TECHNOLOGY AND ORGANIZATION OF CONSTRUCTION

DOI 10.36622/VSTU.2020.2.46.002

UDC 639.86:004

E. P. Gorbaneva¹, A. V. Mishchenko²

INFORMATION MODELING OF REAL ESTATE AT THE STAGE OF SURVEY WORKS

Voronezh State Technical University^{1,2}

Russia, Voronezh

¹*PhD in Engineering, Assoc. Prof. of the Dept. of Technology, Organization of Construction, Expertise and Property Management, e-mail: egorbaneva@vgasu.vrn.ru*

²*Undergraduate of the Dept. of Technology, Organization of Construction, Expertise and Property Management, e-mail: mi9539@yandex.ru*

Statement of the problem. Perform a review of scientific papers and regulatory documents used in information modeling. Explore information modeling technology at all stages of the life cycle of capital construction projects. Demonstrate the practical implementation of information modeling technology by the example of survey work.

Results. Deficiencies of the existing regulatory documents used in information modeling are identified. The tasks of information modeling technologies in the construction industry throughout the life cycle are formulated. The application of information modeling technology at the stage of engineering surveys of the life cycle of the capital construction object with the justification of its economic efficiency is considered.

Conclusions. For the effective application of information modeling technologies and ensuring the fulfillment of the tasks entrusted to it, it is necessary to create a full-fledged production regulatory framework that defines the status of the information model and the requirements for documentation received on its basis by various participants at all stages of construction production, as well as containing requirements for the storage of documents and making into her changes.

Keywords: information modeling, BIM-technologies, life cycle, engineering surveys, normative documentation, software systems, economic efficiency.

Introduction. Use of advanced information modeling technologies in construction in the territory of the Russian Federation is part of the national policy in the field of information technology application for various fields of activity and the overall “digitalization” of the economy.

A particular feature of information modeling technologies at all stages of the life cycle of a construction object is the involvement in the process of designing a model, filling it with information and handling this information by a broad range of users in various fields of activity (builders, engineers, economists, maintenance services, etc.) as well as high information richness of the model. Presently research is being actively carried out in certain areas of application of information modeling technologies in the construction industry [10, 11, 13]. A comprehensive assessment of the application of information modeling technologies is presented in a few studies [2, 5, 9, 17]. The most reliable are those that rely on the experience of practical application including overseas one [3, 6, 9, 16].

A key role is played by statistical research [1, 9, 19, 20, 21]. There are studies that describe a number of advantages of using information modeling technologies without critical assessment and substantiation [12] and are commercial. Some investigations are rather theoretical as their conclusions and outcomes do not allow for practical experience [2, 4, 7, 8, 12]. Most studies fail to provide objective performance indicators that can be compared or measured.

An assessment of compliance with regulatory requirements and the applied tools of practical implementation of information modeling technologies (software) as well as an assessment of their economic efficiency are not provided for any stage of the life cycle of an object.

Therefore it is becoming essential to study information modeling technology at all stages of the life cycle of major construction objects and demonstrate practical implementation of information modeling technology using the example of surveys.

1. Review of information modeling of construction objects. The process of designing and using information on completed construction projects as well as those in progress in order to coordinate input data, organize joint production and storage of data as well as to employ them for various purposes at all stages of the life cycle (section 3.10 of Construction Rules (CII) 333.1325800.2017) is internationally referred to as BIM (Building Information Modeling or Building Information Model).

The concept of information modeling of construction objects originated in the mid-80s with the emergence of computer technology and software. These systems were the first ones to ensure the functioning of complex automated facilities such as factory industrial complexes, large international airports, and nuclear power plants. Originally, these systems did not provide any explicit information about the structures and other building elements of the building and did not contain a virtual model of a building, but what they had was necessary information about engineering systems and automation to control their operation.

For the first time the term “building model” came about in the article by Simon Ruffle published in 1986 [22] and the term “Building Information Model” did in the article by G. A. Van Nederwin and F. P. Tolman [23] where the principle of using the information model was accurately formed. The first software capable of designing virtual models of buildings (3D models) emerged long before the abbreviation BIM back in 1984. The “pioneer” in this area was GRAPHISOFT which launched a massive software product for personal computers ArchiCAD. The term or abbreviation BIM was coined by Autodesk which in 2002 released the document “Building Information Modeling [18] which became a manifesto for the wide use of the BIM concept.

