Volume 11 • Issue 3 • 2019

sciendo

International Society for Manufacturing, Service and Management Engineering

received: 30 April 2019
accepted: 15 September 2019

pages: 38-47

Integration of digital technologies in the field of construction in the Russian Federation

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ABSTRACT
The article presents the study that mainly focused on the changes made as a result of collaborative innovations in business relationships developed during the period of digitalisation in the construction field of the Russian Federation. It is a conceptual piece of work based on the systematic approach to the analysis, literature review and comparative analysis. The digitalisation of investment and construction projects is technologically based on the integration of solutions, such as the building information model (BIM), high-performance IT-systems, cloud platforms and the Internet-of-Things, resulting in unified and constant connectivity, specialised mobile applications, robotic equipment, unmanned vehicles, additive technologies, AR/VR services for the analysis of Big-Data, and blockchain technologies. The integration of digital technologies is a radical innovation, which highlights collaborative innovations in business relationships and makes it possible to form a united digital ecosystem that allows firms to manage, control and regulate the full lifecycle of a construction project, and then, the property in real-time. The contribution of this work to the construction field is the offered model for the creation of a digital ecosystem and the described role of the government in the model. Also, this work can be used for the integration of BIM technologies in construction companies.

KEY WORDS
digital ecosystem, digital technologies, investment and construction project, BIM technology, collaborative innovation, digital economy

DOI: 10.2478/emj-2019-0019

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Introduction

Today, the emergence of a new technological order is accompanied by the simultaneous development of digital technologies, which contributes to the efficiency of the national and global economy. The main reason to implement digital technologies is the aim to increase the speed of decision-making and the management quality of the main business processes. For example, in the report "Digital Dividends", the World Bank underlines that digital technologies help firms to increase productivity, help people to find jobs and expand opportunities, and help governments to provide better public services to citizens. However, the impact of the use of digital technologies depends on improvements of the business climate, the efficiency of the education and healthcare systems and the existing management practices. These circumstances contribute to changes in roles performed by each participant of economic relations, including the state, in the process of economic transformation (World Development Report, 2016).

In 2017, Russia took action to form and develop the information society at the federal level, within the framework of which, the state programme "Digital Economy of the Russian Federation" was developed. The programme establishes the active role of the state in developing a digital ecosystem, which engages the society in the introduction and use of advanced technologies.

The construction industry is no exception as the latest technologies are already used at all stages of investment and construction projects. Modern technologies — such as information modelling of buildings and structures BIM (Building Information Modeling), Big Data, blockchain, the IoT (Internet of Things), 3D printing, resource-saving technologies, and innovative technologies in new building materials — are widely used in the Russian construction sector. The collaboration between the government and firms plays an important role across different stages of the innovation process.

The article discusses the role played by digitalisation in collaborative innovations that transform business relationships in the construction field, reveals main problems posed by the introduction of modern technologies, analyses possible ways of their use in combination with information modelling, and offers a method for the integration of construction market participants at all implementation stages of a construction project on the basis of a BIM information model.

1. Literature review

Currently, BIM-modelling is the most popular technology in the Russian construction sector. According to the report of NRU MGSU (2016), "BIM is the process of creating and managing information at all stages of the lifecycle of a construction project ("planning" – "design" – "construction" – "operation" – "liquidation")." All participants of investment and construction projects undoubtedly indicate possible advantages of this technology, including multifunctional application, adaptability and flexibility of the model. Such benefits result in the reduction of the number of conflicts and the improved quality of performed work, which reduces the cost and shortens the time required for the implementation of an investment and construction project (Kupriyanovsky et al., 2016).

The state actively facilitates the growing use of BIM-modelling. The Ministry of Construction of the Russian Federation has approved a programme for the introduction of information modelling technology, making it mandatory to use BIM-technologies at the stages of design, construction and operation of a capital construction project funded from the state budget.

