предложения по оценке такого значения интенсивности производства СМР, которое наиболее реально учитывает фактические условия строительства и подрядной организации. Применение классических методов теории вероятностей значительно упрощает процедуры сбора исходной информации, а в некоторых случаях позволяет использовать результаты численного эксперимента. Вычислительные процедуры не требуют специальной подготовки и легко поддаются автоматизации (программированию). Результат выполненных исследований представляет собой авторский способ оценки количественного значения организационно-технологической надежности применительно к строительным процессам, выполняемым вручную, а также к технологическим решениям предусматривающим работу ведущих средств механизации при условии вычисления интенсивности производства работ как суммы производительности труда занятых рабочих.

1. Introduction

The aim of the study was to determine the order of evaluation of organizational and technological reliability of construction processes.

In practice, organizational-technological design, the calculated values of the duration cost and duration of construction are very often at odds with actual unit price of construction products, as well as terms of input of objects in operation. Over the past 50 years did not stop attempts to increase the level of reliability of the duration and cost of construction, including as a result of practical application of the index of organizational-technological reliability (OTR) the project indicators. For the period developed many approaches to the calculation of quantitative values of OTR. From the point of view of the author, the stump of the reliability obtained in the design of organizational and technological solutions does not always provide the required accuracy.

Object of research are the processes of production of construction works. Subject of research: the ability of organizational and technological processes construction of buildings and structures to make construction products in a specified period (including, without exceeding the set price).

Most of the authors of the publications included in this work, under the organizational and technological reliability (OTR) understand quite exhaustive, which became a classic definition provided by one of the pioneers of engineering in construction A. A. Gusakov [1]. It is important to emphasize that the concept of organizational– technological reliability in the publications is rather widespread. The results of the study while this index in a variety of fields including design, creation of construction products and buildings and structures allow you to combine the application of OTR in three groups: the design of building structures, operation of machines, mechanisms and technological equipment and construction and installation works manually.

Probabilistic structural analysis most often relies on the formal definition of distribution functions of magnitude "reliability". Calculation of quantitative indicators of sustainability, values of strain are considered as the result of changes in external loads and simultaneous variations of the resistance of structures to external influences. The problem of determining the reliability of structures is reduced to calculating the probability of a loss of resistance (the onset of the limit state), which is represented by the graphical intersection of the distribution function of the loads (or forces) and the distribution function of measure describing the resistance to these loads [2].

Assessment of organizational and technological reliability of operation of means of mechanization in construction can be subdivided into two parts. The first part involves determining the probability of failure-free operation of machines and mechanisms, and the second is providing the most comprehensive resource utilization of mechanization in the construction of buildings and structures. If the order of evaluation of reliability of technical systems is governed by the regulations of the current Russian national system of standards GOST R 5190.5-2005, the assessment of the OTR operation of technological systems and kits has a variety of original approaches [3].

To calculate the value of OTR in relation to the execution of construction works in Russia there is no normative document that defines the execution order of the calculations. Probably, the lack of a standard should explain the impressive number of published proprietary methodologies designed to assess the reliability of the processes of construction of buildings and structures, each of which uses, sometimes, unique conceptual apparatus and offers to determine the OTR: "the construction organization [4], elements of the organizational structure of an investment construction project", "housing construction [5–7]". You should pay attention to the practical application of the indicator OTR when planning: defining "matching sequentially executed [8]", using the "binary structure in terms of a probabilistic temporal parameters [9]", "definition of duration of the critical path [10, 11]". Approaches to the assessment of organizational and technological reliability, taken separately is the technological process are cited in published works A.A. Lapidous [12], I.K. Poteryaeva [3], P.P. Oleynik [13], V.R. Molodetskiy [14], P.N. Kurochkin [15].

Among the methods used to calculate quantitative values of OTR found in the published works, include:

- methods of probability theory: determination of the mathematical expectation [8, 9] as the evaluation of reliability (probability) of the results (the accuracy of the prediction table. 1 [3]); the integral of the distribution density function of Laplace [16], Poisson "flow" of failures [17], the function of the beta distribution probability density of a random variable [18], assessment of deviations from specified parameters [19], the "clearance" of a number to adequately sample [20];

- the construction of mathematical models: spatial reliability using K-dimensional cube [4], a simulation model "input – output" [21], ABC-analysis [22], the Kohonen self-organizing maps for clustering of network elements [23], figure Kiviat petal-type [24], "dummy poles" on the histogram [14], the model Black–Scholes [25];

- application of fuzzy set theory [12];

- the use of standard methods [26], Russian State Standard GOST R 27.606-2013, based on the RCM methodology [27, 28];

- expert evaluation [15];

- structural-matrix approach [29];

- PRI-reliability index as the ratio of the actually performed volume to the plan [30, 31].

