The application of automated systems in construction

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Abstract. The construction of modern buildings and structures is unthinkable without the use of digital technologies and equipment. The purpose of the study was to identify measures to reduce the cost of construction of real estate and project management. The subject of the study was modern automated systems for monitoring the progress of work and managing investment flows in the construction of facilities. The analysis of calculation results we can conclude that in comparison with traditional methods of construction, application of systems of automation of designing and implementation of construction works on the one hand leads to a rise in the cost of construction, but on the other allows you to save on logistical, human and energy resources, and enhance the competitiveness of construction organizations. The obtained equations, with the value of the coefficient of determination (91.4%), allowed us to evaluate the implemented measures for the automation of construction production.

1. Introduction
Modern production is unthinkable without application of automated systems and digital modeling tools. The construction industry is also not left aside where the use of modern systems of design, calculation and management of construction production allows to significantly reduce the cost of production and avoid critical errors.

The concept of computer modeling got its beginning and was formed in different scientific European communities and USA communities almost at the same time, but in different terminology and, besides all, in different languages. In 1975, the journal of the American Institute of Architects published an article by Chuck Eastman, Professor at the Georgia Institute of Technology, entitled "Building Description System", in which the concept of building information model was first introduced. In 1986, British scientist Robbert Aish, already famous at that time in the development of architectural CAD-system RUCAPS, and later - an employee of Bentley Systems, in one of his works explained the real example of a high-rise structure using a computer model, using the term "Building Modeling", which in modern terms means "information modeling of the building". Recently Robert has moved to work in Autodesk company [1,2]. Must be this fact, together with purchase Revit on border 1990 - 2000 gives the right to the USA to name itself BIM ancestors.

Russia against the background of European countries and the United States has long remained in the shadow of "digital" design of construction support. Only in 2014 the Ministry of Construction and Housing and Communal Services of the Russian Federation signed the decree "On approval of the Plan of phased introduction of information modeling technologies in the field of industrial and civil construction".
By order of the President of the Russian Federation from 19.07.2018 No PR-1235 the task of application of information modeling in the construction industry was set. According to what the project of the federal law "About modification of the Town-planning code of the Russian Federation" about transition to a control system of a cycle of objects of capital construction by application of methods of information modelling for the purpose of modernization of a building industry and improvement of quality of building manufacture has been developed. On June 18, 2019 a new SR 404.1325800.2018 "Information Modeling in Construction, Rules for Development of Plans for Projects Implemented Using Information Modeling Technology" was published. This article describes the processes of project planning in construction, implemented using information modeling methods that can be used in the construction of objects of various functional purposes, their reconstruction and major repairs [3].

The purpose of the study was to identify measures to reduce the cost of construction of real estate and project management. The subject of the study was modern automated systems for monitoring the progress of work and managing investment flows in the construction of facilities. The main objective of the research was to develop measures to reduce the cost of construction products by using modern equipment, as well as the development of a mathematical model that allows a sufficient degree of confidence to reflect the result of the implementation of the proposed measures on the internal price of products.

2. Methods

However, compared to the traditional approach, digital design has a number of advantages:

- reduction of time of preparation of the design documentation;
- possibility of revealing errors of 2D designing;
- reduction of cost of construction;
- the control over expenses;
- reduction of time for project realization.

At the design stage of the construction organization project and the production project, the digital model of the construction site allows to avoid undesirable consequences from the negative and harmful factors, as well as to optimize time, human and material resources. In particular, analyzing 3D model of the projected building, it is possible to choose the most rational methods of work production, to organize the territory of the construction site and control the processes of technological operations, as well as to carry out operational management of financial resources [4,5].