Research into the introduction and use of information modelling technologies in Russia revealed the main challenge, which is the lack of official statistical data on the actual number of design, development or construction companies that use the latest technologies in their business. For example, according to the report of NRU MGSU (2016), Russia has about 51 000 project management companies that employ approx. 500 000 designers. This year, more than 100 000 software licenses were sold for the supporting technology of information modelling. However, except for a few dozen of the largest market players, companies rarely declare the use of BIM-modelling and are ready to share practical experience in the implementation of pilot projects. This mostly happens because of an unsuccessful experience with the introduction of BIM-modelling, which occurs due to predictable losses related to implementation as well as unreadiness to absorb such losses. Companies operating in the Russian construction market indicate such barriers as a slowdown in the productivity at the initial stage, the cost increase due to the introduction of such a large-scale technology and the need for organisational restructuring (Talapov, 2015; Kallaur, 2018).

This situation is reinforced by the shortcomings of the regulatory framework and the lack of common national standards for the implementation of construction projects, as well as a common understanding of the lifecycle of a construction project, the shortage of qualified personnel in the labour market, the high cost of software and the need to adapt foreign programmes to Russian conditions (Talapov, 2015; Ginzburg, 2016).

The possibility to use information modelling at all stages of the life cycle of a capital construction project is emphasised by many researchers (Talapov, 2015; Ginzburg, 2016; Churbanov and Shamara, 2018). According to the concept of BIM maturity levels, which was developed by Bew and Richards (2014) to describe the development of information modelling, levels 0–3 can be distinguished, from 2D to iBIM (integrated BIM). The collaboration in the form of information exchange between different parties begins at Level 2, when the General Model is built and analysed using various programmes in one of the main interfaces, such as IFC (Industry Foundation Class) or COBie (Building Information Exchange). Level 3 BIM or an integrated model implies full cooperation between the participants of the investment and construction project and shared access to a centralised repository of the BIM model.

In addition, the concept of "BIM measurement" should be underlined, which is the number of different indicators of the information model. The 3D model is complemented using new information to develop an n-D BIM model (Ginzburg, 2016; Pilyay, 2017). The first important organisational parameter that complements the model is the time factor. A 4D model contains information about calendar planning and a sequence of actions. 4D was the basis for creating a 5D model, which connects economic information, namely, the financial costs at each stage of implementation. Here, YIT company is one of the few examples available on the Russian market (Mironov, 2018). A 6D model includes information "as built." It reflects the already developed property and is intended for the use at the stage of operation. A 7D model allows to manage and control the property with the help of the data transmission system with built-in sensors and "smart" engineering infrastructure.

The literature on technology information modelling and British standards offers two concepts, i.e., AIM (Asset Information Model) and PIM (Project Information Model), distinguishing between the two models already in terms of creating and managing the asset. This division is rather logical as it provokes the creation of the object technical customer, and often manages another person — the operator. A PIM appears at the stages of object creation (planning, design, construction, reconstruction or restoration), while an AIM collects information related to the current maintenance and management of the property (NBS BIM Object Standard, 2016).

Ginzburg has another point of view, and does not divide the model or its functional application but combines everything into one BLC IM (Building Life Cycle Information Modelling) model. One thing remains clear: information modelling can extend to the entire lifecycle of an object. However, in contemporary Russia, BIM-technologies are mostly used at the design stage, less often at the construction stage, and do not reach further lifecycle stages. The development is mainly hindered by divergent interests of participants of the investment and construction project.

As a result, the most successful application of information modelling technologies used for construction projects was among Russian integrated full-cycle companies, which were able to assess BIM benefits at each stage of the project implementation to maximise the economic effect (Kallaur, 2018). Despite this, it is important to note the study (Churbanov and Shamara, 2018), which analyses the impact of the development of information modelling technologies on the relationship between the participants of the investment and construction project. The model of disintegrated procurement, which is the traditional scheme of relations ("design" – "tender" – "construction"), will attract the contractor at an early stage and consider its technological and resource capabilities, as well as contribute to the development of a management contract.

Integration of BIM modelling is radical innovation. Only radical innovation is relevant to the growth of a company, regardless of whether it is developed internally or through collaboration with domestic or foreign partners (Hsieh et al., 2018).