Like any other technology, information modeling technologies in the field of construction production should be considered as a system of tools, regulatory documents governing their use for each type of activity involved in production (investment activity, research, inspection, design, construction, operation, etc.), and its efficiency as productivity and the ratio of consumed resources to a final product.

Based on the above, the concept of information modeling technology will be shown in a diagram in Fig. 1.

Fig. 1. Concept of information modeling technology [6]

Presently information modeling technologies in the construction industry are grappling with a variety of tasks throughout the entire life cycle of an object:

1. Application of information modeling to justify investment:

— analysis of the location and engineering-geological and environmental situation of a future construction site;

- development and comparison of options for architectural and urban planning concepts;
- visualization.

2. Application of information modeling in survey and design:

- release of drawings and specifications;
- verification and evaluation of technical solutions;
- spatial interdisciplinary coordination and collision detection;
- calculation of the scope of work and cost estimates;
- engineering and technical calculations;
- development of a construction organization project, a comprehensive enlarged network schedule.

3. Application of Building Information Modeling:

- visualization of the construction process, data integration into the construction network schedule for

- a) analysis and optimization of the sequence of work on a project;
- b) search for spatio-temporal intersections that may emerge through the course of construction;
- c) inspecting the viability of organizational and technological solutions;
- d) controlling the completed physical volumes of construction and installation as well as visualization of a plan-fact analysis.

- construction management

- a) development of a comprehensive integrated network schedule and working hours;
- b) coordination of construction and installation and commissioning works with the development and design of operating documentation and equipment supplies;
- c) operational planning and monitoring of construction, installation and commissioning works;
- d) optimization of the number of personnel at the construction site;
- e) analysis of the current state of the construction project and the development of compensating measures.

- Geodetic alignment works. Geodetic control in construction;
- Monitoring labor protection and industrial safety at the construction site;
- Digital production of building structures and products.

4. Application of information modeling in operation:

- Scheduling maintenance and repairs;
- Monitoring of operational characteristics;

- Management of the operation of buildings and structures;
- Emergency simulation.

Broadly, any technology is a collection of methods and tools for achieving a desired outcome. In production, these methods are clearly defined technical regulations, instructions, conditions and other regulatory documents and tools are all kinds of equipment, machines and software. It is impossible to look at technology separately, either as a regulation or as a tool, because this will not be a technology by definition and in essence, just as technology cannot be considered in isolation from the existing realities. A prerequisite for any effective technology should be compliance with the regulations, the employed tools, as well as ensuring the pay-back of the material, monetary, human and other resources to be further invested. It is only when these conditions are met that technology can ensure efficient production. Besides, the more complex the technology is, the more active elements it contains, the more challenging it is to make sure that it is efficient.

2. Review of normative documents used in information modeling. In order to determine how compliant the current regulatory documentation is with the applied information modeling tools, its nature, purpose, as well as specialties and activities in the field of construction production it is focused on were investigated (Table 1).

Currently the basic requirements for the documentation of almost all participants in construction production are specified by the Unified System for Design Documentation (ESKD) which contains 46 valid documents. This regulatory system determines the composition and type of all production documentation and contains clear requirements for it. Accordingly, this documentation system is of a production nature. Determining the nature of the documentation is one of the major criteria for its assessment.

With a sufficient degree of knowledge of individual aspects of the use of IM technologies, a full-fledged comprehensive assessment of their economic efficiency confirmed by examples of practical implementation is not provided in the studied material. The overwhelming majority of the current GOST standards on information modeling are translations of international documents or are compiled from their individual chapters. None of them are of a production nature. The current Construction Rules can be conditionally referred to as production as they describe production processes from the standpoint of their organization as well as the rules for the formation of models. Some of the sections of Construction Rules do not contain requirements for the received documentation. A number of provisions of the joint venture are strongly theorized, but some points are instrumental in practical implementation.

