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ОТЕЧЕСТВЕННЫЙ И ЗАРУБЕЖНЫЙ ОПЫТ МОДЕЛИРОВАНИЯ ОРГАНИЗАЦИОННО-ТЕХНОЛОГИЧЕСКОЙ НАДЁЖНОСТИ СТРОИТЕЛЬНОГО ПРОИЗВОДСТВА НА СОВРЕМЕННОМ ЭТАПЕ

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В статье обоснована актуальность проблемы повышения эффективности организации строительного производства путем моделирования организационно-технологической надежности строительства на современном этапе. Представлен обзор отечественного и зарубежного опыта решения указанной проблемы. Сформулированы основные выводы по современному состоянию теоретической проработанности темы и ее практической реализации. Определены основные направления дальнейших научных исследований. Основанием подхода авторов является положение, что моделирование организационно-технологической надежности строительного производства как сложной системы необходимо начинать с моделирования её подсистем: строительно-монтажных работ, так как надёжность системы зависит от надёжности её компонентов. Данная статья направлена на системное представление методов моделирования строительно-монтажных работ с целью повышения организационно-технологической надёжности строительного производства. Цель статьи – комплексное представление методов моделирования организационно-технологической надёжности строительного производства, применяющихся на современном этапе развития строительной науки и науки об организации строительного производства. Статья интересна для читателей, интересующихся использованием экономико-математических моделей и методов в современной системе организации строительного производства при выборе вариантов строительно-монтажных работ: а именно, руководствоваться моделями, учитывающими различные целевые критерии строительства зданий и сооружений, в том числе разнонаправленные и нечёткие.

Ключевые слова: *строительство, моделирование, организационно-технологическая надёжность, строительное производство, строительно-монтажные работы*

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RUSSIAN AND INTERNATIONAL EXPERIENCE IN SIMULATION OF THE ORGANIZATIONAL AND TECHNOLOGICAL RELIABILITY OF MODERN CONSTRUCTION PRODUCTION

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The paper argues that the problem of an increased efficiency of a construction production company is important nowadays by simulating the organizational and technological reliability of construction. An overview of Russian and international experience in solving this problem is presented. The current state of theoretical elaboration of the topic and its practical implementation are outlined in the paper. The main directions of further scientific research are also defined. The authors base their approach on the simulation of the organizational and technological reliability of construction production as a complex system, which should start with simulation of its subsystems such as construction and installation works, since the reliability of the system depends on the reliability of its components. This paper systematically reflects the modeling methods of construction and installation works in order to improve the organizational and technological reliability of construction production. The purpose of the article is the integrated presentation of methods for modeling the organizational and technological reliability of construction, which are used at the current stage of development of science of construction operations organization and the construction science as a whole. The article is particularly useful to the readers interested in the use of economic-mathematical models and methods in modern construction operations system, namely, to use models that account for different target criteria for the constructions, including multi-directional and fuzzy.

Key words: *construction, simulation, organizational and technological reliability, construction operations, construction and installation works*

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The study is relevant to the scientists and practitioners in the field of construction due to the fact that modern buildings are subjected to high requirements of compliance with safety, reliability, comfort, energy efficiency [15-17]. These requirements should be satisfied throughout the building life cycle, but the required parameters of the future building are being developed in its early stages of design and construction. At the design stage, the future parameters can be calculated precisely, but during the construction and installation process they can undergo significant changes because the main characteristic feature of construction and installation works is their versatility (CIW). These particular works can be carried out in different technological ways even with the same building materials, products and structures, but, for example, by different contracting construction organizations. It is the cause of different construction time and costs or engineering and economical indicators for the same construction. Additionally, the production of CIW may be altered by force majeure, due to changes of weather, disruptions in the supply of building materials, products and structures, returns of the materials due to poor quality, etc. All of these conditions affect the quality of the construction site. Targets for the construction of buildings may be the achievement of certain energy efficiency indicators, a certain value of construction costs, and precise timing. The successful completion of one or several construction sites is defined as the achievement of the planned objectives within the established limits on the duration and time of completion, the estimated cost of construction, the quality of the work and the specification of the requirements for the results. At the same time the deliverable must be accepted by the customer in the prescribed order. Thus, the key parameters affecting the final result of the construction are the duration, cost, and quality of the performed works. The concept of organizational and technological reliability (OTR) of construction production unites these parameters. Considering that construction production is a complex man-machine system, consisting of technical and labour resources, as well as taking into account the multi-variant production of construction works and the presence of many factors, affecting the quality of construction facilities, it is possible to improve the OTR of construction production by modelling it as a whole and modelling the production of CIW for different target criteria. Thus, the simulation of the OTR of construction operations as a complex system should begin with the simulation of its subsystems: construction and installation works, since the reliability of the system depends on the reliability of its components. Also it seems necessary to systematize and comprehensively present models for increasing the organizational and technological reliability of construction operations when selecting CIW by technological and organizational aspects. Moreover, there are contradictions in both practice and theory that determine the relevance of the study.