Collaborative ideation is key for innovation. The implementation of suitable appropriability mechanisms during collaborative ideation is a necessary yet difficult task. This difficulty arises from a high level of uncertainty and a low level of codification because partners work on loosely defined concepts that may change during the collaboration. Firms can employ several appropriability mechanisms to protect their knowledge (Gama, 2019).

The model of integrated procurement or an integrated implementation method of the investment and construction project ("Integrated Project Delivery") will be the basis for interaction between designers and builders and the accelerated development of integrated engineering. In the case of both models, it will trigger the formation of a partnership mechanism based on the principles of risk- and responsibility-sharing, and common interests in the success of the project. Thus, a developed ecosystem contributes to increased locational capital wealth and prosperity (Audretsch et al., 2018).

The BIM technology is the basis for digitalisation of investment and construction processes; however, in the Russian Federation, the blockchain technology has become widespread. Blockchain is a database of sequential operating records that are stored in a distributed form on different storage devices and is not bound to a single master server (Ablyazov and Petrov, 2019). As part of an investment and construction project, this technology is most interesting from the financial side of the process, especially in the case of transition to the use of smart contracts between the participants of the investment and construction project. In this case, blockchain provides the security of transactions due to the mandatory encryption and distribution of data storage; exceptional transparency of the process, which is ensured by the general and equal access to the history of transactions of all participants; and acceleration of operations due to the absence of intermediaries. Despite the obvious advantages of blockchain, the spread of this technology in Russia is hampered by the high cost of personnel training and the high-energy consumption of the necessary equipment. However, there have been several pilot projects on the conclusion of contracts regarding shared building-based blockchain, for example, when blockchain was implemented in the process of the conclusion of contracts regarding the shared participation, the technical development of which was performed by specialists from Vnesheconombank (Ablyazov and Petrov, 2019).

The use of the blockchain technology in financial smart contracts acts in synergy with BIM modelling, opening up the possibility to build entire databases of projects, building elements and materials, which could be accessed by any developer, and to which any contractor could connect with its product. At the same time, the results of transactions can be immediately visualised in a BIM model. This feature would solve one of the most important drawbacks of n-D modelling — the lack of data security.

Equally broad opportunities for the construction sector are offered by the augmented (AR — Augmented Reality) and virtual (VR — Virtual Reality) realities. The first is rather firmly established in the field of interior design. The most promising application of virtual reality is the ability to review a 3D-BIM project. VR solutions allow to quickly digitise a BIM model for an interactive experience, making it possible to travel inside an object that has not yet been built, for example, using the Virtuix Omni platform. This is convenient for the demonstration of the future project to the customer, as done by the American company BIM-CAVE, and in other cases. During the construction stage, it becomes possible to track the progress of the project remotely, using unmanned aerial vehicles with photographic and laser equipment. This allows avoiding mistakes in the design of the object by analysing it structurally and visually in the context of the future landscape, and during the construction of the project. The main disadvantage of this technology, of course, is the price. Even though the ability to demonstrate the model to the customer does not require significant investments, the developer will face large-scale costs in terms of the management of remote monitoring of the construction progress (Obodnikovy et al., 2018).

In Russia, big data analytics is often used in project management systems and in the analysis of the sales market, as well as in the further management and operation of the finished property, although it is possible to use it very effectively in the implementation of construction and installation works. Firstly, this technology contributes to the adoption of more effective management decisions at all stages of an investment and construction project, and secondly, it allows optimising the design and construction processes, thereby reducing project costs. In the future, the use of big data in conjunction with information modelling will be used in the analysis of a complex generalised information model of the living environment, such as Living Environment Information Modeling, aimed at solving problems related to urban planning (Ginzburg, 2016).

