Innovative technologies in construction: international experience and problems of incorporation in Russia

IOP Conf. Series: Materials Science and Engineering **497** (2019) 012004 doi:10.1088/1757-899X/497/1/012004

Innovative technologies in construction: international experience and problems of incorporation in Russia

Veronika Asaul [1]* **and Elena Pesotskaya** [2]

[1] Saint Petersburg State University of Architecture and Civil Engineering, Vtoraja Krasnoarmejskaja ul., 4, St. Petersburg, 190005, Russia
[2] Saint Petersburg State University of Economics, Sadovaya st., 21, St. Petersburg, 191023, Russia

* E-mail: asaul@inbox.ru

Abstract. The importance of incorporating innovations in construction under modern economic conditions has been substantiated in the article. The author has explored the main scientific approaches to determining construction operations and specific features of the constituent components thereof. The key problems of the construction sphere, which demand application of technological innovations, have been classified. Consideration has been given to peculiarities and key aspects of incorporating innovations in construction in accordance with designated problems with the aim of increasing efficiency of the production process. Essential innovative solutions applicable to the practices of construction activity abroad and in Russia in accordance with the stages of implementation of the investment and construction project have been analyzed. Investigation of basic advantages and risks of incorporating innovations in construction has been carried out. The author has articulated major proposals aimed at solving revealed problems of the construction sphere by means of innovative technologies. The problems obstructing incorporation of up-to-date innovative technologies in construction have been explored and the ways of solving thereof have been proposed.

1. Introduction

Improvement of the production process in construction sphere due to incorporation of innovative technologies becomes a burning need under conditions of stiffening competitive environment of the construction business, complication of investment relations in Russia and increasing requirements to the quality of construction produce.

The relevance of incorporating innovations in construction is substantiated by the increased demand for the real estate objects and, accordingly, by the growth of construction volumes, necessity of acceleration of putting objects into operation, minimization of cost of construction and installation operations and provision of the most efficient use of resources. At that, the build-up of volumes of the construction operations shall be provided in an intensive way.

The formation of an efficient strategy of development of the construction sphere, acceleration of implementation of investment and construction projects, increasing effectiveness and transparency of interaction of participants of the investment and construction market demand construction transfer to the whole new level due to intensification of production processes, reduction of the prime cost of construction operations and optimization of utilization of material and technical, financial and labor

resources. The specified problems may be solved through incorporation of up-to-date innovative technologies into construction.

According to the scientific economical literature the intensification of production is a process of development of public production based on the achievements of scientific and technical progress aimed at the efficient and sustainable use of all types of resources [1]. The scientific and technical progress is a driver of both production intensification and introduction of innovations [1].

The introduction of innovations is the priority task of the construction sphere development at the state level. In order to do so, different programs have been developed, which are aimed at activation of introduction of innovative solutions, and which make it possible to fundamentally improve the production process [2] [3]. At that, the innovations in the construction sphere may be of technological character, consisting in building and introducing products with the new consumer properties: materials, structures; the innovations may be of organizational and managerial character fundamentally increasing the efficiency of construction operations.

The introduction of innovative technologies will be effected at all life cycle stages of the investment and construction projects: at the stage of designing, fabrication of construction materials and structures; at the stage of construction and installation operations; during operation of capital construction object.

2. Up-to-date innovative technologies in construction

The construction operations are understood as a complex of interrelated construction and installation operations and processes intended for building and renovation of the fixed assets. The main production operations in construction include erection of new buildings and structures, expansion, reconstruction, technical upgrading and repair of operating enterprises, buildings and structures. The organization of construction operations is an interrelated system of planning and implementation of types of construction and installation operations, determining sequence, stages and time limits of work fulfillment, provision with resources for efficient and high-grade process of construction of facilities. The main components of production process in construction include material and technical supply, drawing up design specifications and estimates, design, architectural designing of real estate object, carrying out of construction and installation operations, handing over object and its further operation. Proceeding from the experience of foreign countries, it is possible to distinguish the key problems of construction operations, which can be solved due to innovative tools and digital technologies:

1. High prime cost of construction operations, inefficient use of resources by the construction sphere enterprises due to outdated technologies of construction operations and labor organization, which brings about low quality of construction products and low efficiency of construction operations;
2. Lengthy periods of implementing investment and construction projects and failure to abide by the deadlines;
3. Inefficient energy consumption by the capital construction objects at the stage of operating thereof due to outdated construction materials and technologies.