Table 1

Current Information Modeling Regulations (September 2019)

Guideline Documentation	Comments
GOST FOCT P 10.0.02-2019/ICO 16739-1:2008	Contains no requirements for final products or documentation
GOST FOCT P 10.0.03-2019/ICO 29481-1:2016	
GOST FOCT P 10.0.04-2019/ICO 29481-2:2012	Only describe the general principles
GOST FOCT P 10.0.05-2019/ICO 12006-2:2015	Do not identify the status of Information Model as a document
GOST FOCT P 10.0.06-2019/ICO 12006-3:2007	
GOST FOCT P 58439.1-2019	Are not of production nature
GOST FOCT P 58439.2-2019	Are translations of English-language documents or formed using their individual chapters
GOST FOCT P 57311-2016	
GOST FOCT P 57563-2017/ISO/TS 12911:2012	
Construction Rules CII 301.1325800.2017 Building Information Modeling. Rules for the organization of work by production and technical departments	Contains requirements for the organization of work by VET departments, describes the principles of work using information modeling technologies. A solid theoretical model. Does not consider the increase in labor costs and the specifics of interaction between participants in the construction industry. Of conditionally production nature
Construction Rules CII 328.1325800.2017 Building Information Modeling. Rules for describing information model components	Applicable to the processes of IM of buildings and structures, establishes requirements for the components of IM and the rules for filling in their attributes. Aimed at developers of IM of major construction objects as well as developers of libraries of their components. Of conditionally production nature
Construction Rules CII 331.1325800.2017 Building Information Modeling. Exchange rules between information models of objects and models used in software systems	The document is intended for design and operation of information systems that interact with each other during the life cycle of buildings and structures. The document is aimed at developers of information exchange systems and technical support apparatus and does not contain requirements for the practical implementation of information exchange between participants. Not of production nature
Construction Rules CII 333.1325800.2017 Building Information Modeling. Rules for the formation of an information model of objects at various stages of the life cycle	Applicable to the processes of information modeling in the design, construction and operation of objects of mass construction, contains requirements for information models focused on various stages of the life cycle. A number of provisions are recommendations
Construction Rules CII 404.1325800.2018 Building Information Modeling. Rules for the development of project plans implemented using information modeling technology	Applicable to planning of projects in construction, implemented using IM technology, establishes general rules, the procedure for the development and structure of project plans. Focused on all participants
Other Guideline Documentation	
Guideline manual. Ensuring interoperability in information modeling of construction objects	
Guidelines for calculating the cost of design while using information modeling technology performed with the involvement of funds from the budget of the city of Moscow	

Given that it has been 5 years since the implementation of information modeling technologies in the Russian Federation, and out of all the guideline documentation only 9 GOST standards and 5 Construction Rules have been enforced, among which there are no production ones similar to the current ESKD system, it should be concluded that the rate of development of regulatory documents on information modeling is extremely low.

3. Application of information modeling technologies for a capital construction object at the stage of engineering surveys. Surveys in construction are divided into geological, geodetic, as well as measurement and survey at existing construction sites. There is no reliable information on the practical application of information modeling technologies in geological surveys in construction in the Russian Federation, although their application is technically possible.

The above normative documentation mentions an engineering digital terrain model (MCMM) [14], but there is no division of the geological and geodetic parts of it as independent elements performed based on different types of work.

Let us look at the use of information modeling tools in geodetic surveys and measurement and survey work since as of September 2019, these types of work have practical implementation. The results of the investigation are shown in Fig. 2—11.

Fig. 2. Scanning using reference marks
(a few scanning stations are employed)

Fig. 3. Scanning without reference marks
(there are a lot more scanning station employed)

The major tool for information modeling during geodetic surveys is ground laser scanning. It can be implemented in two ways — with the use of reference marks and without them. The

following describes an example of work performed at the Voronezh-2A gas distribution station (Fig. 2, Fig. 3).

