Innovative technologies in on-line construction production management

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Abstract. The article considers the problem of using on-line programming and management programs in the organization and construction technology. The introduction substantiates the importance and significance of the on-line construction management problem, reports on the universal model development of such management. The methods and study section give an idea of the on-line construction management methods. A visual diagram of the control model is proposed. The results and discussion section explore the prospects for using the programs based on this technology. The application areas of innovative software in construction are proposed. A review of such systems’ real application examples in the large construction companies’ practice is given. In conclusion, it is concluded that there is a significant reduction in human factors to ensure high quality construction, reducing time and labor costs when applying the proposed method of construction management and the merits of the model developed by the authors.

Introduction
Innovative BIM technology is information modelling of buildings and structures, the implementation of high-quality and thorough the control of all operations performed at each stage of the object’s life cycle, including in real time (on-line). BIM - technologies are used to achieve a wide range of tasks, starting with the detailed visualization of the interiors and exteriors of buildings using images, and ending with automated control of construction equipment.

They allow to implement the architectural concepts to the capabilities of modern technologies as close as possible and in real time to predict the probability of constructing a building with specified characteristics while maintaining the original architectural design [2-5]. Before the advent of these technologies, architectural design in the implementation of technological and organizational capabilities relied solely on experience and experiment. Currently, the prognostic models’ construction is possible based on computer multifunctional and multi-level modelling of architectural and construction reality.

Currently, the actual problem of design and construction organization in the world is the accounting of the variable factors in real time.

The 4D modelling method developed in the early 2000s turned out to be in demand on the one hand, and on the other hand too complicated for widespread adoption.

The authors of this report suggest a simplified 4D modelling system using BIM technology in the construction organization.
1. Methods and study
BIM-modelling and its special case in this concept - 4D-modelling allows us to divide the building process into a number of structural categories, the implementation of which is possible in real-time and space monitoring mode.

The nominal 4D modelling system includes the actual 3D model of an object and the network model (calendar-network diagram) of this object’s construction. The 3D model transposes the basic information about the object in the most visual form, while the network model shows the technological and time component of the work [1]. An important component in the 4D modelling implementation is the calculation of resources, allowing to identify the basic construction technology, economically sound method and work plan. The use of modern information technologies makes it possible to update and automate not only the basic calculations and the choice of the solutions used, but also the arrangement of mechanization tools and auxiliary objects on the site. Selection of the crane’s optimal position, access roads, storage locations, etc. is possible to carry out in a prolonged version, moving equipment and temporary huts from object to object during the structures’ complexes and networks construction [2,3].

Visualization of the resource allocation model, including cost and material as well as technical indicators, greatly facilitates the planning and organization of construction in the process of preparing and implementing an object or a complex of objects. Our system gives an opportunity to take into account shortcomings and errors at the stages of construction management in all specific areas. As a result, verification of the plans and projects’ content as a whole is greatly simplified, since missing elements or not updated links are immediately marked on the resulting model. Automated selection of the optimal solutions, which reduces the amount of the resources spent, the amount of the equipment involved, intensifies the process of the object’s building. Software using 4D modelling makes it possible to significantly reduce the project preparation time [3,4,5].

2. Results and discussion
We consider a situation where a 4D graphical model greatly simplifies visual comparison. The second task is a visual comparison of the plan with the fact or the options for organizational and technological solutions to each other. This is especially true for the construction of the facilities network, when work is carried out in parallel on a number of sites, which creates significant deviations of the construction fact from the construction plan of the facilities. The formation of a realistic approach to the objects’ construction is impossible without proper processes’ visualization, which is significantly simplified with 4D modelling programs [6].

For example, the workload study at the entrance to the site. There are the frequent cases when, in conditions of high building density, one large-sized unit of equipment can block the trucks with materials, etc., from entering the site, which entails delays and downtime in the construction process. 4D modelling also gives a possibility to adjust and optimize this process.

