Implementing large-scale construction projects through application of the systematic and integrated method

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Abstract. Dynamic development of the construction manufacturing and technology industry requires new strategies based on integrated solutions for consolidated tasks and objectives. A large-scale construction project technology is a complex integrated process with a great number of interrelated parties involved. This process is associated with links and factors of various nature and frequency that introduce significant changes in the technology resulting in violations of the set pace. The main features of a systemically important large-scale construction project can be optimized through identification of destabilizing factors and formalization of links within the project with due regard for an integrated approach to production processes. The current situation calls for integrated tackling of construction projects with a view to minimize labor costs and contingencies and, accordingly, to improve the key performance indicators, including, but not limited to, a reduced duration of construction, an enhanced quality, and a higher reliability and lower costs of works. This article deals with various lines of research for an initial stage of development of the concept of a systematic and integrated method of implementation of large-scale construction projects. Depending on the problem to be solved, research may be focused on combination of associated production processes; formation of integrated production crews and teams; identification of a reliability factor of a structural subdivision; reallocation of manpower following changes in skills; improved performance quality indicators of integrated production crews and teams. This research needs to be described with the use of mathematical tools formalizing a systematic and integrated method. Consistent and predictable results can be achieved more efficiently and successfully if activities are concerted and all processes are interrelated and oriented on a shared objective.

1. Introduction
Duration of construction projects is subject to construction norms and regulations (1). Adherence to these regulatory requirements depends on availability of investments, design and estimate documentation, material and technical resources, and manpower.

Construction project deadlines are predetermined in the design; however, in practice they are not always met, resulting in cost increases and potential risks of incomplete construction. Considering the recent scale of construction, appropriate legislative action is taken to introduce greater punitive measures to developers, who fail to meet the stated deadlines (2,3).

In Moscow alone, integrated construction projects for over 2.7 million square meters of residential space and 140 infrastructural facilities in 90 districts of the city, including 57 schools, 52 medical institutions and 31 kindergartens, are scheduled for completion by the end of 2020. (4)
Essential conditions for efficient integrated development in the construction industry included setting relevant priorities, updating the strategy of achieving the set objectives, and formation of structural subdivisions charged with the main function of implementing a large-scale project.

This requires a systemic and integrated approach based on the scientific discipline of system engineering.

The basis of our research is formed by works associated with system designing of organizational structures of large-scale construction processes with the use of a wide variety of tasks to be tackled. In particular, it includes research into the integral potential model [5,6] of efficiency of organizational and technological solutions for a construction facility, which makes it possible to take into consideration the impact of organizational, technological, and managerial solutions on implementation of a construction process.

We have also studied some papers [7,8,9] that offer an approach to solving the problem of resource allocation optimization in the planning of construction and installation works. They focus on manpower (work teams) as structural subdivisions determining duration of works, a project key performance indicator.

Alireza Ahmadian Fard Fini and Taha H. Rashidi [10] in their paper present a mathematical model for identifying the optimal combination of single-skilled and multi-skilled workers with different levels of experience in the crew to minimize the duration of construction projects by accounting for the overlapping effects of multiskilling and skill level.

An interesting line of research is described in paper [11], which offers a methodology of quantitative evaluation of factors affecting the productivity and quality of masonry works with consideration of three factors: compatibility, conformity to requirements, and professionalism.

According to Academician A. A. Gusakov [12], “Organizational and technological reliability is the efficiency of organizational, technological and managerial economic solutions in achieving the target construction output amidst random disturbances inherent to construction as a complex probabilistic system”.

2. Discussion (Findings and Discussion)

Based on the undertaken analysis and research, the authors have identified lines of research and have set objectives described herein as an initial stage of developing the concept of a systematic and integrated method of implementation of a large-scale project. The authors have also identified research for achieving the set objectives by developing a corresponding algorithm.

Unlike the analyzed works and research, this paper presents some aspects for the development of a systematic and integrated method of implementation of a large-scale project with account of a large variety of conditions.

3. Methods

Research into a systematic and integrated method of implementation of large-scale projects has shown that a synergistic effect resulting from supplementing the system approach with an integrated review of production processes offers the possibility of optimization of the project’s key performance indicators, including, but not limited to, a shorter duration and lower costs of construction, and a higher quality and reliability of erected facilities.
In turn, an integrated approach to production processes within a large-scale construction project offers a possibility of packaging similar or associated processes into consolidated production group modules for optimization of the project parameters.

Formation of an integrated system provides for all its elements to be adaptable and adjustable depending on the functioning of their constituent models, for achieving a high quality output. Behavior of the formed integrated system should be forecast by various methods, including the imitation modelling, the scheduling theory, the theory of probability or the theory of random processes with the black box concept applied in most cases.