Methodological issues of the organizational and technological reliability of the construction were investigated in the works of A.A. Volkov, V.M. Lebedev, which investigated the OTR control systems of construction. A.V. Ginsburg considered OTR of construction production in terms of automation and management of building organizations. M.L. Shpric evaluated OTR construction of multi - variant building complexes.V.V. Burchik, N.P. Kuz'mich considered OTR in terms of sustainable development of organizations. S.M. Kuznetsova, N.A. Sirotkina, O.A. Legostaeva, S.N. Yachmen'kova examined the evaluation of OTR of construction.

V.A. Afanas'eva, V.S. Balickiy, S.A. Barkalov, S.A. Bolotin, M.S. Budnikov, S.N. Bulgakov, V.N. Burkov, N.V. Varlamov, V.I. Voropaev, I.G. Galkin, L.G. Golub, A.A. Gusakov, L.B. Zelencov, N.I. Il'in, YU.A. Kulikov, S.V. Nikolaev, YU.B. Monfred, P.P. Olejnik, B.V. Prykin, V.I. Rybal'skiy, V.I. Telichenko, V.I. Torkatyuk, V.N. Trenev, S.A. Ushackiy, V.D. Shapiro, A.K. Shrejber, T.N. Cay, A.D. Cvirkun, R.I. Fokov, etc. studied the development of methods and selection of organizational and technological techniques for construction and installation work in terms of organizational and technological reliability.

Modern international research is also aimed at developing calendar plans of work schedules along with linking them to BIM - models of construction objects [1]. The international publications contain a systematic approach to the modelling of building processes, considering the influence of construction work on the characteristics of the construction site and the environment. Also the impact of the life cycle of a building on the choice of construction and installation options is considered [2]. Different simulation techniques are applied. For example, Life Cycle Assessment Methodology (LCA) is a systematic environmental management tool for analysing and evaluating the environmental impact of a product or process in a holistic manner. Bilek, Rice and Matthew described it in their study [3]. Their paper states that in assessing the life cycle of a building, the building processes play not a major but still a significant role, and proposed LCA design model is aggregated into eight main categories: site preparation, foundation, concrete works, blockwork, metal framing, finishing works, load handling, power consumptions. This approach is justified by the fact that construction has many processes and it is not appropriate to model each of them separately.

The authors of the monograph «Model of building processes» use IDEF $_0$(Integrated Computer Aided Manufacturing Definition) to simulate the construction and installation works by the methodology of functional modeling, allowing graphical representation of all CIW stages: site preparation, "zero" cycle, erection of building superstructure block, finishing works, special purpose works and commissioning of a facility [4]. The functions of the system are analyzed independently of the objects they operate by. It allows more precise modelling of the logic and interaction of processes. Authors fully encourage using the methodology of functional modeling [5, 6].

International scientists have also developed simulation techniques for large construction projects that are exposed to external and uncontrolled events that affect their schedule and financial results. The study [7] proposes criteria for modeling large and complex systems, such as construction projects, to support life cycle management, risk assessment and simulation of cyclical operations. Providing these items, they introduce the concept of hybrid modelling, which includes a set of models: the modelling of networks vertically (bottom-up and top-down) and horizontally (dependency/relativity) to represent a hierarchy of construction operations and organizations; use of library item concepts, agent model philosophy, Monte Carlo analysis and Discrete Event Simulation (DES) with resource use analysis, including Queuing algorithms. The programming paradigm is object-oriented programming, modified according to an agent-based modeling philosophy and automating generation of modeling library icons. Hybrid modeling allows life-cycle management: import and export capabilities to databases and automation of data and documentation input operations.