Summing up the interim, it is necessary to note especially the definition of organizational and technological reliability. To assess the technical reliability (availability or time to failure) are characteristics of operational reliability, among which the most often are: time to failure, probability of failure, the overhaul life of components and aggregates, factors of readiness, technical use. In addition, technical systems, in most cases, belong to this category of systems in which the creation of reserves, providing a given level of reliability, very difficult, but if possible, it is quite expensive. Unlike technical systems, organizational and technological decisions of construction of buildings and armed represent the interaction of people and mechanization. This interaction is stochastic in nature, which is "absolutely not taken into account either by the organizational-technological documentation, nor in the existing normative-reference base (building regulations, etc.) [4]". These methods estimate the probabilistic nature of intensity of construction and installation works, or time-consuming and require special training, or do not provide the required accuracy of calculations.

The aim of the study was to determine the order of evaluation of organizational and technological reliability of construction processes.

Objectives of the study:

- to systematize calculation methods of organizational-technological reliability in the practice, the development of projects of construction of buildings and structures;

- to define the scope of the practical application of the author's approach taking into account the specifics of construction processes.

2. Research methods

In this paper we use classical methods of probability theory, suggesting the most likely outcome observations, and if such measurements are impossible (or difficult) to apply the methods of numerical experiment. The curve of cumulative probability (cumulative curve) is performed using standard methods of probability theory.based on the conditions not more (or less) of a given (technical or normative) values. For sampling the initial values describing the behavior of the process is proposed to carry out field

3. Results and Discussion

Differences of reliability of functioning of technical systems and organizational-technological solutions of the construction pay attention to the features of the sequence of construction and installation works. The degree of involvement of technical systems in the processes of construction of building structures it is easy to identify three groups:

- the first group includes jobs that are mechanized (for example, earth-wide, performed for the most part manipulators: bulldozers, scrapers, excavators);

- the second should include the processes involving the interaction of people and leading machines, it is impossible to perform work in the absence of at least one of the parts (for example, installation of precast concrete structures: interaction of the lifting mechanism and management (team) installers, or concrete mixture, where interact the leading machine – paver and link concrete workers);

- the third fall of work carried out without direct participation of the master, i.e., hand (stonework, installation of partitions of gypsum boards, installation of reinforcement frame, etc.), including the use of hand-held power tool.

The calculation of the reliability of the operation processes assigned to the first group, defined by the uptime manipulators (technical systems) and governed by applicable regulations GOST R 51901.5-2005. The performance of the funds mechanization in this case depends on the skill of the driver (operator) driving the car, as well as rational formations of a set of machines (such as excavator – car-truck). As the experience of the author, it is rarely possible to avoid complex (for example, when working excavator – car-truck most often, the number of the auxiliary machines is chosen considering the conditions of continuous operation of the presenter unit of the excavator).

For organizational and technological solutions related to the second group, we have to solve the problem of determining the rational ratio of the number of workers in the chain necessary to ensure the smooth operation of the master based on the current state elemental estimate standards for construction work (SEES). As an example we present the calculation for the number of workers in the link to organizational and technological solutions representing the interaction of people and the main machine (crane and concrete pump) that is used when laying concrete mixture in the overlap (Russian state itemized construction estimates GESN 81-02-06-2017.). The results of the calculations are given in table 1.

Table 1. Labor costs and time the leading machines for the construction of slabs in small-panel formworks (concrete mixture), for 10 m² of the ceiling structure (SEES 06-01-103)

No	Table SEES	Costs time the main machine mash.h.	Labour cost, people.	The estimated number of workers in the link, people.
The concrete mixture, tower crane, lifting capacity 8 tons.				
1	06-01-103-1	1.79	20.35	11.37
2	06-01-103-2	1.90	20.35	10.71
3	06-01-103-3	2.02	20.83	10.31
4	06-01-103-4	2.14	21.06	9.84
The concrete mixture, the concrete with the capacity of 65 m3 / h.				
5	06-01-103-5	0.81	20.01	24.70
6	06-01-103-6	0.93	20.01	21.52
7	06-01-103-7	1.16	20.47	17.65
8	06-01-103-8	1.28	20.71	16.18

Does not require proof procedure for computing the number of workers required for laying of concrete mixes with the target intensity (performance):

$$N_R = \frac{R}{R_M} \tag{1}$$

where N_R is the number of workers in the team (crew), persons (column 5, tab. 1);

- R – the cost of labor established a standard to perform unit work volume, person / h (column 4, table. 1);

- R_M – time costs of the basic technological machines set the standard for of the compliance unit volume of the work, mash. h (column 3, tab. 1).