In addition to the obvious advantages, the use of a full digital model allows to increase automation and mechanization of construction production, and to save energy resources for household needs (by reducing the construction period), for the operation of construction equipment (by optimizing the work performed and reducing unnecessary technological operations), etc. [6,7]. The sequence of formation of complex 3D model at the organization of construction and installation works is shown in Figure 1. One of the labor-intensive processes in the construction of the underground part of the building and geodetic support of construction is the creation of a topographic basis. Application of modern unmanned aerial vehicles equipped with high-precision equipment for obtaining digital maps and three-dimensional models is an effective solution in comparison with traditional methods [8,9].

Application of these technologies allows to reduce time expenses for topographic survey creation by 15-20% without quality loss. The obtained surface model can be used not only for fixation of geodetic axes but also for calculation of earthwork volumes and quality control of their execution.

Another aspect of work automation in the construction of real estate is the use of modern construction equipment and methods of mechanized work. In particular, modern software makes it possible to monitor in real time the technical condition and productivity of machinery, as well as to identify under-loaded machines and optimize their work schedule [10,11].
Figure 1. Formation of complex 3D model at planning of construction and installation works

The integration of digital surface models into 4D positioning systems allows for more thorough monitoring of the efficiency of construction machinery use. Application of modern diagnostic complexes of remote control, aimed at maintenance of machinery in serviceable condition, allows to reduce the risk of sudden failure and reduce overuse of energy resources in the course of machines with faulty equipment [12].

It is important to synchronize the digital model of the construction with the work schedule. For example, synchronization of the calendar schedule with constructive elements of 3D model can be done with the help of Autodesk Navisworks Freedom plugin.

Synchronization of the schedule with the 3D model elements of the project allows you to analyze the planned model for spatial and temporal conflicts, especially the data is relevant for the installation of engineering utilities [13,14].

The control of execution and fixation of actually developed and mastered constructive elements of 3D-model of a building at installation on a building site, will help to display actually mounted elements of a building or a construction with the subsequent construction of actual model of a building. If necessary, the 3-D model will show the assembled structural elements on the specified date.

Identification of data for a given period will make it possible to calculate the completed volumes, the term of construction completion, the number of construction materials and equipment required for completion of construction and will help to create a unified database of statistical indicators with its structure and analysis.

The conducted research of BIM-modelling of the project with application of such programs as "Autodesk Revit" and "MS Project" has allowed to estimate in the theory convenience and possibilities for the further development of an information technology in the Russian Federation and to draw certain conclusions.

3. Results and Discussion

The researches were carried out on the basis of methodology of designing of the organization of construction of MDS 12-46.2008 "Methodical recommendations on development and design of the project of the organization of construction, the project of the organization of demolition (disassembly), the project of works".

It is impossible to manage processes, to predict their development without studying the nature, strength and other features of the links between the factors that influence the phenomena under study.
A distinction is made between two types of relationships between phenomena and influencing factors: strictly deterministic and statistical (stochastic). The specificity of the object of the experiment in the conditions of the research has determined the choice of mathematical tools [15,16].

Therefore, correlation-regression analysis was used as a basic methodology for studying the complex influence of modern information and resource-saving technologies on the efficiency of construction organizations. The statistical sample was conducted on 32 construction organizations of the Vladimir region. The sample was carried out with the following prerequisites:

1) feature-factors are in cause-effect relation with the resulting indicator;
2) feature-factors are neither components of the resulting feature nor its functions;
3) the feature-factors do not duplicate each other (with correlation coefficient more than 0.8);
4) the feature-factors are not factors of different levels, i.e. the base level factor and its sub-factors.

Taking into account the above, a system of indicators has been formed. As a result indicator the following indicators were proposed: gross income of construction organizations for 2019 million rubles. ($U_1$), and the output level indicator per employee ($U_2$) thousand rubles.

The factor indicators of the level of use of information and resource-saving technologies were selected as factors affecting the result:

1. Fund construction with modern means of mechanization $F_m$, thousand rubles / person;
2. Fund construction with modern information and software systems $F_i$, thousand rubles / person;
3. The coefficient of renewal of the innovative component of fixed assets, $C_{or}$;
4. Energy intensity CIW $E_{ciw}$, conv. unit
5. Growth rate of energy facilities of auxiliary industries $\Delta E_{ai}$, %

The parameters of the regression equation are calculated using the least squares method. The mathematical apparatus of the least squares method consists in calculating such values of factor features for which the sum of the squares of deviations of the calculated values of the factor feature from the actual ones will be minimal.

