To a question of a choice of a method of production of construction works on set of technological cards

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Abstract. The need to create an automated system for selecting rational organizational and technological solutions based on modern design technologies. Methods. Based on known BIM building information modeling objects are created by the Bank (information base) of typical technological cards (TC) from which the method of the study criteria based on modified genetic algorithms (GA) is the most efficient TC for this type of work. Results. The article deals with the choice of the method of production of construction works on the set of technological maps of construction and installation works. Conclusion.

1. Introduction
The efficiency of building production, its outcomes are largely determined by the degree of organization of construction processes which in turn depend on the quality of decision of tasks of designing of building and construction works and primarily, the formation of model’s construction and selection based on the most rational organizational-technological decisions (OTR).

Organizational and technological design, as it is known, is the most important element of preparation of construction production and includes tasks of modeling of construction processes at construction of objects. The solution of problems of organizational and technological design of building production (without use and with use of the computer) associated with several difficulties caused by insufficient regard to the existing methods of organization and technology of construction production, the actual conditions of work and possibilities of modern computing. In this regard, there is a need to improve methods for solving problems of designing and construction of works subject to the requirements of construction practice, simulation of construction and selection of the most rational organizational-technological decisions.

As part of the automation of the choice of the method of production of construction works on the set of technological cards (TC), a model of multi-criteria optimization based on genetic algorithms was developed to select the most suitable analogue of a typical TC.

Process maps (TC), which are part of the work production project (PPR), are usually developed for complex types of work and work performed by new methods. They are the basis of scientific organization of construction processes and are developed according to current standards (SNiP, GOST, Enir, instructions).

The technological map is a set of rules, norms, instructions and schemes for the implementation of a given project or part of it. The use of TC allows to exclude various variations and interpretations of a method of action in this situation. This is an instruction that allows you to most effectively and quickly
do a given type of work. The structure of the technological map: scope; organization and technology of work; requirements for quality and acceptance of work; calculation of labor costs, machine time and wages; schedule of work; material and technical resources; safety; technical and economic indicators.

The main purpose of TC is to assist builders and designers in the development of technological documentation. According to the TC, the technological sequence of construction processes is established, weekly-daily schedules and orders to produce works are made. They are used to justify the duration of construction of objects in the calendar plans and network schedules.

TC are developed by leading design and construction organizations to perform General construction and specialized works. In some cases, TC is developed for complex construction and installation processes [11–13]. It is possible to facilitate the development of TC, improve their quality and reduce the development time only based on the use of the most modern information technologies [14].

Linking the algorithm of automated selection of standard TC with the program of information modeling, it becomes possible to use the technique not only for design, but also for real production of works. For example, in the production of stone works with the help of robots-masons, whose work is carried out based on the information model of the building by selecting the necessary TC.

2. Methods and materials

The analysis showed that in the last decade, Russian scientists conducted research and proposed effective development on modeling of construction processes and the choice on their basis of organizational and technological solutions, to optimize the parameters of the flow and parallel-flow organization of construction, on the variant design of technological and organizational solutions; proposed methods to improve the regulatory framework of organizational and technological design; expanded opportunities for versatile evaluation of options. This is confirmed by the developments presented in the works of Afanasyev V.A., Antanavichyus K.A., Beletsky B.F., Budnikov M.C., Buslenko N.P., Velichkin V.Z., Voropaev V.I., Golub D.G., Isakov A.A., Mikhailov B.C., Nebritov B.N., Sadovsky V.I., Rybalsky V.I. Fokov R.I., and other scientists in the works of research, design and educational institutions of construction profile [1, 4–10].

Modern methods and techniques of construction involve the use of information modeling (BIM), which involves the creation of a common information model of construction object is the necessary basis for its creation and use and development at different stages of design and throughout construction and operation.

Building information modeling (BIM) is the process of collectively creating and using building information, forming a solid basis for all decisions throughout the life cycle of the facility (from the earliest concepts to the detailed design, construction, operation and demolition). BIM tools are designed to eliminate redundancy, re-entry and loss of data, errors in their transmission and conversion.