Different values of the number of workers (column 5, tab. 1) are not integers. In this regard, the engineer-technologist to calculate the duration of works (in this example, bridging), you must set the intensity value of the production for maintenance of organizational-technological solutions of laying of concrete mixes. Obviously, to take the number of workers in a part different from an integer value, contrary to common sense. In this regard, for practical calculations the author uses the expression:

$$W_I = \frac{N_R}{R} - W_M \begin{cases} > 0 \Rightarrow W_I = W_M \\ < 0 \Rightarrow W_I = \dfrac{N_R}{R} \end{cases} \tag{2}$$

where W_I – the intensity (capacity) of the production work for the given organizational-technological solutions;

- W_M – performance main (host) machine organizational and technological process involving the interaction of people means of mechanization of construction and erection works (performance of the basic machine is associated with downtime of the machine, necessary to perform individual scope of work the proportion: $W_I = \frac{1}{R_M}$).

The study of the expression 2 to calculate the intensity of construction and installation works in the functioning of organizational and technological solutions, which is the interaction between machines and workers, can make a simple conclusion about the existence of reserve production capacity. The reserve is the result of rounding up or down the number of workers in the team (team). The value of the stock of production capacity, the formation of financed project as a result of rounding, is given in table. 2.

Table 2. The estimated intensity value for the organizational-technological solutions of laying of concrete mix in the overlap (SEES 06-01-103) and the amount of internal reserve power

Table SEES	**Option 1: working with a lack**				**Option 2: working with excess**			
	Col. working, people., N_R	The intensity of work, m2 in h,, W_I	Stock power on the car:		Col. working, people., N_R	The intensity of work, m2 in h,, W_I	Power reserve working	
			m2 in h	%			m2 in h	%
1	2	3	4	5	6	7	8	9
The concrete mixture, tower crane, lifting capacity 8 tons.								
06-01-091-1	11	5.41	0.18	3.24	12	5.59	0.31	5.26
06-01-091-2	10	4.91	0.35	6.63	11	5.26	0.14	2.63
06-01-091-3	10	4.80	0.15	3.02	11	4.95	0.33	6.26
06-01-091-4	9	4.27	0.40	8.55	10	4.67	0.08	1.59
The concrete mixture, the concrete with the capacity of 65 m3 / h.								
06-01-091-5	24	11.99	0.35	2.85	25	12.35	0.15	1.19
06-01-091-6	21	10.49	0.26	2.40	22	10.75	0.24	2.20
06-01-091-7	17	8.30	0.32	3.66	18	8.62	0.17	1.96
06-01-091-8	16	7.73	0.09	1.11	17	7.81	0.40	4.83

In the case that the duration of works is calculated in terms of intensity equal to the operating performance the main (host) machine (WI = WM, variant 2, column 7, table. 2), then the value of organizational-technological reliability largely depends on the probability of uninterrupted operation of machines and tools and is evaluated on the basis of the existing norm of positive documents (GOST). If the duration calculation done on the total value of productivity of workers ($W_I = \frac{N_R}{R}$,option 1, column 3, tab. 2), then OTR is determined by the probability of replacement jobs in the prescribed volume element of concrete (for this example). These findings do not take into account the economic impact of the length for alternatives 1 and 2 (table. 2).

Organizational and technological reliability of construction works performed manually, in most cases, eliminates the calculation of the technical reliability of the means of mechanization used as the master process. However, the destabilizing factors make the technology of construction of building structures in stochastic processes. These methods assess the reliability, as a rule, very time consuming, and their practical use requires special training in the field of probability theory and mathematical statistics. According to the author, to simplify the estimation of the probability of execution of works in time is possible under condition of the compliance calculation procedures in relation to the array of values that describes the measure of productivity for a certain period of time.

The accumulation of information about the performance of the work, describing construction processes performed manually may take from several days to several months. For example, when monitoring the productivity per hour for the accumulation of an array of 100 values enough 13 shifts. If the initial information to consider the performance in change, can require up to 4 months. It is important to emphasize that in terms of time performance in shift, you must enter the correction factors that account for the unevenness of the intensity of work for one shift (or example, the performance one hour before a lunch break is often lower afternoon by 25–35 %).

The practical application of the indicator "organizational and technological reliability" involves the solution of tasks that are correctly grouped into two groups. The first group – the task of finding the reliability (validity) of the quantitative values of indicators describing the process of functioning of technological process in construction (typically, the performance or the intensity of production work). The second group includes tasks that are usually called about the inverse, that is, for a given level of reliability (reliability) should be determined quantitative value of the indicator. From the point of view of the author, the greatest value in practice, the construction of objects of civil and industrial use has increased intensity (productivity) of the work. The solution of direct and inverse problem, it is advisable to illustrate on the graph (Fig. 1a, b).