One of the most promising technologies is the Internet of Things, which is a fully automated network of wirelessly connected devices and systems. Due to the IoT, monitoring and timely repair of construction equipment, management of material and technical supply of construction production, energy-saving and safety at the construction site are possible at the construction stage. At the stage of operation of the property, sensors can detect technical defects to warn about the occurrence of pre-emergency situations in communication systems etc. The obvious advantage of using the IoT is cost reduction, but the practical introduction and full-featured application of this technology is a time-consuming and expensive process. Besides, cybersecurity and physical security of sensors are issues of concern at all times. Currently, the IoT in Russia has only become widespread at the stage of real estate operation, and it is used together with resource-saving technologies. One example of such resource-saving technologies is the management system "Smart House", which is a single system of a building operating on the basis of sensors, control elements and actuators and combining power supply, security, heating, ventilation, water supply etc. The use of resource-saving technologies can meet the domestic needs of real-estate users and significantly reduce operating costs. However, these technologies have not been properly developed in Russia, and the number of equipped buildings is no greater than 0.1%, which is due to the low awareness of the population and, often, high implementation costs.

According to the Analytical Report by J'son & Partners Consulting (2019), IoT platforms can be divided into three types:

- analytical platforms and applications that optimise the consumption of resources and modes of operation of equipment/systems used in buildings and structures;
- IoT-platforms and cloud applications that not only undertake the functional analysis and recommendations regarding the optimal modes of operation of the equipment but also have a control loop (BMS/BAS (Building Management Systems / Building Automation Systems) and BEMS (Building Energy Management Systems));
- computer-aided design systems that implement the concept of 7DBIM, which not only covers the design and construction stages of the building, but also the stage of its operation, and, thus, intersects with the cloud BMS/BAS/BEMS. In the future, the synchronisation of BIM with this technology will carry out the practical implementation of the transition to the sixth or seventh dimension of the BIM model due to the possibility to obtain a continuous flow of data from both the building under construction and the operated building. Data collection through advanced technologies — such as photo-video recording, laser scanning, embedding sensors and transmission devices in the construction equipment, drones, etc. — allow the creation of a real digital copy (digital twin) of the object under construction for the transition from the configuration of the model "as-designed" to "as-built".

3D printing is a method of construction of building structures, which is based on the layer-by-layer build-up of a part by the print head. Printing in the construction process can be used in two ways. The first method involves printing directly at the construction site, with the printer available on-site. The second method is to print separate blocks under factory conditions, and then transport them to the construction site. The use of 3D printing provides productivity growth, reducing labour intensity, increasing the speed of production, and reducing the cost of construction. The 3D printing market in Russia has been growing at a steady pace over the past eight years (in quantitative terms, it has grown ten times), but according to the Analytical Report by J'son & Partners Consulting (2019), Russia's share in the global 3D printing market is only 1.5%. To stimulate the development of 3D printing, competence centres are being established, and national standards are under preparation. The "Comprehensive action plan for the development and implementation of additive technologies in the Russian Federation for the period 2018-2025" has been developed with the aim to consolidate the efforts of Russian scientists and developers of additive production facilities.

The relationship between 3D printing and BIM modelling is especially important at the design stage of a building. Before starting with 3D printing, a 3D model must be created, which is most often made using specialised software. At the same time, the creation of a BIM model permits to determine specific physical properties of different components as well as set more information parameters of a manufacturing technology, which make the design process more flexible and transparent. In the early stages of planning, 3D printing can significantly improve the manufacturing efficiency of building of structures (Ignatova and Utkin, 2019).

2. Research methods

The conceptual design of the study was based on theories that analyse the transformation and integration processes in the national and global economy, in various economic sectors in general and in the construction sector in particular. The focus was placed on the mechanism used for the improvement of the construction sector efficiency on the basis of the integration of its participants. Therefore, the authors considered the theory of inter-organisational interaction and marketing relations from the point of view of the traditional market as well as the transformation of the economy due to the development of digital technologies. The study was conducted on the basis of a systematic approach to the analysis of the problems of construction development.

The unique feature of the article is the analysis of the results derived from own research of construction companies operating on the territory of St. Petersburg and the Leningrad Oblast. The obtained research data, in contrast to the data of official statistics, consider the specifics of informal relations established due to the interaction of participants in the construction market. It is a conceptual work, which captures the complexity of integrating digital technologies in a business process, linkages in relationships of firms, their basic principles and preconditions, which determine the basic concepts and arguments.

