Selection of Organizational and Technological Solutions for Construction

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Abstract. The article describes methods and techniques of selecting the most efficient solutions for construction. Selection of the best organizational, technological and cost-effective selection for construction of buildings and related structures is one of the key issues of constructions operations studied by virtually all the leading universities in the Russian Federation. This issue becomes relevant when new construction processes are introduced and when minor quantitative changes, which in the majority of cases result in a change in the technology and organization of works, are made to a project. Currently, there is an issue of formalization of the problem on all stages, as well as of the more precise definition of direct and inverse connections between separate stages of selecting an organizational and technological solution (OTS) for construction of buildings and related structures. Having analyzed research papers and building information modeling tools for developing an OTS, we may assert that the selection of organizational and technological solutions is insufficiently elaborated in the sphere of automation and still requires a large amount of manual labor regarding, particularly, selection of a model flow chart of CP. Results of multiple studies in the sphere of virtual reality support implementation of the "direct design" concept. Architectural and construction visualization as one of the spheres of 3D graphics helps to evaluate whether a building or any architectural form fits the existing construction site to a high degree of accuracy.

1. Introduction
Construction of buildings and related structures is a complex operation characterized not only by complexity of tasks and dynamic character, but also by a versatility of solutions regarding the organization and technology of construction.

So far, the main stages of selecting an organizational and technological solution for construction of buildings and related structures have been determined [1-20]; however, the generally accepted approach does not result in a definitive choice of the technology and organization of works, as it is insufficiently formalized; it does not allow for consideration of all the possible options; it does not involve the possibility of a probabilistic assessment of building methods and of giving due consideration to disturbances; it employs a marginally objective and "rigid" instrument for comparing options.

Today, we may identify several primary areas characterized by a specific approach and resulting in solution to the issue of optimal selection of a method of works.
The first of these areas is observed in the process of creative activity of an engineer who tries to find the most fruitful solution for the given circumstances and finds it by comparing several options; in some cases, this process occurs subconsciously, when there is no clear selection problem model.

Studies of selection of rational methods of works associated with attempts to analytically solve the problem of finding "the best solution for the given circumstances" may be attributed to the next area. The analytical approach to resolving the problem of selecting an optimal organizational and technological building solution is no less interesting. There are many techniques of analytical problem solving [7], the most telling of which is a technique suggested by West German engineers.

Finally, the last area is observed when the problem of selecting a method of works has become a specific instance of application of mathematical programming methods due to the use of modern computing hardware, new technologies (BIM, in particular), and new divisions of applied mathematics (operations research, systems theory, etc.).

The BIM (Building Information Modeling) technology of information modeling of objects is an evolved version of a currently generally accepted computer-aided design (CAD) system. Apart from three-dimensional drawing, the primary difference of the BIM from CAD systems consists in a model of a database including detailed information on technological, technical, architectural, construction-engineering, costing, and economic characteristics of an object. The database may be supplemented with legal, operational, environmental, or other information depending on the circumstances. The most important thing for us is that it contains a database of flow charts of works.

"Thanks to technological progress and spread of the building information modeling (BIM) technology, there appeared new possibilities for improving design processes, for instance, the 4D BIM technology (a 3D model + time) allows linking building components to the construction schedule and visualizing the construction process. Use of the data stored in the building information model (BIM), integration of these data with the data of completed projects, use of planning software, and further development of automation algorithms will help to reduce time and improve quality of the works schedule creation process" [9, 11, 13, 19, 20].

ARCHICAD STAR(T) Edition 2017 may be used as one of the instruments, as it contains all the tools required for creating floor plans, sectional views, facades, operation charts, 3D views and detailing BIM projects. STAR(T) Edition 2017 features high performance and significant improvements of working with project documents. ARCHICAD STAR(T) Edition 2017 is based on the state-of-the-art technology of Building Information Modeling and building methods implemented in ARCHICAD 20. Furthermore, ARCHICAD STAR(T) Edition 2017 features most functions and solutions of ARCHICAD 20.