The scanning methods have few fundamental differences. In the case of scanning without reference marks, but with a large number of stations, the time for performing field and office work (scanning and processing of point clouds itself) increases, but the number of blind spots in point clouds decreases (Fig. 4). Mostly, if the scanning stations are located correctly, scanning by stamps is sufficient for geodetic work (Fig. 5).

Fig. 4. Scanning using reference marks
(blind spots are visible)

Fig. 5. Scanning without reference marks
(there are no blind spots)

Fig. 6. Complete point cloud

Fig. 7. Removing excessive points

After the scan has been completed, the point clouds are merged. For scanning with reference marks, it is performed automatically, for scanning without reference marks manually. Cyclone and True View packages from Leica Geosystems were employed for processing, cleaning point clouds, as well as forming visualization (Fig. 6, Fig. 7).

The formation of the topographical plan and relief is performed using virtual mapping in Autodesk Civil 3D (Fig. 8, Fig. 9).

Fig. 8. Vectorization of laser scanning using the coordinates of the point clouds

Fig. 9. Triangulation of the surface and designing a 3D model

Topographic design in accordance with current regulations is performed using Autodesk Autocad. For comparison, there is a topographic plan developed earlier based on tacheometric survey (Fig. 10, Fig. 11).

Fig. 10. Designing a topographical plan using a three dimensional model obtained using laser scanning

Fig. 11. Topographical plan using three dimensional scanning (for comparison)

Overall, for geodetic surveys laser scanning is an effective and accurate method that allows one to obtain a three-dimensional terrain model based on point clouds and generate topographic plans. The time spent on performing works using laser scanning is similar to that spent on performing works using tachymetric surveys while designing topographic plans. It increases if it is necessary to design a three-dimensional terrain model. Its main serious drawback can be considered the inability to work on unprepared terrain in conditions of snow cover, tall grass, bushes and other vegetation.

In all fairness, it is worth noting that a digital terrain model can also be obtained by means of tacheometric survey without using laser scanning, e.g., with the Trimble geodetic complex which includes a total station, GPS-receivers and the Trimble Business Center Complete software package. This method is cheaper and has no disadvantages of laser scanning, but requires slightly more time-consuming field work. But regardless of the methods for obtaining spatial coordinates in geodesy, the design of topographic plans in compliance with GOST is performed using graphic CAD systems.

For geodetic surveys, the general level of efficiency of software and hardware should be considered sufficient.

4. Application of information modeling technologies at various stages of the life cycle of a major construction object.

Presently, there are a lot of software systems and individual programs for solving various design problems. Organizations employ the following software systems:

- Autodesk Autocad and Revit for architectural and construction design as well as design of heating and ventilation systems, water supply and sanitation.
- Trimble Tekla for design of metal and reinforced concrete structures.
- Autodesk Autocad and Civil 3D for design of master plans.
- Aveva PDMS for design of technological sites for gas production, gas transmission and gas distribution enterprises.
- Bentley Raceway and Cable Management, Autodesk Autocad and Revit for design of cable routes and equipment for ET, SS, PS, instrumentation, etc.
- Navisworks Manage for formation of the final assemblies of a model from various parts of projects performed in different software.

All the above software systems are manufactured overseas and require adaptation to obtain documentation or parts of it in accordance with the applicable standards.

Based on the research and the provisions of Construction Rules 333.1325800.2017, a table of the actual application of information modeling technologies by enterprises of the construction industry of the Russian Federation was designed (Table 2). Table 2 shows that use of information modeling technologies has not been implemented for a lot of the tasks assigned to them in the field of construction production.

Table 2

Implementation of the application of information modeling technologies
(according to sections 5.4, 5.5, 5.6, 5.7, 5.8 SP 333.1325800.2017 [14])

Purpose	Implementation	Degree of implementation	Comments
Justification of investment			
Analysis of the location and engineering and geological and environmental situation of a future construction site	Not implemented	—	
Development and comparison of options for architectural and urban planning concepts	Not implemented	—	
Vizualization	Implemented	Sufficient	

Table 2 (continuing)