Following is a description of some methods:
- The imitation modelling reproduces the state of the system at any given period of time, including the situations of limited input information, insufficiently specified conditions or complexity of formalization of received data (13).
- The black box method allows identification, to the fullest extent possible, of the system’s motion vector subject to availability of a variety of quality input data.
- The scheduling theory is a section of discrete mathematics focused on intrasystem streamlining (14).
- The theory of random processes is a mathematical science focused on laws governing random processes in evolution (15, 16, 17, 18).

In addition to the above-mentioned methods, a great importance has been assumed in the last half a century by the research technology of computer-based simulation experiment (19, 20, 21). Mathematic simulation is widely used in all fields of science, especially in the construction industry. This is due to the fact that natural experiments on construction sites, especially in large-scale projects, are very
expensive and sometimes dangerous. An unsuccessful experiment may lead to irreversible consequences.

The need for an integrated approach to large-scale construction projects is manifested in the construction industry characterized by a large number of varied factors, elements and links requiring an assessment for a more efficient coordination of subsequent operations.

The main line of development of the systemic and integrated approach identifiable at this point is an integrated review of a large-scale construction project with the purpose of finding an optimum selection of organizational and technological solutions.

Large-scale construction is a complex process implemented through multiple interconnected actions of participants. It is associated with factors of diverse nature and frequency, which introduce material changes in the technology and disrupt the set pace. Identification and subsequent assessment of factors affecting the results of application of methods, models and theories allow for a high-quality construction design output.

In this connection, there is a need for scrupulous research and analysis of factors affecting the construction processes.

An objective assessment of organizational and technological solutions requires a feedback between the resulting indicator and the indicators generated in the course of scheduling of construction and installation works. This indicator should be based on the theory of probability and mathematical statistics, because the output of a project is affected by a great number of objective impacts (factors) of construction.

Formalization of links within a systemically important large-scale construction project coupled with an integrated approach to production processes will ensure optimization of its main characteristics.

Depending on the assigned task, research may be focused on the following lines:

- Combining associated production processes;
- Reallocation of manpower due to skill changes;
- Formation of integrated production crews and teams;
- Improvement of quality performance indicators of integrated production crews and teams;
- Improvement of quality performance indicators of structural subdivisions within a construction project;
- Search for a reliability indicator for elements of a structural subdivision;
- Identification of a reliability indicator for a structural subdivision.

**Figure 2. Research used as the basis of the systemic and integrated method.**

These lines should be described by any of the above-mentioned methods using mathematical tools.
An objective assessment of organizational and technological solutions requires a feedback between the resulting indicator with the indicators generated in the course of scheduling of construction and installation works.

4. Findings

In conclusion it should be noted that the ideas put forward and the tasks set herein will be used as an initial stage of development of the concept of a systemic and integrated method. Follow-up research will be conducted in future papers according to the following algorithm:

- Carrying out analytical work;
- Generalization and presentation of analysis findings;
- Development of theoretic organizational and technical activities and proposals for elimination of shortcomings and losses;
- Setting tasks for formation of a mathematical model;
- Formation of a mathematical model;
- Development of an operational algorithm;
- Formalization of the method of an integrated systemic approach to implementation of a large-scale construction project.

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References

[1] Construction Regulations 48.13330.2011. Organization of construction.
[2] Federal Law No.214-ФЗ On Participation in Shared Construction of Multi-Apartment Buildings and Other Real Estate Projects and On Amendment of Some Legislative Acts of the Russian Federation (as amended) dated December 30, 2004.
[3] Federal Law of the Russian Federation No. 2300-1 On Protection of Consumer Rights dated February 07, 1992 (revised on May 01, 2017).
[4] https://stroy.mos.ru/news/v-moskvie-postroiat-2-7-mln-kv-m-zhil-ia-schiet-biudzhieta-do-2020-ghoda
[5] Lapidus A A, Abramov I L. Organizational and process-related design of private low-rise construction projects when developing a calendar plan – Science Bulletin 4-2017.
[6] Lapidus A A, Abramov I L. Calculating a construction company’s resource potential as a bidder – Science Bulletin 9-2017-p.6-9.
[7] Mishchenko V Y, Yemelyanov D I, Tikhonenko A A. Developing a method for optimized resource distribution in calendar planning based on genetic algorithms. Voronezh State University Architecture and Civil Engineering p. 76-78.
[8] Mishchenko V Y, Yemelyanov D I, Tikhonenko A A. Rationale for Use of Genetic Algorithms for Optimization of Resource Allocation in Calendar Construction Planning // Industrial and Civil Engineering, 2013, No. 10, p. 69-71
[9] Mishchenko V Y, Gorbaneva E P, Yoeun Rithy, Fan Noot Lin Application of the flow method in low-rise urban residential development in hot climates. Voronezh State University of Architecture and Civil Engineering. Ho Chi Minh City University of Architecture. P. 28-38.
[10] Alireza Ahmadian Fard Fini, Taha H. Rashidi. Incorporating Multiskilling and Learning in the Optimization of Crew Composition. Journal of Construction Engineering and Management 142(5):04015106. 2015.
[11] Laura Floreza, Jean C. Cortissoz. Defining a mathematical function for labor productivity in masonry construction: A case study. Procedia Engineering, 164 (2016). P. 42 – 48.
[12] Gusakov A A. System technology in construction. Moscow, ASV Publishers, 2004.
[13] https://revolution.allbest.ru/emodel/00527398_0.html
[14] https://infourok.ru/prezentaciya-po-informatike-na-temu-model-cherntogo-yaschika-1542300.html