A whole software package is usually used for comprehensive project development when using BIM programs. Information modeling software interaction schemes may include an unlimited number of programs. The standard software package includes such giants as Microsoft Office applications, as well as three-dimensional modeling programs - Archicad, visualization programs (3D Max, BIMx), a master plan program (Civil3D), calculation programs (Allplan, Lira, Tekla), and many other programs. Among them there is a specific group of programs to develop organizational and technological solutions: Primavera, MS Project, Integra, Navisworks, and many other programs.

In construction, a flow chart (FC) is one of the main organizational and technological design documents. A flow chart is based on a plan of actions to organize labor using the most efficient modern mechanical equipment, as well as accessories, tools, and devices. A flow chart ensures economical, high quality and safe performance of works, because it reflects regulatory requirements and safety instructions.

Studies revealed the need in developing an automated FC selection technique and integrating FC selection automation to production using the information modeling technology.

To develop an optimal automated OTS selection technique, we studied the criteria affecting selection of an organizational and technological solution for building and installation works. Experts' answers were processed using the analytic hierarchy process (T. Saaty) with quantification of weights of criteria, and calculated the concordance coefficient, as well as the Pearson coefficient.
The expert survey helped to determine and rank the main criteria affecting performance of building and installation works the most. According to the analysis results, the criteria may be arranged from the largest to the smallest weight as follows: cost, duration, degree of mechanization, and labor intensity. A pattern and an algorithm for automated FC selection from a database were developed. They enable automated selection of a flow chart best fitting the given CP [1].

The technique based on expert opinions allows not only comparing methods of works taking into consideration the effect of combinations of factors of production and modes of their interaction, but also systematically analyzing the problems of selecting the best method out of the available ones. At the same time, any construction process is considered from the point of view of achieving one or another goal representing in the end a set of specific objectives of varying significance.

The technique may be integrated into practice by developing building information modeling-based software. The point is that a whole software package is usually used for comprehensive project development when using BIM programs. Information modeling software interaction schemes may include an unlimited number of programs. The standard software package includes such giants as Microsoft Office applications, as well as three-dimensional modeling programs - Archicad, visualization programs (3D Max, BIMx), a master plan program (Civil3D), calculation programs (Allplan, Lira, Tekla), and numerous other programs.

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The integration offer consists in linking the developed technique and the algorithm with an OTS design program. To solve this problem, the technique may in concept collaborate with Navisworks.

See data from the study conducted by McGraw-Hill Construction [5] below. The two most widespread reasons to use the BIM are an owner's request (85%) and an aspiration to save time and money (76%).

BIM users in Europe: architects - 47%, engineers - 38%; other specialists - 24%. BIM users in North America: architects - 60%, engineers - 42%; other specialists - 50%.

According to the survey, 41% of the respondents assume that their profit increased after the BIM had been introduced; 55% are sure that the BIM helps to reduce project costs (39% of them indicate a reduction of costs by more than 25%); 41% are convinced that the BIM does not result in a change in the number of employees; 21% and 13% - that fewer/more personnel are required after the BIM is introduced, respectively.

Reasons to use the BIM in sustainable construction: simulation of power consumption by the building (80% of companies); simulation of lighting, including daytime lighting (69%); compliance with power consumption standard requirements (65%); evaluation of quality of the equipment and selection thereof (64%); evaluation of the effect of using renewable power sources (63%); natural ventilation analysis (57%).

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Introduction of the suggested automation model to construction on the basis of building information modeling software suites with linking of the algorithm to the organizational and technological planning program. Such a link between an automated FC selection algorithm and an information modeling program makes use of a technique to select an organizational and technological solution possible.

Each of the aforementioned areas is characterized by both a specific approach to problem solving and a technique to select the best solution.

Most widely used products designed to choose an optimal solution for construction of buildings and related structures belong to the first area [5, 7-10].
Selection of a building method is characterized by building models serving as a basis for selecting the optimal solution. Model building requires precise definition of the goal, areas, conditions of methods and means, as well as criteria and methods of evaluating results. A mathematical construction model for a building or its part is used for accurate analysis of physical, economic and organizational parameters, as well as for predicting the model's behavior if these parameters change.

Among the first models of building organization and technology were network models. Results of long use of these models demonstrate both their effectiveness and drawbacks. The latter are caused by imperfections of network models, insufficient flexibility thereof in construction conditions, as well as by failure thereof to account for a multivariate technology and organization of works.