3. Research results

As a scientific concept, relationship marketing describes the formation of long-term relationships with customers and partners, which requires the company to improve business practices to maximise the value of these relationships to the client. Neither the theory of inter-organisational relations (Oliver, 1990) as a scientific methodology nor the concept of relationship marketing (Zieliński, 2013) is new. At the same time, under the conditions of digitalisation, these relations acquire a special status and organisational design. Hence, more detailed consideration is required in terms of the changing role of organisations in the digitalisation of the economy and with the view of collaborative innovation in business relationships. The efficiency of the organisation is achieved by reducing costs resulting from the automation of basic business processes, including at the production level. As a field of material production, construction is a rather complex area of activity. Thus, the implementation of a construction project of a residential building may involve 70 organisations from the beginning of its design to commissioning. Such a great number of participants results in the complex coordination of their activities and in the optimisation of construction project management solutions. In this regard, the digitalisation of the construction field is undoubtedly objectively necessary. According to the study of the effectiveness of BIM-technologies in Russian organisations, the digitalisation of projects contributes to a 25% increase in the net discounted income; the growth of the profitability index to 14–15%; a 20% increase in the internal rate of return; the crushing of the payback period of the project to 17%; and a 30% reduction in the project costs associated with cost reductions at the production stage. Describing the effectiveness presented in the framework of the concept of "relationship marketing", both business partners and consumers of goods and services of construction organisations receive the benefits of digitalisation. Brought together in a single information space, construction project participants create a single concept of the future product. This helps to minimise losses that could be incurred by each participant in relation to the coordination of project details, teamwork, a common vision of the project goals, the possibility of implementing innovative solutions etc. The same positive findings have been demonstrated in construction markets of the UK, Canada, the USA and a number of European countries. Despite various positive aspects noted by construction sector participants, they all boil down to the fact that the formation of relations within the project is based on a mutual benefit (reciprocity) (Assessment of the use of BIM-technologies in construction. The results of the study of the effectiveness of BIM-technologies in investment and construction projects of Russian companies).

BIM-modelling technology is gaining popularity among developers in Russia due to economic efficiency and the possibility of combining it with other software products. The technological basis for the digitalisation of the investment and construction process is the integration of BIM, high-performance IT-systems, cloud platforms and IoT solutions that provide unified and constant connectivity, specialised mobile applications, robotic equipment, unmanned vehicles, additive technologies, AR/VR, services for the analysis of Big Data, and blockchain technologies. Such integration makes it possible to form a united digital ecosystem that allows managing, controlling and regulating the full lifecycle of the construction project, and then, the property in real-time. The synergistic effect can be achieved only by ensuring the compatibility and interaction of technological solutions with the possibility of seamless data exchange, storage, synchronisation and access in real-time (Analytical Report of J'son & Partners Consulting, 2019).

The first prerequisites for the creation of a united digital ecosystem at the state level are replenishing banks of normative-technical and methodological documentation, standard forms of contracts for all participants of the investment and construction project; state information and analytical systems — sources of information about land plots, prices, contract tenders etc. This will form the basis of state requirements and standards for the implementation of BIM modelling at all stages and will ensure timely accounting for changing environmental conditions (Churbanov and Shamara, 2018).

The unified digital ecosystem based on the information model will not only allow the use of all kinds of automated tools but also provide regulated access to data about the object to all stakeholders of the investment and construction project (Analytical Report of J'son & Partners Consulting, 2019).