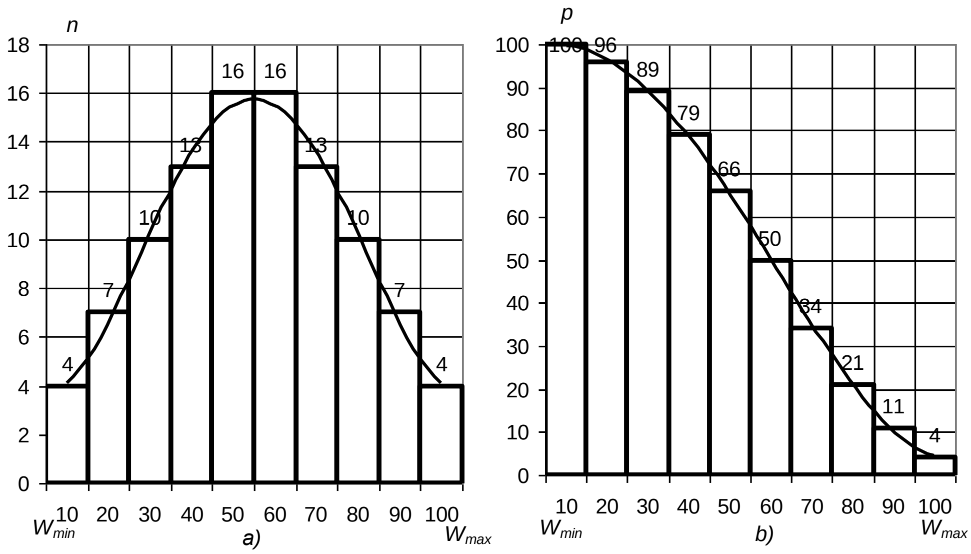

Figure 1. Schedule of functions of random variables WI: a) distribution density; b) the curve of cumulative probabilities

On the chart (Fig. 1 a, b) the x-axis shows the change in the intensity of production work ($W_{Imax} > W_I > W_{Imin}$) in percent. The ordinate of the graph of a probability density function (Fig. 1 a) shows the number of values from the set of values $W_I(N)$ located in the corresponding interval (range of area on 0 to 100%, W_{Imin} = 0%, W_{Imax} = 100%). The ordinate of the curve of cumulative probability (Fig. 1 b)- shows the changing probabilities depending on the magnitude of intensity of production (W_I).

From the position of the classical conception of probability theory, the probability of each of values constituting the set of values $W_I(N)$ equal to p = 0.01 (if number of values in a sample N = 100). However, when considering the probabilities of each of the intervals of the $W_{Imax} > W_I > W_{Imin}$ obviously, the highest probability interval of 0.4 $W_{Imax} > W_{In} >$ 0.6 W_{Imax} and equal to p = 0.16 (see Fig. 1a).

In practice, when calculating the duration of the construction works of no special interest is the probability value of each element of the sample, and even separately of each interval. Actually, it really is important to determine the probability that the intensity of production work will not be below the estimated (or specified design) values [32]. To achieve this purpose, perfect use of the curve of cumulative probability (Fig. 1b).

The solution of the direct problem involves calculating the probability that the intensity value of the production of works in the course of erection of building structures, will not be less than the set value, for example 0.8 [33] (W_{In}). With this purpose it is necessary to set the interval in which the estimated intensity value on the x-axis and then determine the corresponding probability value on the y-axis (Fig. 1b). The reverse procedure can be applied when solving the opposite problem: finding the estimated intensity values for a given probability value (OTR). This approach allows us to assess the specific conditions, regardless of the existence of the counterpart [34].

Practical determination of the intensity of production in individual manufacturing process (e.g., concrete mixture) is performed by the author on the basis of the specified level of organizational and technological reliability. The specified level for the most part, is taken equal to R = 0.8. The validity of this approach is confirmed by published results of research of Molodetskiy V.R. [14]. The author's approach is that instead of the interval of intensity values when calculating the length of production work, use a discrete value for a given level of probability. It is important to emphasize that this approach allows us to estimate the probability of activity (performance) of the employee and does not require assessment "health of the human operator by means of professional selection, training, health monitoring [35]".

Indeed, in case of representation of the OTR graph of a curve of the accumulated probability, it is necessary and sufficient set of values of the intensity of production work (W_{In}) to split into two parts. The first contains values less than the calculated value (not satisfying the condition). This separation allows you to find an indicator which divides a set of values, that is, a border. With this purpose it is necessary to sort the values by ascending order (lowest to highest). It is obvious that the likelihood (OTR) p = 0.8, boundary value will correspond to the index, which occupies in the sample number n = 21 (assuming that the number of values in a sample N = 100).