The network models currently used in Russia are overly "rigid"; they rule out options of performance of works if resources become limited and reflect the designers' subjective approach.

According to publications on network planning and control [2, 5, 7, 14-16] and use of probabilistic network models in construction, network models will soon become an effective means to both evaluate the building process and control it.

Network models have already become a subject of special studies in Russia and abroad. The most important reason substantiating such detailed studies consists in peculiarities of mathematical characteristics of network models. Effectiveness of the optimal solution search process may be significantly improved by employing these peculiarities.

Currently, the ways to solve the problem [1-3, 6] primarily come down to a search for imitation models more or less reflecting the process of construction of buildings and related structures. The latter (models) are based on different mathematical apparatus (statistical decision theory, game theory, correlation theory, etc.)

2. Materials and methods

The ongoing comprehensive study [1] aimed at designing methods to develop and implement OTS for construction demonstrated that problems that cannot be resolved automatically are observed on all stages of preparatory work; this significantly increases the time to prepare construction documentation.

The building information modeling (BIM) is a technology to optimize design and construction processes based on the use of a single building model and exchange of information on any objects by all members throughout the life cycle: from the owner's idea and the first architect's drafts to maintenance of a finished building. One of the advantages of the BIM over the computer-aided design (CAD) system consists in support of distributed use; this makes use of this technology to implement the IDA possible. BIM tools are intended to rule out excessiveness, reentry and loss of data, errors of data transfer and transformation.

BIM principles developed by Robert Aish in 1986: three-dimensional modeling; automatic drawing; smart parametrization of objects; sets of projected data corresponding with objects; division of the construction process by timed stages.

Advantages of the BIM: reduced design period; reduced project costs; higher performance of operation thanks to the ease of information acquisition; improved consistency of construction documentation; availability of specific information on manufacturers of materials, and quantitative characteristics for evaluation and tender action.

3. Results

CAD use helps to double/triple performance of a structural designer and a technologist, improve effectiveness of interaction between different divisions, as well as the level and quality of design-engineering works. Furthermore, CAD use may help to reduce the time required for production design engineering, relieve structural designers of non-productive operations, expand possibilities of complex equipment design and production, as well as to create a single unified design-engineering database at the enterprise. In their turn, all of these advantages positively affect the enterprise's financial state.
Outstanding progress and rapid development of the computing equipment in the recent decades demonstrate a very special role of computers, which, on the one hand, serve as a means of supporting a project process, and on the other hand, as an intermediary dramatically increasing effectiveness of a human's intellectual activity.

Furthermore, there is now a possibility to use a virtual reality technology as a morphological environment. The direct design concept appeared as a result of the analysis of use of virtual technology as an instrument to visualize project solutions regarding organization and technology of construction [1]. It is based on full immersion of a construction engineer in the designed environment. An engineer is inside the designed space, determines the course of changes, and interactively implements these changes by moving forms inside the virtual space. See an example of such an "immersion" in Fig. 1.

![Fig. 1. Master plan of an object](image)

The 3DS Max 3D-modeling suite has been being developed since 1990s and has achieved a certain degree of perfection. This is confirmed by its popularity in the blooming industry of the cinema, TV and computer games. Impressive credibility of 3D special effects in TV screens, inconceivably realistic virtual reality of three-dimensional computer worlds and numerous high quality architectural and design projects completed using the 3D max suite have become ingrained and occupied a prominent place in our everyday lives.

Design of a three-dimensional model of a construction site. Modeling usually takes up 50-80% of the working process. It is important to understand that the time spent on modeling primarily depends on complexity of the situation at the site, the building or the room, not on the size (dimensions). The time spent on model texturing depends on the complexity of materials and their diversity. It is much easier and faster to texture a single-story industrial building than a small cottage with several kinds of stones and facing bricks.
Visualization involves customization of lighting, environment, and materials. On this stage, the computer model takes a photorealistic presentable appearance on, the image's quality is adjusted. It may take up 10-50% of the working process. The visualization quality directly depends on the designer's (constructor's) experience and professionalism.

The main components of the cost of visualization are amount and quality of work.