The process of creating a 4D model is simplified by creating a 3D model of high detail comparable to that of a work plan. Individual elements (or groups) in the 3D model are tied to combinatorial tasks and deadlines — performing graphic and design work, preparatory, installation, etc., depending on the combinatorial task specifics. The proposed concept of the 4D model links model elements to plan elements in real time, logged by programming tools.

Our proposed algorithm (Fig. 1) includes a control system, when each subsequent stage involves full completion of the previous one.

By means of the current software systems such as MS Project+Autodesk, JI Orbiter, IndorCAD scenarios in which the introduction of this algorithm becomes mandatory and the monitoring of the implementation of the planned work is automated at all stages of the plan, can be envisaged.

Thus, problem solving is automated, which is facilitated by the pre-prepared options for choosing the implementation paths, for example, the same transport access to the site taking into account spatial interference. Until this signaling factor is passed in the algorithm, it is impossible to go to the next
level of project development, and in turn, high visualization and self-learning software make it possible to quickly select the optimal scheme for solving the problem using the analogy method.

Thus, when forming models, it is always important to understand what the final result should be and how to reach it.

Software developers took care of 4D schedulers and created the tools to combine 3D model objects directly inside the program for linking with one type of work or, conversely, to break the model element “into captures”. This gives an opportunity to work with an existing model without redoing it under the schedule.

Created 4D-model (it is visualized in the framework of the general project in full, in the framework of stage design - in parts. This makes it possible to see all the events that occur in the user’s desired time period, including taking into account the changes made.

The entire construction process visualization in real-time context at the construction site is an opportunity for the designers, owners, contractors and all other project participants to see the entire construction process in real time, which eliminates most of the adverse factors. In other words, visualization contributes to the intuitive perception and understanding of the whole process.

The technological algorithm for simplifying 4D modelling assumes:

- formation of the calculation tools’ composition, including the calculation of schedules, calendars, the possibility of breaking down model elements “into captures”, etc.;
- verification within the single 4D model framework of 3D elements and fragments of calendar-network plans, integration with the most advanced Microsoft Project system to date;
- the use of the system does not imply a long process of implementation and abandonment of other systems. In most cases, it simply complements the existing CAD and project management systems.
- addition of the existing CAD with a developed algorithm.

In practice, this means the use of 4D modelling in conjunction with traditional technologies providing auxiliary control.

Implementation of the proposed technology is as follows.

Instead of the traditional several options development for planning an object, one option with pre-calculated characteristics is selected, which is facilitated by the automated processing of the proposed model based on the entered data. If, as a result of designing by the traditional method, the object’s options may differ in the amount of work, preliminary cost, etc., then the use of a simplified 4D-model makes it possible to determine the best option.

At the design stage, the results of engineering surveys are automatically transformed into a calculated terrain model, which immediately involves the selection of the optimal building scheme, foundation designs, calculation of the work volume, etc. depending on the proposed construction project.

When using the traditional approach, the design itself starts only after the DTM formation completion, which inevitably leads to significant time costs. BIM-technology makes it possible to minimize time costs by performing the work on the refinement of the DTM and the design itself independently.

Parallel work of designers and surveyors is possible through the use of a common data environment (CDE), which provides a separately prepared terrain model as a DTM layer. In the process of filling the digital model with information about buildings, utilities and other significant objects, designers receive changes through CDE in model and can adjust the design decisions to take into account the changes received. This allows to detect the conflicts in the early stages of design and make the appropriate changes to the design solution long before construction.

The modelled design objects are fully parameterized: during the design process, any parameters of the object can be modified without the need for additional calculations.

Using the common data environment allows all the participants in the process not only to see the relevant information on the projected object, but also to be able to insert comments by attaching them to a particular project object.
Designers directly performing the design work can immediately see comments and quickly make changes to the model.

At the construction stage, the automated control system for the construction machines monitors the current position of the working body of the machine in height and slope in order to accurately repeat the previously prepared design surface [12, 13]. Also, this system carries out spatial control of the transport and supply equipment, which helps to prevent interruptions in production cycles.