Thus, for a given value of *p* (for example *p* = 0.8) is necessary and sufficient to take from the ordered sample (*N* = 100) the value of n = 21. To retrieve the number of values which is different from 100, it is recommended to use the equation to find the number corresponding to the calculated (design) value of the intensity of production work:

$$n = 100N(1 - p) + 1 \quad (3),$$

where n is the indicator number in the ordered sample values;

- *p* – the set level of organizational and technological reliability (probability, e.g., *p* = 0.8);

- *N* – number of values in the array.

4. Conclusions

Thus, when determining the calculated (design) values of the intensity of construction and installation works it is necessary to take into account the peculiarities of the processes of the erection of the discussion of buildings and structures: fully mechanized working together machines and people, as well as performed entirely by hand.

For fully mechanized processes, the assessment of organizational and technological reliability is advantageously carried out by applying the standard (in accordance with Russian State Standard GOST) methods of assessment of technical reliability.

For the processes of construction of building structures manually determining the design value of the intensity of the production of works corresponding to a given level of reliability, should be performed by dividing the set of values obtained as a result of observations into two groups (compliant and non compliant design value). The value of the corresponding edge, it is advisable to determine how the project (or defined for calculating, for example, duration).

The most effective field of application of the described approach of calculation of OTR should include construction processes performed entirely by hand and using leading technology of mechanization, subject to the calculation of the intensity of production work on the total performance.

Reference

1. Gusakov A.A. *Organizatsionno-tekhnologicheskaya nadezhnost stroitelnogo proizvodstva* [Organizational and technological reliability of construction production]. Moscow: Stroyizdat. 1974. 252 p. (rus)
2. Ivashenko Yu.A.. Ferder A.V. Sistema uravneniye dlya opredeleniya funktsii raspredeleniya pri veroyatnostnykh metodakh rascheta [The system equation for determining the distribution function in probabilistic calculation methods]. *Bulletin of the South Ural state University.* 2017. No. 1. Pp. 34–37. (rus)
3. Poteryayev I.K. Metodika rascheta chisla transportnykh sredstv v transportnykh operatsiyakh asfaltobetonnoy smesi [The method of calculating the number of vehicles in the transportation operations asphalt mixture]. *Bulletin of the Kuzbass technical University.* 2016. No. 1. Pp. 83–88. (rus)
4. Ginzburg A.V. Organizatsionno-tekhnologicheskaya nadezhnost stroitelnykh system [Organizational-technological reliability of building systems]. *Vestnik MGSU.* 2010. No. 4. Pp. 251–255. (rus)
5. Morozenko A.A.. Voronkov I.E. Problemy otsenki povysheniya nadezhnosti elementov organizatsionnoy struktury investitsionno- stroitelnogo proyekta [Problems of assessment of reliability of elements of the organizational structure investment - construction project]. *Industrial and civil construction.* 2014. No. 12. Pp. 30–32. (rus)
6. Mikhaylova E.V. Osobennosti stroitelnogo kompleksa Volgogradskoy oblasti [Characteristics of the construction complex of Volgograd region*]. Business. Education. Right. Bulletin of the Volgograd Institute of business.* 2011. No. 4. Pp. 44–47. (rus)
7. Vasilenko Zh.A. Kriterii otsenki nadezhnosti sistemy upravleniya zhilishchnym stroitelstvom [Evaluation criteria reliability of control system of housing construction]. *Engineering journal of Don.* 2012. No. 3. Pp. 702–705. (rus)

Литература

1. Гусаков А.А. Организационно-технологическая надежность строительного производства. М.: Стройиздат, 1974. 252 с.
2. Ивашенко Ю.А., Фердер А.В. Система уравнение для определения функции распределения при вероятностных методах расчета // Вестник Южно-Уральского государственного университета. 2017. № 1. С. 34–37.
3. Потеряев И.К. Методика расчета числа транспортных средств в транспортных операциях асфальтобетонной смеси // Вестник Кузбасского технического университета. 2016. № 1. С. 83–88.
4. Гинзбург А.В. Организационно-технологическая надежность строительных систем // Вестник МГСУ. 2010. № 4. С. 251–255.
5. Морозенко А.А., Воронков И.Е. Проблемы оценки повышения надежности элементов организационной структуры инвестиционно- строительного проекта // Промышленное и гражданское строительство. 2014. № 12. С. 30–32.
6. Михайлова Е.В. Особенности строительного комплекса Волгоградской области // Бизнес. Образование. Право. Вестник Волгоградского института бизнеса. 2011. № 4. С. 44–47.
7. Василенко Ж.А. Критерии оценки надежности системы управления жилищным строительством // Инженерный вестник Дона. 2012. № 3. С. 702–705.
8. Болотин С.А., Котовская М. А. Адаптация метода критической цепи при поточной организации работ // Недвижимость: экономика, управление. 2014. № 3-4. С. 38–43.
9. Калугин Ю.Б. Графоаналитическая модель и приближенный метод оценки сроков выполнения проекта с вероятностными временными параметрами //