Real-time visualization and localization require context-sensitive information (such as space, place, time) for the normal functioning of the system. In this way, a BIM model can provide spatial relationships, while sensor technology can provide location and time information. Modern localization methods (indoors) use probabilistic algorithms to estimate orientation, which often require a lot of computing power. Since the model contains the exact location of the components, the BIM model provides the following advantage: there is no need to assess the true position of the landmarks, and the complexity of the process and the machine time of the algorithm is dramatically reduced.

Information modeling technology of objects (Building Information Modeling) is a development of the computer-aided design (CAD) system generally accepted today. The main difference from the latter, in addition to three-dimensional drawing, is the presence of the model database containing detailed information about the technological, technical, architectural, engineering, construction, estimate, economic characteristics of the object. Depending on the specific requirements, the database can be supplemented with legal, operational, environmental and other information, the most important for our case is the database of technological maps for the work performed.
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As mentioned above, for the purpose of optimal selection of TM from the information base according to the studied criteria, a technique based on modified genetic algorithms has been developed (GA). The GA methodology offers three optimization options:

- compliance with the required duration of the project,
- minimization of project cost indicators,
- minimization of mechanical strength indicators,
- minimization of indicators of labor intensity of processes.

The target function has the following form:

\[
\text{Minimization} \quad \sum_{i=1}^{n} \sum_{j=1}^{m} C_{ij} \cdot K_{ij} + I \cdot D + P \cdot \sum_{i=1}^{n} \sum_{j=1}^{m} C_{ij} \cdot K_{ij}
\]

When the restriction \( D \leq T \), where \( n \) – is the number of works in the project; \( m_i \) – is the number of alternatives to the TC process \( i \); \( C_{ij} \) – direct costs – \( th \) process, when you select the alternative \( j \); \( K_{ij} \) – is a binary variable of process \( i \) when alternative \( j \) is chosen, then \( K_{ij} \) equals 1, otherwise equals 0 \( K_{ij} \); \( I \) – indirect costs for the project per unit time; \( D \) – is the execution time of the process; \( T \) – is the required execution time of the process; \( P \) – is the percentage of indirect costs.

The process should be selected one of the possible typical technological maps, the most optimal. This requires compliance with time and resource constraints, which can be represented as follows:

\begin{align}
\text{type relationship (end-start)} & \quad S_B \geq S_A + D_{Aij} + L_{AB}, \\
\text{link of the form (start-start)} & \quad S_B \geq S_A + L_{AB}, \\
\text{type relationship (ending-ending)} & \quad S_B + D_{Bij} \geq S_A + D_{Aij} + L_{AB}, \\
\text{type relationship (start-end)} & \quad S_B + D_{Bij} \geq S_A + L_{AB},
\end{align}

where \( S_B \) – start time of process \( B \); \( S_A \) – start time of process \( A \); \( D_{Aij} \) – duration of process \( A \) when alternative \( j \) is selected; \( D_{Bij} \) – duration of process \( B \) when alternative \( j \) is selected; \( L_{AB} \) – technological break.

The model of automation based on modified genetic algorithms is developed considering the acceleration of obtaining the optimal choice of TC due to the evaluation of inefficient solutions in the process of the algorithm and their clipping. At the stage of formation of information base of TM (population) for each technological process its repeatability is checked. If there are identical individuals in the population, the final choice of the optimal variant will be carried out considering the studied criteria and the weights of their influence established by experts. In addition, each TC is checked for the possibility of application and adaptation to the specified conditions [1, 3–6].

The population is evaluated, selected, propagated, and updated until the conditions for stopping the algorithm are met. Thanks to this, the individual with the best indicators of fitness for this project will be selected.

In other words, the principle of operation of the algorithm is as follows: after selecting the most suitable process cards by name and design features, if there is a problem of further choice of TC, the algorithm gives preference to TC:

- first, with a lower cost,
- in the second place, with the shortest duration,
- in the third place, with the lowest value of mechanical strength,
- in the fourth place, with the lowest value of labor.