During the construction process, control executive surveys of actually constructed surfaces can be carried out by the technology itself, for which the working bodies are equipped with laser levels and sensors of mobile laser scanning systems. This makes it easy to download the results of such surveys and visualize them.

Upon the construction completion, the operation phase of the facility follows. At this stage, traditionally, information models are created and maintained through the object-information systems. If there was a 4D model created at the previous stages, it would be logical to use it at the operation stage. The requirements to the composition and volumes of information used to solve the problems at these life cycle stages also differ.

At the beginning of the operation phase, all data of the 4D model that can be used at this stage is imported into the database of the operating company. The project itself is also placed in a common data warehouse. At the same time, the coherence of the project’s various elements and their corresponding objects in the database is not lost. The company’s base continues to develop and is replenished with materials for certification, diagnostics and other information on the complex of structures or facility.

When performing repair or other work, the 4D model records the updated or updated data on the facility state, its operational characteristics and prognostic data on operation. If, when new parts of the object occurred (during reconstruction or redevelopment), their design was carried out, then all design and other documentation is also entered in the 4D model.

The results of the performed diagnostics are also stored in the corresponding sections of the 4D model. Based on them, an assessment of the operational state of the facility is made and, if necessary, the repairs are scheduled. The repair project is carried out in CAD, as the initial data for the design, the information accumulated in the 4D model during the operation of the facility is used, as well as the source information about the project of the facility completed at the design stage. Thus, in order to be able to use the information to complete a repair or a reconstruction project, it is necessary to provide the “reverse” data transmission from the management company, the design operator and the construction organization. After the development of the repair project and the actual implementation of the repair work, information on the repair performed, the repair project itself, information on the parameters of the object changed during the repair process, as well as the information on warranty obligations [16] can be included in the 4D model. As a result, during the operation phase, various types of data should be cyclically transmitted for fixing in the model.

The largest companies have experience in implementing such technologies. For example, AFI Development. It was founded in 2001 and is a subsidiary of the international holding Africa Israel Investments Ltd. The company occupies a leading position in the real estate market of Moscow and the Moscow region. As a development part of the residential complex “European”, the building volume is 370,000 m² remote control of construction production was used, which included:

- shooting and decoding of independent data from the surveillance cameras at building sites and mechanisms;
- independent control of the materials consumption through bar-coding with automatic sending of the consumable lots check lists with verification by the terms in the calendar schedule;
- on-line-control of executive and regulatory documents (electronic document management).

4D modelling was involved only at the stage of comparing the volumes and the terms of the work performed with the model in a semi-automated mode, i.e. involving the remote operators.

This allowed us to achieve the following results:

1. increase the efficiency of the materials expenditure by 13% by reducing unaccounted costs.
2. reduction of downtime and work delays caused by the non-technological factors by 6%.
3. reduction of time for processing and preparation of executive and reporting documentation to 25%.
4. improving the quality of the specific performers’ work (subjectively, according to the results of the personnel management reviews).

CL Group is one of the largest Russian development companies, for 25 years specializing in the construction of the most complex and iconic Moscow objects - multifunctional complexes, residential and commercial real estate. High-profile professional expertise, accumulated experience, the use of high-quality and modern technologies have ensured recognition of the professional environment for construction projects of the Capital Group holding.

The innovative approach of CL Group is the use of 4D modelling at all stages of construction, starting from the organizational stage of preparing documents and ending with monitoring the status of multifunctional complexes, through a fire safety system and load monitoring sensors built into the building’s structural design. At the responsibility stages of the developer, i.e. before putting the object into operation, continuous work has been performed with the database on-line access, where any changes in the state of the object, resources and mechanisms in the process were recorded, as well as a schedule for predicting the development of situations with the development of favourable and unfavourable factors was built. This made it possible to foresee and minimize the delays in deliveries to the most problematic building sites.