In general, a BIM model can be represented as a tree, the branches of which are auxiliary technologies. Thus, the use of a BIM-model to bring together the participants of an investment and construction project makes it possible to connect the described technologies — Big Data, blockchain, IoT and 3D-printing — at each section of the project path. During the initial planning of the project, at the stage of acquisition of the site for construction, it is possible to use deep Big Data analysis to identify the needs of potential customers as well as to search among thousands of options for the optimal project. This results in the most acceptable information and analytical system, such as a BIM model of an investment and construction project. Then, the model can be used together with the blockchain technology for the conclusion of contracts and the procurement of construction materials. During construction works, the BIM model is connected to the Internet of Things, allowing the use of various technical means, such as sensors, to monitor the optimal progress of the construction process, adjusting the project in accordance with real-time indications and even for compliance with safety regulations. At the same time, virtual reality technology can be used for greater clarity, allowing to visually inspect the model of the object under construction. It is at this stage that the transition to the as-built (6D-BIM) model occurs at the expense of IoT platforms from the original as-designed model. At the same time, before or during the construction phase, based on the parameters of the BIM model, it is possible to use the 3D printing technology, both for the construction of the capital construction project as a whole or for its individual blocks. Finally, when the investment and construction project is finished, and the stage of operation starts, the IoT technology is used for the optimal implementation of energy-saving technologies. At the same time, using BIM-modelling as the basis of the investment and construction project, all participants can have access to the full picture at each stage of the project, and refer to a single standard of digital interaction. Fig. 1 presents the model for the creation of a digital ecosystem in the field of construction.

It should be noted that this model could function only subject to certain conditions, including the developed norms and standards, an implemented mechanism of state control, and the availability of technical solutions and software as well as qualified specialists to all participants.

In the Report on the World Development 2016 "Digital Dividends", the World Bank observed that the digital revolution could generate new, consumer-friendly business models but not when established companies control the entry process; and technology can improve the productivity of workers but not when they lack the skills and knowledge to use it (World Development Report, 2016).

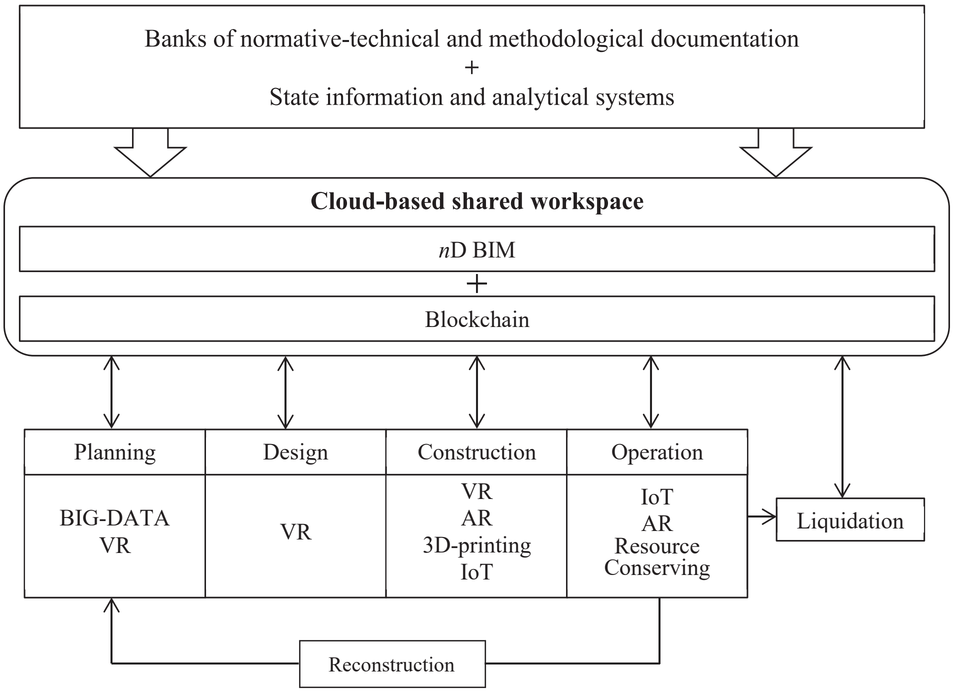

Fig. 1. Model for the creation of a digital ecosystem in the field of construction