3. Results
Each process card is identified by a unique identification number (id) that is used to make the request. In turn, the type of work in which the card is contained is also determined by its identification number.

Since the electronic directory is focused on personal and mobile computers, and is designed for WEB resources, therefore, its compatibility is free to any platform. and further development and updating of the system will not create any problems for users, since the system is in the cloud.

To work with the database, a set of QtSql classes is connected to work with databases using the structured query language SQL and the QSqlDatabase class to represent the database connection.

To demonstrate the work of the algorithm to improve the adoption of OTR in the production of stone works, a matrix of parameters was compiled from the information base of technological cards (TC), which presents the parameters from the TC: cost, duration, mechanical strength, labor costs.

Typical process maps are compared by the weight of the impact of criteria on the project. As a result, priority is placed in the selection and the total weight of the impact of criteria on the project is greater in the selected TC, which will be selected by the algorithm for use in the production of construction works in the project for the construction of the building.

In addition, the characteristics of workspaces (type, size, and location) and the work that takes place in the activity areas change over time during construction and move in three dimensions. Without the use of 4D modeling, it is almost impossible to detect conflicts of workspaces on the construction site. The development of a model for visualization of works with 3D workspaces on the basis of the building information model and taking into account the time parameter from the construction schedule, allows you to track the performance of works and at the design stage to determine any conflicts between their workspaces [8–10].

In some cases, it is important that the designer promptly provided information base containing: requirements for the installation of scaffolding and examples of their placement; regulations of production quality control, including input, operational and acceptance control; methods of determining the need for materials, products and structures, machinery and equipment, tooling, tools, inventory and accessories; requirements for transportation, warehousing and storage of products and materials; measures for safety and labor protection, environmental and fire safety; information on other issues that are reflected in the TC.

When solving specific target tasks contained in the TC, the latter must ensure full compliance of input and output data of these tasks with the requirements of regulatory and methodological documentation.

Software modules that automate the solution of specific tasks must have computational and graphical components. There are such variants when graphic modules are implemented as some add-on over Autocad package of the last versions, and calculation modules of the program work, for example, in the environment of FoxPRO and C++ [14].

Software modules are required to provide crane selection in the parameters of the load and the height of rise; the drawing of the crane with reference to the objects of the construction site; the requirements calculation in the inventory of administrative buildings; and the development of technological schemes; computer-aided design of pits; selection of effective use of excavation and transport vehicles; calculation of dewatering of pits and trenches; selection of hoisting devices; calculation and selection of lighting equipment; calculation of loads and energy consumption for construction and installation works; calculation of the need for storage areas.

It is necessary that the output data of the calculation modules of the programs are issued according to the current standards of organizational and technological documentation in the form of calculation, graphic, formalized text materials. The documentation generated in this way could be used by the contractor during the construction of the facility without any modifications.

Currently, work is underway on the automated development of TC. The necessary condition for automation of TC development is their unification, and the degree of unification is objectively low. Now, there is no automated solution to several tasks: layout of formwork, installation of scaffolding, solutions to produce geodetic works, etc. While it is impossible to automate the coordination of joint work of construction equipment in cramped conditions. For example, several cranes in a small area
may encounter boom equipment. It is extremely difficult to determine the optimal schedule of their joint work and movement [11–13].

There are, however, areas of TC, the automation of which is the prospect of the near future. This is the formation of realistic images of models of performance of specified types of work; the use of banks, databases. For example, on construction machines, tools, labor intensity base [11,12]. Based on the design and calculation data are generated tabular reports: the schedule of production of works, bill of quantities, schedules of requirements in equipment and personnel.

For registration of drawings the database of construction equipment and conditionally-graphic designations are used. Selection of load-lifting mechanisms is carried out based on the entered data: weight and sizes of cargo and load-grabbing devices; departure of cargo; height of lifting of cargo.