8. Bolotin S.A.. Kotovskaya M. A. Adaptatsiya metoda kriticheskoy tsepi pri potochnoy organizatsii rabot [The adaptation of the method of critical chain in a production organization of work]. *Real Estate: economy, management.* 2014. No. 3-4. Pp. 38–43. (rus)
9. Kalugin Yu.B. Grafoanaliticheskaya model i priblizhennyy metod otsenki srokov vypolneniya proyekta s veroyatnostnymi vremennymi parametrami [Graphical-analytical model and an approximate method of assessment of the timing of the project with probabilistic time parameters]. *News of higher educational institutions. Construction.* 2015. No. 7. Pp. 26–37. (rus)
10. Goldratt E.M. *Critical Chain.* Great Barrington, MA: North River Press, 1997.
11. Goldratt E.M. *Theory of Constrains.* Croton-on-Hudson, NY: North River Press, 1990.
12. Lapidus A.A.. Makarov A.N. Teoriya nechetkikh mnozhestv na etapakh modelirovaniya organizatsii stroitelnykh protsessov vozvedeniya mnogoetazhnykh zdaniy [The theory of fuzzy sets in the modelling stages of the construction processes the construction of high-rise buildings]. *Industrial and civil construction.* 2016. No. 6. Pp. 66–71. (rus)
13. Oleynik P.P. Analiz i razrabotka norm prodolzhitelnosti stroitelstva zhilykh zdaniy tipovykh seriy [Analysis and development of norms of duration of construction of residential buildings of typical series]. *Mechanization of construction.* 2008. No. 2. Pp. 18–23. (rus)
14. Molodetskiy V.R.. Martysh A.A. Veroyatnostnyye parametry vypolneniya otdelnoy stroitelno-montazhnoy raboty [Probabilistic parameters of implementation of different construction works]. *Bulletin of Prydniprovsk state Academy of civil engineering and architectures.* 2013. No. 3. Pp. 8–14. (rus)
15. Kurochka P.N.. Molozin S.V.. Telnykh V.G. Otsenka nadezhnosti elementov organizatsionnoy sistemy [Evaluation of the reliability of the elements of the organizational system]. *Bulletin of Voronezh state technical University.* 2010. No. 7. Pp. 27–30. (rus)
16. Shulzhenko N.A.. Pushilina Yu.N.. Chubarov D.I. Otsenka organizatsionno-tekhnologicheskoy nadezhnosti pri organizatsii podgotovki territorii pod zastroyku [Evaluation of organizational and technological reliability in the provision of training areas for development]. *Izvestiya of the Tula state University.* 2016. No. 7-2. Pp. 152–157. (rus)
17. Pakhomova E.G.. Bredikhina N.V. Veroyatnostnyye zakonomernosti vozniknoveniya otkazov stroitelnogo potoka [Probabilistic patterns of occurrence of failures of construction flow]. *Izvestiya of southwest state University.* 2016. No. 6. Pp. 35–40. (rus)
18. Velichkin V.Z. Upravleniye i nadezhnost realizatsii stroitelnykh program [Management and implementation of reliability programs construction]. *Engineering construction magazine.* 2014. No. 7. Pp. 74–79. (rus)
19. Kostyuchenko V.V. Upravleniye protsessom povysheniya effektivnosti organizatsionno- tekhnologicheskikh stroitelnykh system [Managing the process of improving the efficiency of the organizational and technological construction systems]. *Engineering journal of Don.* 2012. No. 1. Pp. 536–542. (rus)
20. Nedavniy O.I.. Kuznetsov S.M.. Kandaurova N.M. Obosnovaniye vremeni proizvodstva stroitelnykh rabot [Justification for the production of building work]. *News of higher educational institutions. Construction.* 2013. No. 9. Pp. 107–114. (rus)