Purpose	Implementation	Degree of implementation	Comments
Survey and design			
Release of drawings and specifications	Implemented	Insufficient	For some sections simulation is limited or not involved
Inspection and evaluation of technical solutions	Implemented	Sufficient	
Spatial interdisciplinary coordination and identification of conflicts	Implemented	Sufficient	
Calculation of the amount of works and cost estimation	Not implemented	—	
Engineering and technical calculations	Implemented	Insufficient	Problems with compatibility of the data format
Development of a construction organization project, a comprehensive extended network schedule	Not implemented	—	
Construction			
Visualization of the construction process, data integration into the construction network schedule for			
analysis and optimization of the sequence of project work	Not implemented	—	
search for space-time intersections that may take place during the construction	Not implemented	—	
checking the viability of organizational and technological solutions	Not implemented	—	
control of the completed physical volumes of construction and installation work and visualization of the plan-fact analysis	Not implemented	—	
Construction Management			
development of a comprehensive integrated network schedule and work schedule	Not implemented	—	
coordination of construction, installation and commissioning works with the development and issuance of working documentation and equipment supplies	Not implemented	—	
timely planning and monitoring of construction, installation and commissioning works	Not implemented	—	
optimization of the number of personnel at the construction site	Not implemented	—	
analysis of the current state of construction and the development of compensating measures	Not implemented	—	

Table 2 (continuing)

Purpose	Implementation	Degree of implementation	Comments
Geodetic alignment works. Geodetic control in construction	Not implemented	—	
Occupational health and safety monitoring at the construction site	Not implemented	—	
Digital production of building structures and products	Not implemented	—	
Operation			
Maintenance and repair planning	Not implemented	—	
Monitoring the operational characteristics	Implemented*	Sufficient*	For highly important objects*
Management of the operation of buildings and structures	Implemented*	Sufficient*	
Emergency simulation	Implemented*	Insufficient	All the situations cannot be modeled *

5. Assessment of the economic efficiency of information modeling technologies. An assessment of the economic efficiency of information modeling technologies should be performed using that of the payback of software and hardware. For this purpose the averaged models of enterprises (survey, design, construction) are provided considering necessary equipment and software (with the required number of licenses) considering the wages of the employees of the enterprise as well as the costs of the technical support. These models do not allow for the costs of purchasing (upgrading) workstations, server and network equipment as well as of purchasing licensed operating systems, antivirus tools, and individual calculation software.

The models of enterprises planning investment and construction projects, construction and operation of facilities are provided conditionally due to lack of practical experience in the use of information modeling technologies and the inability to accurately evaluate the need and degree of their application in enterprises due to the peculiarities of planning and operation processes for objects of various purposes.

Let us look at an enterprise involved in geodetic surveys. Their information modeling tools are software systems or software and hardware complexes that provide the construction of an information model of the terrain based on tacheometric survey data. Also, while conducting a geodetic survey, it is possible to make use of laser scanning software and hardware complexes (ground, mobile or air). Ground complexes are effective for most construction projects and the most cost-efficient.

As these surveys are highly specialized, for an organization conducting geodetic surveys, a small team suffices. A team of 2 people is commonly enough to perform work on one site. A small group firm of 3 field teams and a surveyor is capable of conducting a fairly large amount of survey work. For the model of the firm under consideration, an accountant is also included on the staff.

The specifics of the work of a firm involved in geodetic surveys is a quick turnover of funds (receipt of income, expenses for expenses, payment of wages to the employees, etc.), without the formation or with the formation of a small reserve fund. The required firm personnel are presented in Table 3.

Table 3

Required staff of a firm involved in geodetic surveys

Position	Number
Director-General Engineer Surveyor (field works)	1
Engineer Surveyor (field works)	5
Surveyor Topographer (office worker)	1
Accountant	1
Total	8

Let us identify the required composition of software and hardware systems for the above model of the firm. The list is compiled using the most common complexes and software in the market (Table 4).