Interpretation of the obtained regression equations:

$$U_1 = 12.553 + 0.02F_m + 0.045F_i + 0.087C_{or} - 0.08E_{ciw} - 0.002\Delta E_{ai}$$  \(1\)

Checking by Fischer's F-test allowed us to establish that the equation is statistically significant. The equation was optimized by step-by-step regression by excluding one factor from the model. As a result, the regression equation takes the following form:

$$U_1 = 18.336 + 0.061F_m + 0.058F_i + 0.087C_{or}$$  \(2\)

Repeated testing using Fischer's F-criterion showed that the resulting equation is statistically significant. The resulting value of the F-criterion was greater than the table value-71.25>4.25

The remaining three factor features in the equation determine the variation of the effective indicator by 91.4%. The multiple determination coefficient is 0.914. The closeness of the relationship between factor characteristics is quite high, this is confirmed by the calculation of the multiple correlation coefficient (0.931).

The study found that the resulting gross income of a construction organization is influenced by three factors: Capital-modern mechanization $F_m$, capital to labour ratio of the modern information and program - technical systems of the $F_i$, the rate of renewal of fixed assets of the innovation component of the $C_{or}$.

Analysis of the stability of correlation and regression model showed that all factors included in the equation to have a positive effect on effective index, i.e. by increasing the capital-labor ratio modern mechanization for 1 unit, the gross income of a construction organization increases 0.061 million rubles the average for the sample, by increasing the capital-labor ratio modern information and software systems 0.058 million rubles, respectively. And the coefficient of renewal of the innovative component of fixed assets - 0.087 million rubles.
Analyzing the general statistics on the value of investments in fixed assets, it is possible to note a systematic increase in absolute indicators (Figure 2), but a decrease in relative ones. At the same time, there is a systematic increase in the percentage of depreciation of fixed assets (Figure 3).

![Figure 2. Investments in fixed capital of construction organizations](image)

![Figure 3. Change in the size and degree of depreciation of fixed assets of construction companies](image)

The researches have shown, that application of systems of automation and digitalization on the one hand allows to raise levels of fund construction by modern means of mechanization and software systems that leads to increase of the given output, but on the other hand against the background of decrease in gross income there is an additional burden on the building organizations of region.

Application of software products has allowed to simplify considerably process of the coordination of the executive and design documentation in spite of the fact that at first there were certain difficulties in joint interaction of the customer, the contractor and the general designer. The additional stimulus
was the possibility of direct control of execution of design and construction and installation works in real time with mobile applications.

The conducted studies revealed both positive and negative aspects of the proposed solutions:

The positive aspects include:
- As a result of application of the modern software products based on creation of a uniform database and possibility of joint management, allows to reduce essentially terms on performance of design works and the coordination of technological decisions on erection of buildings, especially in the conditions of possible change of a schedule of delivery of building materials or at revealing of the additional restrictions which have not been found out at a design stage (in the considered project, in the course of construction and erection works, there were found utility systems that were not applied to the executive schemes, which required changes to the project of excavation works and dismantling of utility systems);
- The use of modern systems of work automation, in particular, earthworks, allows to reduce the number of technological operations, which leads to an increase in productivity, reducing the time of operation of the machine, and thus increases the resource before repair and MOT;
- The introduction of modern methods of work, as well as their proper planning allows reducing the need for human and material resources, which ultimately affects energy savings;
- The application of modern technologies allows not only to reduce the need for material, technical, human and energy resources, but also to reduce the cost of construction and increase the competitiveness of the construction organization.