21. Gusev B.V., Guseva A.Yu., Litvinovskiy E.M. Ustoychivost i nadezhnost raboty konveyernykh tekhnologicheskikh liniy po proizvodstvu sbornogo zhelezobetona [The stability and reliability of the conveyor technological lines for manufacture of precast reinforced concrete]. *Concrete Technology.* 2015. No. 7-8. Pp. 30–31. (rus)
22. Rakhutin M.G.. Pankratenko N.A. Ispolzovaniye AVS – analiza pri issledovanii nadezhnosti tonneleprokhodcheskogo kompleksa dlya prokladki Известия высших учебных заведений. Строительство. 2015. № 7. С. 26–37.
10. Goldratt E.M. Critical Chain. Great Barrington, MA: North River Press, 1997.
11. Goldratt E.M., Theory of Constrains, Croton-on-Hudson, NY: North River Press, 1990.
12. Лапидус А.А., Макаров А.Н. Теория нечетких множеств на этапах моделирования организации строительных процессов возведения многоэтажных зданий // Промышленное и гражданское строительство. 2016. № 6. С. 66–71.
13. Олейник П.П. Анализ и разработка норм продолжительности строительства жилых зданий типовых серий // Механизация строительства. 2008. № 2. С. 18–23.
14. Молодецкий В.Р., Мартыш А.А. Вероятностные параметры выполнения отдельной строительно-монтажной работы // Вiсник придніпровськоі державноі академії будівництва та архітектури. 2013. № 3. С. 8–14.
15. Курочка П.Н., Молозин С.В., Тельных В.Г. Оценка надежности элементов организационной системы // Вестник Воронежского государственного технического университета. 2010. № 7. С. 27–30.
16. Шульженко Н.А., Пушилина Ю.Н., Чубаров Д.И. Оценка организационно-технологической надежности при организации подготовки территории под застройку // Известия Тульского государственного университета. 2016. № 7-2. С. 152–157.
17. Пахомова Е.Г., Бредихина Н.В. Вероятностные закономерности возникновения отказов строительного потока // Известия Юго-Западного государственного университета. 2016. № 6. С. 35–40.
18. Величкин В.З. Управление и надежность реализации строительных программ // Инженерно- строительный журнал. 2014. № 7. С. 74–79.
19. Костюченко В.В. Управление процессом повышения эффективности организационно- технологических строительных систем // Инженерный вестник Дона. 2012. № 1. С. 536–542.
20. Недавний О.И., Кузнецов С.М., Кандаурова Н.М. Обоснование времени производства строительных работ // Известия высших учебных заведений. Строительство. 2013. № 9. С. 107–114.
21. Гусев Б.В., Гусева А.Ю., Литвиновский Е.М. Устойчивость и надежность работы конвейерных технологических линий по производству сборного железобетона // Технологии бетонов. 2015. № 7-8. С. 30–31
22. Рахутин М.Г., Панкратенко Н.А. Использование АВС – анализа при исследовании надежности тоннелепроходческого комплекса для прокладки эскалаторного тоннеля // Известия высших учебных заведений. Горный журнал. 2013. № 1. С. 40–43.
23. Мелькумов В.Н., Кузнецова Г.А., Кобылев А.Н. Использование кластерного анализа для повышения надежности инженерных сетей // Вестник Воронежского государственного технического университета. 2012. № 11. С. 141–145.
24. Газарян Р.К., Чулков В.О., Грабовый К.П., Кулаков К.Ю. Оценка уровня организационно-технологической надежности функционирования строительных промышленных предприятий // Вестник МГСУ. 2012. № 3. С. 218–222.
25. Кабанов В.Н., Михайлова Е.В. Определение организационно-технологической надежности строительной организации // Экономика строительства. 2012. № 4. С. 67–79.
26. Беляков М. Формирование оптамальной программы обслуживания оборудования с использованием RCM-анализа // Сухие строительные смеси. 2015. № 5. С. 41–44.