Table 4

Identifying the need for software tools

Purpose of a package	Name of a package	Number required
Survey work	Tachometer Trimble M3 DR TA 1"	3
	Satellite receiver RTK Trimble R8	3
Laser scanning	Laser scanner and tachometer Trimble SX-10	1
Processing the results of the tacheometric scanning	Trimble Business Center Complete	1
Processing the results of laser scanning (point clouds)	Trimble RealWorks Base	1
Designing a 3D model of the location Designing the documentation	Autodesk Civil 3D	2
Software packages Trimble Business Center Complete and Trimble RealWorks Base do not require annual license renewal		

According to the reference book of basic prices [15] for engineering surveys, the cost of survey works (field + topographic plan) at a site with a profile height of 0.25 m, difficulty category II, with the current price coefficient — 4.15 (Q2 2019) is 32952, 66 rubles (27 460.55 rubles + 20 % VAT) for 1 hectare.

Therefore with an average workload of a company of 1 hectare per day, the total income from tacheometric surveys and topographic plans alone will be 32.95266×247 (working days for 2019) = 8139.31 thousand roubles.

Because the cost of laser scanning work is identified individually and the market value of these works is 25—30 roubles per 1m^2 of scanned area (area of the territory) in September 2019, provided that the company is occupied with laser scanning works that make up 5 % of the total volume, the total income will be 32.95266×234.65 (95 %) + 250.00×12.35 (5 %) = $7732.34 + 3087.5 = 10819.8$ thousand roubles. Hence even in the first year of using laser scanning tools as an element of information modeling technologies, the enterprise brings in the profit of $10819.8 - 5520.0 - 3730.0 - 95.0 - 289.7 - 149.0 = 1036.1$ thousand roubles.

Conclusions. For effective use of information modeling technologies and ensuring the completion of tasks they are expected to solve, it is essential to design a full-fledged production regulatory framework that identifies the status of the information model and the requirements for documentation obtained on its basis by various participants at all stages of construction production as well as containing requirements for storing documentation and making changes to it. This will make it possible to specify uniform requirements for the model and documentation in the federal level for all participants in the construction industry, which will have a positive impact on their interaction.

The formation of the production regulatory framework should be performed considering the specifics of information modeling similarly to the existing ESKD system with the formation of separate documents for participants in the construction industry, documentation requirements that were not previously specified. The priority in the development of this system should be primary as it is the major guideline for all of the production units at construction industry enterprises. The development of other documents should be performed following the formation of the production regulatory framework. At the same time, the use of overseas experience in the development of regulatory documents should be used for reference but not as a primary source. It is recommended that a lot of software tools that require the development of complex technologies for interaction between individual programs are dismissed. Design of “basic” universal software systems capable of meeting the requirements of as many participants in the construction industry as possible and capable of comprehensively addressing their problems

should be prioritized, e.g., the use of Autocad with existing technologies. This will make it possible to effectively and quickly tackle any production issues, to quickly exchange complete information between production participants without converting into universal formats without involving additional software and developing technologies for interaction between it and the major software. I.e., interoperability issues are addressed. It is also possible to reduce or completely eliminate technical support.

Such packages should be developed taking into account the newly developed production regulatory framework. The most viable solution is to develop software systems in keeping with the regulatory framework. In order to achieve the best results as well as prompt response and joint solution of organizational and technical issues, domestic software developers should be given priority. The massive use of the “major” domestically manufactured software systems will provide inexpensive and high-quality solutions to all participants in the construction industry and ensure their implementation and adaptation at enterprises in a short time and with minimal costs. It is also critical to understand that with a detailed development of the information model the design time cannot be reduced but rather increased. At the same time high detailing of the model allows one to decompose its elements into step-by-step types of work, which, along with the visibility of the model, can reduce the time for construction and installation and ensure early commissioning of an object. Striking the balance between design and construction will reduce the time and cost of implementing construction projects.

Hence for effective use of IM technologies and ensuring the completion of the tasks they are expected to solve it is essential:

- to design an industrial regulatory framework;
- to dismiss a lot of the software employed and the concept of the “major software package”;
- to rethink production processes, their cost and implementation time.

All in all, information modeling technologies certainly hold a great promise that is delivered provided that a lot of issues are comprehensively addressed and, at the very least, the above measures are implemented. But no matter what technology is chosen to employ, it only remains a tool in the hands of a professional and it is the major task facing the industry to make this tool comprehensible, convenient, productive and efficient.