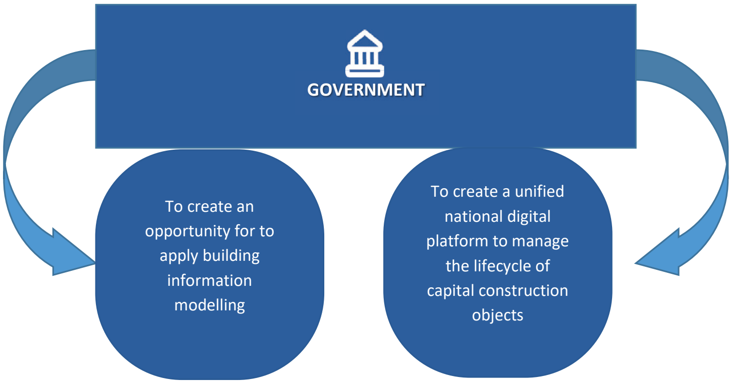

Fig. 2. Role of the government in the creation of a digital ecosystem in the field of Construction

The analysis of labour resources in the construction market of St. Petersburg and the Leningrad Oblast revealed that the greatest shortage of skilled workers was observed in the following positions: masons, concrete workers, installers of engineering networks, engineers of technical training, estimate and contract departments, and designers. In addition, there was a serious lack of construction line managers, primarily, skilled supervisors. These problems in the construction sector stemmed from the economic crisis of the 1990s when a significant outflow of qualified personnel occurred from the construction sector to other industries.

In addition, vacancies attract labour migrants from Central Asia, who do not have the necessary skills to build complex facilities. These circumstances result in high levels of manual labour. American architect Daniel Libeskind refused to hire the local labour force for the construction works of his buildings in China, basing the argument on the lack of skills required to master the complex innovations used in the construction sector.

With the view of the economic transformation, the most urgent priority for the development of the construction sector is the optimisation of labour resources in accordance with the changing conditions of the external and internal environments. The labour productivity of the Russian construction sector is low compared to other countries, which is largely due to the use of outdated management and production technologies that use high proportions of unskilled labour. The solution to this issue fundamentally requires to develop a system for the training of management personnel that meets the requirements of international and domestic professional standards.

The intensification of construction production requires the initiation and implementation of innovative processes and the structural adjustment for digitalisation on the scale of an organisation, the industry and the country. At the same time, the basis for the reorganisation of the construction sector should be a comprehensive programme aimed at the strategic planning and development of digital technologies that can ensure the coordination of undertaken tasks. Programme documents should aim to design and organise the mechanism for technological development of the construction sector. The mechanism should be based on the introduction of BIM technologies, which should aim to improve productivity. Ultimately, these efforts should contribute to the implementation of a governmental programme for the creation of high-performance jobs.

The role of the state as a framework for the digital economy is important.

The feasibility to integrate this model into real business life depends on a high level of collaboration between partners. All participants need to overcome barriers and become actively involved in the process of communication. The innovative actors need to develop "supportive structures" which would be helpful in the process of integration of BIM technologies. Once started, the process of collaborative innovations will transform business relationships.

4. Discussion of the results

The BIM model becomes an ideal candidate for the role of the root technology, into which other technical means are integrated. Combining of advanced digital technologies on the basis of BIM modelling into a single digital ecosystem will reduce fragmentation in the use of various technological solutions and create conditions for a coherent, unified and continuous investment as well as a construction process, which includes all participants at all stages of the object's lifecycle. In addition, the level of adaptability of the model to external changes increases, which leads to a reduction in the cost of the project.

The widespread use of the BIM technology for the entire lifecycle of a construction project entails the modernisation of the investment and construction process as a unit. This may lead to a change in the traditional disintegrated model of interaction between the participants of the investment and construction project to a partnership based on the information model of the facility, which allows concluding multilateral partnership agreements as opposed to bilateral contracts.

Conclusions

The implementation of digital technologies increases the speed of decision-making and improves the quality of management of main business processes. The integration of technologies — such as BIM, high-performance IT-systems, cloud platforms and IoT solutions, specialised mobile applications, robotic equipment, unmanned vehicles, additive technologies, Big-Data and blockchain — is the basis for the digitalisation of the investment and construction process. The digitalisation of this sector is undoubtedly objectively necessary. Digital technologies create an opportunity to develop a digital ecosystem in the field of construction, which leads to collaborative innovation in business relationships.

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