Cranes are selected from the base, the lifting characteristics of which meet the specified conditions of lifting the load, considering the normative reserves for lifting height and weight of the load.

The program allows you to automatically calculate the radii of the working and hazardous areas, as well as draw their designations on the drawing.

Selection of copra is carried out based on the selected size of piles. From the information database are selected copra, the technical characteristics of which allow you to immerse the piles of the selected diameter and weight. In addition, the database contains the following types of equipment: concrete mixers; concrete pumps; car lifts; bulldozers; drilling rigs; equipment for the device of bored piles; pipe-laying machines; excavators.

The new functionality and content of the program databases can be a breakthrough in the development of organizational and technical documentation. Therefore, the priority for developers is to implement the wishes received in the order of feedback.

As for users, in the ranks of experts and constructive critics, developers hope to see those who are directly associated with the development of technological maps and the introduction of new construction technologies [12].

4. Conclusion

The issues of integrated use of information resources, combining the functionality of different software tools, creating information models of various processes and objects, the development of methods and algorithms for processing and presenting information are widely discussed by the scientific community. In particular, the issues of workspace planning are considered and reflected in the works of scientists Akinci B., Fischer M., Elmahdi A., Guo S.-J., Riley D. and others.

28.07.2017 by order of the Government of the Russian Federation No. 1632-R the Program "Digital economy of the Russian Federation «was adopted. One of the directions of development of the digital economy was called the rapid transition to new standards that ensure the use of modern technologies. In addition, it is necessary to consider the possibility of applying appropriate national and international standards in the development of the Russian regulatory framework. 20.12.2017 g. at the meeting of the presidential Council for strategic development and priority projects, it was noted that at the first stage it is necessary to introduce information modeling technologies in the design process of buildings under construction within the framework of state participation, and then information modeling should be made an industry standard.

This method has been discussed at numerous conferences in NRU MSU, including the 1ST international scientific and practical conference of departments of organizational and technological profile of construction Universities and technical universities. "Experience in the implementation of postgraduate programs in the field of training "Construction". Moscow 2018; VII International scientific and practical conference held on June 5, 2019 in Penza and others [2].

5. Conclusion and conclusions on the work done

Currently, the prospects for the development of the proposed tools are seen primarily in the development of BIM technologies. Currently, there are four levels of BIM maturity, showing how advanced BIM technologies are. 1 level BIM 0 (BIM Level 0) – the level of maturity at which the
exchange of information on capital construction projects at all stages of the life cycle is not carried out or is carried out on paper. 2 BIM level 1 (BIM Level 1) – the maturity level at which two-dimensional drawings and three-dimensional models of capital construction projects are created. Organized information exchange between participants in the creation of electronic information on capital construction and real estate at BIM level 1 is not made. 3 level BIM 2 (BIM Level 2) – the level of maturity at which all participants use their own information models, as well as produce a joint information exchange of data. 4 level BIM 3 (BIM Level 3) – the level of maturity at which the exchange of information on capital construction and real estate at all stages of the life cycle is carried out by all participants of the BIM project, and all work is carried out using a single information model.

In construction, in the simulation of construction production and visual the project construction organization (PIC), the project of production of works (PPR), spatial-temporal coordination of construction participants; planning, management and control (plan-fact); optimization of the construction site and logistics; improvement of geodetic marking works; control of deviations; monitoring of labor protection and industrial safety; in the modular digital production of building structures and products with Assembly on the site; rationalization of Executive documentation and its full reflection in the information model of the object. All this should lead eventually to reduction of terms of erection of buildings; reduce the cost of object creation; ensure access to reliable information about the construction progress; reduce waste; reduce the number of accidents on site and enhance the reliability and quality of the construction.

Calculation of the required parameters in the production of construction and special works, the routing, the automated selection of methods of construction and Assembly based on selection of the necessary TK through BIM technology is correct, as confirmed by the theoretical analysis and the operation of selecting the method of construction works in the aggregate routings. The experimental application of the method described above has shown its effectiveness in the development of the project of a multi-story residential building in Moscow.

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