References

1. Akimova E. M., Kisel' T. N. [The level of use of BIM technologies in Russia]. *Sbornik dokladov uchastnikov Vserossiiskoi nauchno-prakticheskoi konferentsii «Stepanovskie chteniya — 2018: ekonomika i upravlenie v stroitel'stve»* [Proc. "Stepanov Readings — 2018: Economics and management in construction"], 2018, pp. 8—12.

2. Anishchuk N. V. [BIM technologies: advantages and disadvantages]. *Sbornik materialov II Mezhdunarodnoi nauchno-prakticheskoi konferentsii «Innovatsii v informatsionnykh tekhnologiyakh, mashinostroenii i avto-transporte»* [Proc. "Innovations in information technologies, mechanical engineering and motor transport"], 2018, pp. 4—5.
3. Borsuk E. V., Milashevich O. N. [Reconstruction of historical sites using BIM technologies on the example of Durham Cathedral]. *Sbornik statei mezhdunarodnoi nauchnoi konferentsii, posvyashchennoi 50-letiyu Pologotskogo gosudarstvennogo universiteta «Arkhitekturno-stroitel'nyi kompleks: problemy, perspektivy, innovatsii»* [Proc. "Architectural and construction complex: problems, prospects, innovations"], 2018, pp. 8—12.
4. Vorontsova O. V., Shvets Yu. S. [Advantages of BIM technologies in the development of reconstruction projects]. *Sbornik nauchnykh trudov Mezhdunarodnoi nauchno-prakticheskoi konferentsii «Resursoberezhenie i ekologiya stroitel'nykh materialov, izdelii i konstruktivnykh»* [Proc. "Resource conservation and ecology of building materials, products and structures"], 2018, pp. 116—118.
5. Gorbaneva E. P., Byval'tsev K. S. [BIM technologies in the construction industry]. *Sbornik nauchnykh trudov 3-i Mezhdunarodnoi nauchno-prakticheskoi konferentsii molodykh uchenykh, aspirantov, magistrrov i bakalavrov «Proektirovanie i stroitel'stvo»* [Collection of scientific papers of the 3rd International scientific and practical conference of young scientists, postgraduates, masters and bachelors "Design and construction"]. Kursk, 2019, pp. 141—145.
6. Gorbaneva E. P., Sevryukova K. S. [Contribution of information and communication technologies to energy efficiency in the construction sector]. *Sb. nauchn. statei I Vserossiiskoi nauchnoi konferentsii «Informatsionnye tekhnologii v modelirovanii i upravlenii: podkhody, metody, resheniya»* [Proc. "Information technologies in modeling and management: approaches, methods, solutions"]. Tolyatti, 2017, pp. 67—74.
7. Dmitrieva V. V., Davidenko A. Yu. [Organization of building production with the use of BIM technologies]. *Sbornik nauchnykh statei 3-i Mezhdunarodnoi nauchnoi konferentsii perspektivnykh razrabotok molodykh uchenykh «Nauka molodykh — budushchee Rossii»* [Proc. "Young science — the future of Russia"], 2018, pp. 108—111.
8. Zhigulina A. Yu., Marakaev P. E. [Features of implementing BIM technologies in the organization's project activities]. *Sbornik statei «Traditsii i innovatsii v stroitel'stve i arkhitekture. Arkhitektura i dizain, elektronnyi resurs»* [Proc. "Traditions and innovations in construction and architecture. Architecture and design, electronic resource"]. Samara, 2018, pp. 108—112.
9. Makartsova T. N., Firsanova N. V. [Problems of applying BIM technologies in Russia]. *Sbornik statei XII Mezhdunarodnoi nauchno-prakticheskoi konferentsii «Fundamental'nye i prikladnye nauchnye issledovaniya: aktual'nye voprosy, dostizheniya i innovatsii»* [Collection of articles of the XII International scientific and practical conference "Fundamental and applied scientific research: current issues, achievements and innovations"], 2018, pp. 55—57.
10. Klement'eva V. A., Kremcheeva L. R. [Construction project risks and BIM technologies]. *Sbornik statei XX Vserossiiskoi studencheskoi nauchno-prakticheskoi konferentsii Nizhnevartovskogo gosudarstvennogo universiteta* [Collection of articles of the XX all-Russian student scientific and practical conference of Nizhnevartovsk state University], 2018, pp. 64—66.
11. Plotnikov A. D., Kustikova Yu. O. [Promising areas of application of BIM technologies in the operation of buildings and structures]. *Sbornik materialov VI Mezhdunarodnoi nauchnoi konferentsii «Integratsiya,*