The negative aspects include:
- BIM design requires more time and qualification level of executors as well as additional software costs. However, initial time expenses for construction of high-grade 3D-model are compensated by reduction of duration of coordination, statement and adjustment of the design documentation between executors the customer and other interested structures, and to large builders it is easier to operate projects through mobile applications and the Internet;
- The transition to modern systems of automated management of construction and installation works allows to improve the quality of work performed and to implement comprehensive management of construction works on the site. However, the machine parks of construction organizations should be supplied with modern equipment, and retraining of employees to work with this equipment should be carried out, which leads to higher construction costs, which is especially important for regional organizations;
- Automation of work leads to a reduction in the number of workers involved in the production of work, which can cause social tension. On the other hand, it encourages people to learn prospective technologies and methods of work and frees up staff and resources to implement a larger number of projects.

4. Conclusions
In the course of analyzing the results of calculations, the following main conclusions can be drawn:
- The use of automation systems for design and implementation of construction and installation works on the one hand leads to an increase in the cost of construction, but on the other hand it allows you to save on material, technical, human and energy resources, as well as increase the competitiveness of the construction organization;
- It is necessary to develop a modern tax base that allows advanced organizations to implement modern technologies;
- The obtained mathematical dependencies with a sufficient level of the coefficient of determination (91.4%), allow us to evaluate the planned construction technologies in terms of economic efficiency.

References
[1] Alwisy A and Al-Hussein M 2019 Automation in drafting and design for modular construction
manufacturing utilizing 2D CAD and parametric modeling EG-ICE 2010 - 17th Int Work Intell Comput Eng

[2] Gutiérrez Fernández A and Van Rijswijk F 2019 Using Ontologies for Enterprise Architecture Integration and Analysis Lect Notes Bus Inf Process

[3] Yan J, Zlatanova S and Aleksandrov M 2019 ISPRS Ann Photogramm Remote Sens Spat Inf Sci 147-154

[4] Reddy K 2018 BIM for Building Owners and Developers 1-39 DOI: https://doi.org/10.1002/9781119572602.ch1.

[5] Azar E and Kamat V 2017 J Inf Technol Constr 22 247-265

[6] Stepanov M and Gridchin A 2018 Perspectives of construction robots. IOP Conf Ser Mater Sci Eng 327(4) https://doi.org/10.1088/1757-899X/327/4/042126

[7] Heaton J, Parlikad A and Schooling J 2019 Comput Ind 10414-26

[8] Shopov Y, Ognianov O and Filipov A 2018 Development of Technology for Remote Location of Unknown Underground Cavities and Deep-Seated Rockslides by Unmanned Air Systems (UAS). J Phys Conf Ser

[9] Kristal M and Kisel T 2018 Economic efficiency of innovations in construction: The use of the pilotless equipment. MATEC Web Conf 256 DOI: https://doi.org/10.1051/matecconf/201825105006.

[10] Prochorov S 2018 Substitution of the labor market in the construction industry by technical and automated systems MATEC Web Conf 170 DOI: https://doi.org/10.1051/matecconf/201817001086

[11] Kramarenko A and Krasnova K 2017 Sci and educ. modern times 6 (23) 15-23

[12] Reinbold A, Seppänen O and Peltokorpi A 2019 Integrating Indoor Positioning System and BIM to Improve Situational Awareness 27th Annu Conf Int Gr Lean Constr IGLC 2019 DOI: https://doi.org/110.24928/2019/0153

[13] Knyazeva N 2018 Integration of operation and maintenance information model with company's existing information systems IOP Conf Ser Mater Sci Eng 463(4) DOI: https://doi.org/10.1088/1757-899X/463/4/

[14] Rodrigues Santos de Melo R and Bastos Costa D 2019 Eng Constr Archit Manag 26(11) 2705-2722.

[15] Mandičák T, Mesároš P and Tkáč M 2018 Pollack Period 13(3) 61-72 DOI: https://doi.org/10.1556/606.2018.13.3.7

[16] Grzelak L 2019 Int J Comput Math 96 (11) 2209-2228