Computer graphics capabilities help to design three-dimensional models of architectural objects of any complexity and organization in a virtual environment. A 3D model of a building or a site may be corrected as needed on the visualization stage to save time and future financial expenses.

4. Discussion

There are many examples of such models. These are the models proposed by R.I. Fokov, N.P. Buslenko, and B.F. Biletskii, which may be used to one or another degree for selecting organizational and technological solutions for construction.

The main advantage of using mathematical modeling is that it helps not only to define optimal or suboptimal solutions, but also to consider all the events that may occur in specific technical and economic and organizational conditions.

Specially developed Intentsiiia intellectual analytic system (IAS) and Matlab – Neural Network Toolbox and Genetic Algorithm and Direct Search Toolbox extensions packages for the mathematical modeling environment and technical computing are used to implement the considered provisions of the study and improve theoretical validity of the proposed methods.

According to the obtained data, the use of the proposed methods and the OTS development and operational environment for the construction of high-speed railways will give contractors the possibility to efficiently manage the construction site to achieve net profitability and quality building and installation works. Without any doubt, this will positively affect reliability of transportation constructions and railway operation safety.

Many foreign researchers and specialists, such as M. Albert, M.H. Mescon, L.C. Plunkett, T. Santalainen, G. Hale, M. Eddowes, E. Naumann, R.L. Keeney, E.Y. Viglas, J.R. Reilenen, E.L. Mishik, H. Theil and others, made a significant contribution to the study of issues of managerial decision-making, development and implementation of decisions.

Summation of the main areas of selecting the optimal organizational and technological solution for construction of buildings and related structures leads to the following conclusion:

- all three aforementioned areas are valid and reasonable for certain stages of selection of optimal organizational and technological solutions for construction of buildings and related structures to one degree or another and feature practical utility:
- each of these areas helps to define the best fitting ways and an approach to solving the problem of previous projects using them on a farther stage of selection of the optimal solution for construction;
- construction process modeling for buildings, related structures and groups of building structures is the most promising area of identifying the optimal solution, as it is the most effective and reasonable method that absorbed the best of the first two areas; it also enables solving the set problem in the most objective way in comparison with other methods.

This is due to insufficient development of decision making and formalization procedures.

For instance, the problem of OTS structure synthesis is difficult to formalize.

This is due to the fact that development of rational OTS based on efficient construction processes (CP) must be based on experience, knowledge and intuition of a building technologist.

Mathematically, this problem may be reduced to a search for variants of structures in countable sets with a rather large, though limited, number of elements.

It is known that search for solutions is one of the most complex and cumbersome operations. The following stages of OTS generation are difficult to formalize: creation of CP, resource allocation, transition sequence determination, and OTS optimization using various criteria.

The available automated construction preparation systems are based on the concept of active interaction with an engineer (dialog).
In practice, CP are created by a technologist guided by the selected design and technology solution (DTS); the system only provides reference data, operational construction information, and access to the contractor's database.

Although these systems take some burden away from a technologist and help to improve his/her effectiveness, they do not correspond to their name; in fact, they are simply electronic workstations.

As such, CP are created in the same way as before by a technologist guided by his/her knowledge and experience; in many cases, this does not result in rational OTS, and takes up a considerable amount of time for preparation and implementation.

Rapid development of information technologies led to a new cycle of development of the methods and means intended to help plan construction organization and technology using a computer. Theoretical and practical achievements in the sphere of artificial intelligence (AI) attract the most interest.

At the same time, OTS implementation involves close interaction with construction project management systems, particularly, with the change management. Therefore, it is possible to affect not only the duration of a CP, but also its essence, i.e. technology and organization.

It is obvious that integration possibilities will promote improved effectiveness of operation and profitability of contractors.

5. Conclusions
Compatibility of software and data formats is the most pressing issue of technology development.

BIM started as format converters; now, it helps create special formats for storing data about construction objects, such as IFC (industry foundation classes - an international standard of data exchange by various CAD applications supported by software of multiple developers (Autodesk, ArchiCAD, Tekla, Navis, etc.)) or XML. Also, BIM servers may be created.

Integration of modeling programs and operational building control automation programs is a promising focus area.

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