partnerstvo i innovatsii v stroitel'noi nauke i obrazovanii» [Proc. "Integration, partnership and innovation in construction science and education"], 2018, pp. 108—111.

12. Sorokin Yu. Bim-tehnologii v infrastrukture: vzveshivaem vse "za" i "protiv" [Bim technologies in infrastructure: weighing the pros and cons]. *SAPR i grafika*, 2017, no. 11 (253), pp. 14—17.

13. Sorokina E.A., Klashanov F.K. BIM-tehnologii — instrument organizatsii rabot na stroitel'noi ploshchadke [BIM technologies-a tool for organizing work on a construction site]. *Ekonomika i predprinimatel'stvo*, 2018, no. 5 (94), pp. 1188—1190.

14. SP 333.1325800.2017 / Informatsionnoe modelirovanie v stroitel'stve. Pravila formirovaniya informatsionnoi modeli ob"ektov na razlichnykh stadiyakh zhiznennogo tsikla [SP 333.1325800.2017 / Information modeling in construction. Rules for creating an information model of objects at various stages of the life cycle].

15. Spravochnik bazovykh tsen na inzhenernye izyskaniya dlya stroitel'stva. Inzhenerno-geodezicheskie izyskaniya [Reference list of basic prices for engineering surveys for construction. Engineering and geodetic surveys]. Moscow, 2004.

16. Utkina V. N., Smolin A. N. [Russian experience in using BIM technologies in construction design]. *Materialy Vserossiiskoi nauchno-tehnicheskoi konferentsii «Dolgovechnost' stroitel'nykh materialov, izdelii i konstruksii»* [Materials of the all-Russian scientific and technical conference "Durability of building materials, products and structures"], 2018.

17. Chesnokova E. A., Khokhlova V. V., Mishchenko A. V. Ekonomicheskaya effektivnost' primeneniya BIM-tehnologii [Cost-effectiveness of using BIM technologies]. *Stroitel'stvo i nedvizhimost'*, 2018, vol. 1, no. 2-1, pp. 71—75.

18. Autodesk (2002). Building Information Modeling. San Rafael, CA, Autodesk, Inc.

19. Matreninsky S. I., Mishchenko V. Ya., Chernyshov E. M. The systemic approach to modeling of compact build-up development areas and planning of their renovation. *International Journal of Energy and Environmental Engineering*, 2015, vol. 6, no. 9, pp. 32—43.

20. Mishchenko V., Gorbaneva E., Ovchinnikova E., Sevryukova K. (2019) Planning the Optimal Sequence for the Inclusion of Energy-Saving Measures in the Process of Overhauling the Housing Stock. In: Murgul V., Pasetti M. (eds.) *International Scientific Conference Energy Management of Municipal Facilities and Sustainable Energy Technologies EMMFT 2018*. EMMFT-2018 2018. *Advances in Intelligent Systems and Computing*, vol. 983. Springer, Cham.

21. Mishchenko V. Ya., Sheina S. G., Gorbaneva E. P. Increase of energy efficiency during overaul of housing stock in Russian Federation. *IOP Conf. Series: Materials Science and Engineering* 481 (2019) 012031, Safety 2018, IOP Publishing, doi:10.1088/1757-899X/481/1/012031.

22. Ruffle S. Architectural design exposed: from computer-aided-drawing to computer-aided-design. *Environments and Planning B: Planning and Design*, 1986, March 7. P. 385—389.

23. Van Nederveen G. A., Tolman F. P. Modelling multiple views on buildings. *Automation in Construction*, 1992, no. 1 (3), pp. 215—24.