eskalatornogo tonnelya [The use of ABC – analysis in the study of reliability of equipment for laying an escalator tunnel]. *News of higher educational institutions. Mining journal.* 2013. No. 1. Pp. 40–43. (rus)

23. Melkumov V.N.. Kuznetsova G.A.. Kobylev A.N. Ispolzovaniye klasternogo analiza dlya povysheniya nadezhnosti inzhenernykh setey [The use of cluster analysis to improve the reliability of engineering networks]. *Vestnik Voronezh state technical University.* 2012. No. 11. Pp. 141–145. (rus)
24. Gazaryan R.K.. Chulkov V.O.. Grabovyy K.P.. Kulakov K.Yu. Otsenka urovnya organizatsionno-tekhnologicheskoy nadezhnosti funktsionirovaniya stroitelnykh promyshlennykh predpriyatiy [Assessment of the level of organizational and technological reliability of construction of industrial enterprises]. *Vestnik MGSU.* 2012. No. 3. Pp. 218–222. (rus)
25. Kabanov V.N.. Mikhaylova E.V. Opredeleniye organizatsionno-tekhnologicheskoy nadezhnosti stroitelnoy organizatsii [The definition of the organizational-technological reliability of construction organizations]. *Economics of construction.* 2012. No. 4. Pp. 67–79. (rus)
26. Belyakov M. Formirovaniye optamalnoy programmy obsluzhivaniya oborudovaniya s ispolzovaniyem RCM-analiza [The formation of the optimal program of equipment maintenance using RCM analysis]. *Dry mixes.* 2015. No. 5. Pp. 41–44. (rus)
27. Nowlan F.S., Heap H.F. *Reliability-centered Maintenance*. San Francisco: Dolby Access Press, 1978. 466 p.
28. Moubray J. *Reliability-centered Maintenance.* Second Edition. NY: Industrial Press Inc, 1997. 426 p.
29. Mishlanova M.Yu. Razvitiye strukturno-matrichnogo podkhoda v organizatsionnoy diagnostike [The development of the structural matrix approach in organizational diagnostics]. *Vestnik MGSU.* 2012. No. 4. Pp. 220–225. (rus)
30. Ballard G. *Lean Construction and EPC Performance Improvement.* Alarcón, L. F. (ed), Lean Construction, A.A. Balkema, The Netherlands, 1993. 497 pp.
31. González V., Alarcón L.F., Maturana S., Bustamante J.A., Mundaca F. Work-in-process buffer management using the rational commitment model in repetitive projects. *Proceedings 16th Annual Conference of International Group for Lean Construction*. Manchester, UK, 2008.
32. Lapidus A.A. Aktualnyye problemy organizatsionno-tekhnologicheskogo proyektirovaniya [Actual problems of organizational and technological design]. *Technology and organization of construction production.* 2013. No. 3. Pp. 1–13. (rus)
33. Połoński M. the Distribution of duration czynności and the term zakòczenia visited niewzględnieniem elementòw risk analysis. *Acta Scientiarum Polonorum. Architectura*. 2005. Vol. 4. No. 2. Pp. 95–106
34. Radkevich A.V., Hudenko V.F., Gluschenko V.M. Analiz suschestvuyuschih problem organizatsionno-tehnologicheskoy nadezhnosti krovelnyih sistem [Analysis of problems of organizational-technological reliability of roofing systems]. *Science is the progress of transport.* 2015. No. 2. Pp. 222–230. (rus)
35. Samsonkin V.N., Karivskiy F.A., Petrenko R.B., Petinov Ya.P. Obespechenie nadezhnosti «chelovecheskogo faktora» na zheleznodorozhnom transporte Ukrainyi: kak est i kak nuzhno [The reliability of "human factor" on the railway transport of Ukraine: the present and the need]. *Railway transport of Ukraine.* 2014. No. 4. Pp 12–18.

27. Nowlan F.S., Heap H.F. Reliability-centered Maintenance. San Francisco: Dolby Access Press, 1978. 466 p.
28. Moubray J. Reliability-centered Maintenance. Second Edition. NY: Industrial Press Inc, 1997. 426 p.
29. Мишланова М.Ю. Развитие структурно-матричного подхода в организационной диагностике // Вестник МГСУ. 2012. № 4. С. 220–225.
30. Ballard G. Lean Construction and EPC Performance Improvement. Alarcón, L. F. (ed), Lean Construction, A.A. Balkema, The Netherlands, 1993. 497 pp.
31. González V., Alarcón L.F., Maturana S., Bustamante J.A., Mundaca F. Work-in-process buffer management using the rational commitment model in repetitive projects // Proceedings 16th Annual Conference of International Group for Lean Construction, Manchester. UK, 2008.
32. Лапидус А.А. Актуальные проблемы организационно-технологического проектирования // Технология и организация строительного производства. 2013. № 3. С. 1–13.
33. Połoński M. Rozkład czasu trwania czynności a termin zakòczenia przedsięwzięcia z niewzględnieniem elementòw analizy ryzyka // Acta Scientiarum Polonorum. Architectura. 2005. Vol. 4. № 2. Pp. 95–106.
34. Радкевич А.В., Худенко В.Ф., Глущенко В.М. Анализ существующих проблем организационно-технологической надежности кровельных систем // Наука та прогресс транспорту. 2015. № 2. С. 222–230
35. Самсонкин В.Н., Каривский Ф.А., Петренко Р.Б., Петинов Я.П. Обеспечение надежности «человеческого фактора» на железнодорожном транспорте Украины: как есть и как нужно // Железнодорожный транспорт Украины. 2014. № 4. С. 12–18.

Vadim Kabanov,
+7(905)398-36-63; kabanovvn@yandex.ru

Вадим Николаевич Кабанов,
+7(905)398-36-63;
эл. почта: kabanovvn@yandex.ru

Кабанов В.Н. Организационно-технологическая надежность строительного процесса // Инженерно-строительный журнал. 2018. № 1(77). С. 59–67.