Many studies by domestic and foreign scientists are devoted to CIW scheduling and networking, affecting various aspects of their planning and modelling [8]. The study presents the construction

planning model with temporary links based on the scheduling algorithm.This model deals with the problem of the correct sequence with calculation of the process of «Live Partition Mobility» (LPM) taking into account technical and organizational constraints. The study [9] presents a linear programming model for the flow organization of construction, aimed at the formation of linear schedules by the criterion of the lowest cost of construction resources under the constraints of possible reduction of construction time under the influence of risks and force majeure. Monograph [10] presents a created neurodynamic model for optimizing engineering design CONSCOM. It is a prototype of software package for construction planning, cost optimization, and change order management that can be used by both owners and contractors to effectively manage construction projects, with which repetitive and non-repetitive work can be simulated, strategies for multiple construction organizations developed, and the impact of different working conditions on their performance evaluated. It also presents the optimization formulation of the problem of planning a construction project in order to minimize the direct costs of construction, which due to its nonlinear nature is solved by using a neurodynamic model.

The authors of the study [11] draw attention to the fact that the problem of construction planning and resource allocation is a complex and has a stochastic nature. To solve it, it is proposed to implement multi-object optimization, in which project completion time and expected costs are minimized simultaneously. Biruk and Szakowski propose construction planning using resource-constrained methods by creating a mathematical model for optimized planning of linear construction projects, in terms of resource constraints and operational continuity [12].

The complex models require powerful computers and software, so the digitalization of construction is a modern trend. According to Jose Maria Delos Santos, an expert and member of team of Project-Management.com, the modern technological and software trends in construction are construction management software, use of drones, robotic equipment, augmented/virtual reality and 3D printing [13].

Summarizing the review of scientific literature, we can say that the methods and models obtained in these sources are aimed mainly at ensuring the resources involved in the construction organization meet the requirements dictated by the work performed, and choose a rational scheme of crews on construction sites to reduce construction time by reducing crews downtime when moving from site to site. The dependence of the cost of the work on the time of its performance was noted, but it was considered only in the classical formulation of L. Ford and D. Falkerson [14]. Consequently, it is necessary to solve the problem of scheduling work with a close alignment of the necessary resources for their implementation, including limited by the technological relationship of the work performed, which can often be of a different nature. In cases the construction and installation work are on the same site, the dependence between the works is rigid, that is, their violation is impossible or very costly. On the other hand, if the construction and installation work is carried out at various sites, the dependence between such works has advisory nature. So, there could be a possibility of the violation of such dependencies, this leads to additional costs. The acceptability of these costs for a particular enterprise should be required to establish at the stage of organizational and technological design. However, at the stages of implementation of organizational and technological concept, there are often situations when, as a result of quality control of construction and installation work, the company has to redo the already completed sections or to make major changes, which leads to an increase in execution time and involvement of additional resources. Thus, quality assurance is one of the sub-tasks of organizational and technological reliability of construction production, based on theories of flow construction, network planning, control systems. Reliability of the technological system of construction and installation works should be considered in terms of timing, costs, quality parameters of products. At the same time, the methodology of organizational reliability (in terms of timing) has been developed the most.

Thus, the modeling of organizational and technological reliability should be considered from the standpoint of both deterministic nature (as construction processes are regulated), but also taking into account the probabilistic nature inherent in construction as a complex stochastic system.