Setl City is a St. Petersburg company, one of the leaders among the developers of the Northern capital. Currently, this company manages 5 complexes built by it, where all the stages of not only construction but also maintenance are tracked by comparison with the 4D model. An analysis of independent sources shows that the percentage of funds spent on maintaining the functioning of the complex, taking into account the negative impacting factors, is reduced by 7-9% due to the ability to track changes on-line.

In Tatarstan, a decision to recommend to some developers has been made, for example, SK-Trend LLC, to introduce the full cycle on-line development management technology at all organizational, technological, constructive and operational stages.

Thus, the problem solving is automated, which is facilitated by the pre-prepared options for choosing the implementation paths, for example, all the same transport access to the site, taking into account the spatial trips. Until this signal factor is passed in the algorithm, it is impossible to go to the next level of project development, and in turn, high visualization and self-learning software make it possible to quickly select the optimal solution scheme for the problem using the analogy method.

Summary

The key advantages of the technology studied are a significant reduction in human factors to ensure high quality, prevent errors and improve the results accuracy, as well as reduce time and labor costs.

Thus, the objects modelled and constructed by means of the organizational and construction environment on-line control are highly efficient. This is confirmed by the fact that the integrated model is guaranteed to provide transparent and productive construction and operation of the facility [4, p. 334]. Effective design and efficient operation allow for a high degree of financial transparency at all stages of the facility construction. The customer is protected from unreasonable costs and unverified losses.

References

[1] Gaybarian O E, Myasishchev G I 2017 The practical application of client-oriented technologies of linguistic communication Engineering journal of don 47(4) (47) 193.
[2] Goddess G I 2010 The Model of Linguistic persona and Its Relation to Different Types of Texts (Moscow).
[3] Shirina E, Gaybarian O, Myasischev G 2017 Effective management of construction company in terms of linguistic communication *IOP Conf. Series: Earth and Environmental Science* **90** 012077.

[4] Bloch M Y 2004 Pragmatism, Ethics and Aesthetics of Communication. Linguistics and language education in modern Russia (Moscow) 43-67.

[5] Sokolov I A 2007 PhD Thesis abstract (Moscow).

[6] Kostyuchenko V V 2007 The System Organization and Management of Construction (Rostov/Don).

[7] Kliuchnikova O V and Pobegaylov O A 2016 *Procedia Engineering* **150** 2168 – 2172.

[8] Hussey D 2007 Strategic Management (Moscow).

[9] Pobegaylov O A, Myasishchev G I and Gaybarian O E 2016 *Procedia Engineering* **150** 2173-2177.

[10] Abulkhanova K A 1997 Russian mentality: cross-cultural and typological approaches. Russian mentality: issues of psychological theory and practice (Institute of psychology RAS, Moscow).

[11] Babanov A V 2011 The dynamics of the development of sustainable investment climate in regions with unstable economies (ITKOR, Moscow).

[12] Babanov A V 2011 Cyclic backwardness in infrastructure investment in the region’s Economic and Legal. Magazine “Business-in-law” (Media – WAC, Moscow).

[13] Blank I A 2008 Fundamentals of Financial Management (Nika-Tsentr, Kiev).

[14] Richard P, Underhile Ric and Andrew F Wall 2007 *Keeling Liberal Education* **93(4)** 22-31.

[15] Grice G P 2009 *Linguistic pragmatics* **XVI** 217-237.

[16] Kolesov V V 2004 Language and mentality (Petersburg Oriental Studies, Saint-Petersburg).

[17] Kolmykova T S 2009 Investment analysis (INFRA-M, Moscow).

[18] Shmelev A D 2007 Russian language model of the world: materials for the dictionary (Languages of Slavonic culture, Moscow).

[19] Leont’ev A A 2012 Psychophysiological mechanisms of speech. General linguistics:forms of existence, function, language history (Moscow) 314-375.

[20] Vladimirova T E 2010 Called into the fellowship: the Russian discourse in the intercultural communication (Book house "LIBROKOM" Moscow).