[15] Lapidus A A, Feldman A O. Informational interaction between participants in a construction project as an additional factor of assessment of the organizational and technological potential // Bulletin of Moscow State University of Civil Engineering. 2016. Vol. 6. Pages 101-106.

[16] https://ru.wikipedia.org/wiki/Теория_расписаний

[17] http://www.ngpedia.ru/id506984p2.html

[18] http://av.disus.ru/proekt/19156-1-malineckiy-proektirovanie-buduschego-modernizaciya-rossi-reakomenduemaya-forma-bibliograficheskoy-ssilki-malineckiy-proektirovanie-buduscheg.php

[19] Abramov I L, Poznakhiro T Y, Sergeev A The analysis of the functionality of modern systems, methods and scheduling tools, MATEC Web of Conferences 86, 04063 (2016) IPIECS-2016

[20] Chulkov V O, Ghazaryan R K, Kuzina O N Basic cycle of reorganization. Innovations in the sectors of the national economy, as a factor in solving the social and economic problems of our time. Sat. reports and materials of the International Scientific and Practical Conference. Moscow December 5-6, 2014 - Moscow: INO - CRI EiUS, 2014.- P.82-94.

[21] Oleynik P P. Modeling of investment process term reduction. Natural and Technical Sciences Journal. Edition 10 (88). Year 2015. P. 412-414.

[22] Department of the Army. U.S. Army Corps of Engineers. Manual No. 1110-2-3506 Grouting Technology. Washington D.C. (2017).

[23] The Government of Western Australia. The Impact of New Building Techniques and Technologies on the Residential Housing Sector of the Construction Industry. Construction Training Fund (2015)

[24] Bots, P., van Bueren, E, Heuvelhof, E, Hardoy, I, Mitlin, J. E., Satterthwaite, D. (1992), Environmental Problems in Third World Cities. London, Earthscan

[25] Cooke P. (2004), Introduction: regional innovation systems - an evolutionary approach, in Cooke, P, Heidenreich, M. & Braczyk, H. (eds.). Regional Innovation Systems, Routledge, London.

[26] Lapidus A A, Feldman A O. Informational interaction between participants in a construction project as an additional factor of assessment of the organizational and technological potential // Bulletin of Moscow State University of Civil Engineering. 2016. Vol. 6. Pages 101-106.

[27] Bolotin S A, Dadar A Kh, Ptukhina I S. Calendar Planning Simulation in Building Information Modeling Programs and Regression Detailing of Construction Timeline Standards.//Engineering and Construction Journal, 2011, No. 7, p. 82-86.

[28] Lapidus A A. Efficiency Potential of Organizational and Process-Related Solutions of the Construction Project. Bulletin of Moscow State University of Civil Engineering – No. 1 – 2014 – p. 175-180.

[29] Lapidus A A, Makarov A N. Shaping Up Organizational and Process-Related Potential of Manufacturing Roofing Structures for High-Rise Residential Buildings. Bulletin of Moscow State University of Civil Engineering – No. 8 – 2015 – p. 150-160

[30] Mishchenko V Y, Yemelyanov D I, Tikhonenko A A. Developing a method for optimized resource distribution in calendar planning based on genetic algorithms. Voronezh State University Architecture and Civil Engineering p. 76-78.

[31] Mishchenko V Y, Yemelyanov D I, Tikhonenko A A. Rationale for Use of Genetic Algorithms for Optimization of Resource Allocation in Calendar Construction Planning.//Industrial and Civil Engineering, 2013, No. 10, p. 69-71

[32] Mishchenko V Y, Gorbaneva E P, Yoeun Rithy, Fan Noot Lin Application of the flow method in low-rise urban residential development in hot climates. Voronezh State University of Architecture. Ho Chi Minh City University of Architecture. P. 28-38.
[33] Min Liu and Glenn Ballard. Improving Labor Productivity through Production Control. Proceedings for the 16th Annual Conference of the International Group for Lean Construction, Planning and Control. 2008. p. 657-666.