REFERENCES

1. ***Lianying Zhang, Xiang Zhang, Teng Ma.*** *Management of Construction Schedules Based on Building Information Modeling Technology. Emerging Technologies for Information Systems, Computing, and Management. Springer, NY. 2013. V.1. P. 81-88.*
2. ***Cormen T.H., Leiserson C.I., Rivest R.L., Stein C.*** *Algorithms: construction and analysis. 2nd edition, Translated from English, Moscow: Williams Publishing house. 2010. 1296 p.*
3. ***Bilec M., Ries R., Scott Matthews H.*** *Life-Cycle Assessment Modeling of Construction Processes for Buildings. Journal of Infrastructure Systems. V. 16. N 3. 2010. P. 199-205.*
4. ***Karhu Vesa, Keitila Matti, Lahdenpera Pertti.*** *Construction process model. Generic present-states systematization by IDEF0. Espoo 1997. Technical Research Centre of Finland, VTT Tiedotteita – Meddelanden – Research Notes 1845. 190 p.*
5. ***Fedosov S.V., Fedoseev V.N., Kotlov V.G., Petrukhin A.B., Oparina L.A., Martynov I.A.*** *Theoretical bases and methods of increasing energy-efficient residential and public buildings and buildings of textile and light industry. Ivanovo: Pressto. 2018. 320 p. (in Russian).*
6. ***Aloyan R.M., Fedosov S.V., Oparina L.A.*** *Energy-Efficient buildings-state, problems and solutions. Ivanovo: Pressto. 2016. 240 p. (in Russian).*
7. ***Mohamed Moussa, Janaka Y. Ruwanpura, George Jergeas, Tamer Mohamed****. Hybrid Simulation Environment for Construction Projects: Identification of System Design Criteria. Journal of Construction Engineering. Vol. 2014.* Article ID 847430. *12 p.*
8. ***Zdzislaw Hejducki.*** *Scheduling model of construction activity with time couplings. Journal of Civil Engineering and Management. 2003. 9(4). P. 284-291. DOI: 10.1080/13923730.2003.10531341.*
9. ***Biruk S., Jaśkowski P., Czarnigowska A.*** *Updating Linear Schedules with Lowest Cost: a Linear Programming Model. IOP Conf. Series: Materials Science and Engineering. 2017. 072011. 245(7) p. URL: https://www.researchgate.net/publication/320860315_Updating_Linear_Schedules_with_Lowest_Cost_a_Linear_Programming_Model*
10. ***Hojjat Adeli, Asim Karim.*** *Construction scheduling, cost optimization, and management. Taylor & Francis e-Library. 2005. 179 p.*

11. ***Qian Li, Sha Tao, Heap-Yih Chong, Zhijie Sasha Dong***. *Robust Optimization for Integrated Construction Scheduling and Multiscale Resource Allocation. Hindawi Complexity. 2018. P. 1-17.*
12. ***Biruk S., Jaskowski J.*** *Scheduling Linear Construction Projects with Constraints on Resource Availability. Archives of Civil Engineering. 2017. V. 63. N 1. P. 3-15.*
13. ***Jose Maria Delos Santos.*** *2018 Technology and Software Trends in the Construction Industry. URL: https://project-management.com/2018-technology-and-software-trends-in-the-construction-industry*
14. ***Mailyan A.L., Nekhay R.G.*** *Models and algorithms of organizational and technological reliability in the planning and organization of construction production. Rostov-na-Donu: BARA. 2015. 116 p. (in Russian).*
15. ***Aloyan R.M., Petrukhin A.B., Fedoseev V.N., Oparina L.A., Chistyakova Yu. A.*** *Organizational and technical solutions for reducing the energy intensity of the Russian economy on the example of the textile and construction industries. Izv. Vyssh. Uchebn. zavedenij. Tekhnologiya Tekstil'noj Promyshlennosti. 2017. N 4 (370). P. 301-304. (in Russian).*
16. ***Rumyantsev E.V., Fedoseev V.N., Petrukhin A.B., Oparina L.A., Chistyakova Yu.****A. Socio-economic effects of reducing the energy intensity of the Russian economy. Ivanovo: Pressto. 2018. 128 p.*
17. ***Aloyan R.M., Petrukhin A.B., Filimonova N.M., Kapustina N.V.*** *Management of logistic risk factors in the process of production organization. Izv. Vyssh. Uchebn. zavedenij. Tekhnologiya Tekstil'noj Promyshlennosti. 2017. N 4 (370). P. 94-97. (in Russian).*

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