The solution of specified problems required application of up-to-date innovative technologies in construction. The innovative technologies in the construction operations are aimed at the solution of the entire number of missions increasing efficiency of the production process and quality of capital construction objects, namely: saving resources, reducing construction and installation time, environmental friendliness, aesthetics of constructed facilities, durability, adaptability, versatility, comfort and many others [4].

1. The solution of problems of *low efficiency of construction operations and its overestimated prime cost* due to outdated technologies is possible through application of innovative construction materials at all stages of construction and installation operations. The use of innovations in the construction and installation operations is also promising.

Nanotechnologies are successfully used today in manufacturing construction materials, they help to change the standard properties thereof, improve quality and structure [5, 6]. About 20% of the

construction companies in Japan, USA, China and countries of Europe use materials based on nanotechnologies.

For instance, high-strength and endurable concrete is produced with the use of ultra-disperse nanoparticles. The useful life of such material equals to about 500 years, which makes it possible to use it in the defense industry, construction of bridges, high-rise buildings and other strategic infrastructure facilities. High-strength nanosteel is used in the construction of hydro engineering and road facilities. The useful life of construction structures can be extended owing to polymer and composite nano-coatings, which enhance corrosive stability of these structures.

Water-resistant varnishes, paints, mixtures for finishing premises, heat-insulating materials and other "nanomaterials" are also manufactured on the basis of nanotechnologies. The structural composites are the materials with metal, ceramic or polymer matrix, e.g., carbon fiber composite.

The Chinese experts have developed water-resistant nanomaterial. The construction of big national theater in Beijing can be referred to as an example of its application, where a dome of glass has been coated with nanomaterial for protection against moisture and contamination. The useful life of capital construction objects with the use of nanotechnologies equals about 400 years [7].

An important direction for increasing efficiency of construction operations is also the development of innovative technologies at the stage of construction and installation operations.

3D technologies and 3D material are the most promising innovations at this stage. The engineers from all over the world compete in building 3D printers for placement of construction mixtures, while the projects erected by means of 3D printing vary from small edifices to multi-storied blocks [8]. For instance, the Chinese company Winsun has increased productivity and made it possible to implement a significant cost saving by using technology of 3D printing. Now it is possible to build a standard block costing 30,000 dollars [8].

The construction 3D printer works on the basis of technology, where every new layer of construction material is extruded from the printer over a previous layer along a contour specified by the program raising up the walls of the building. Such a technology is referred to as FDM (Fused Deposition Modeling – modeling by means of thread deposition method). At this stage the programs for 3D modeling, such as SketchUp, FreeCAD, Blender, OpenSCAD, Rhinoceros have been developed [8]. The fast-curing powder concrete reinforced with steel or polymer microfiber is used as the construction material for erection of load-bearing elements of the structure [8].

The use of 3D technologies in construction has a very promising character [8]. In particular, Winsun can considerably increase the rate of construction by means of printing walls at the factory prior to assembling building at the site. The new buildings can be erected now by adding one storey a day, which is much quicker than in the traditional construction. For instance, construction of the double-storey house with the area of 1,100 sq. m has taken 3 days with the engagement of three workers only. Winsun technology is more eco-friendly that the traditional reinforced concrete. Construction waste can equal 50% of material according to the closed-cycle concept. Winsun printing process minimizes the amount of waste in the process of construction making it possible to save 30–60% of materials as compared with the traditional construction. This technology is promising for the countries with high expenditures for manpower and environmental standards. It can reduce demand for the skilled workers and increase the quality and accuracy of the construction product. Winsun technology also makes it possible to select any design of the building [9].

2. One of the major problems of the construction sphere are the *long periods of implementation of the investment and construction projects and failure to abide by the assigned deadlines, which leads to the reduction of efficiency of construction operations*. The specified problems may be solved through innovative digital technologies making it possible to accelerate construction at the stage of construction and installation operations, as well as designing of buildings.

The innovative technologies at the stage of designing help increase efficiency of the process of building design development with the use of up-to-date digital technologies. In particular, the technology of building information modeling (BIM) is to be considered as one of the most successful innovative technologies of designing used to date. This technology helps build one or several exact

virtual digital models of the building. Owing to BIM application the process of designing becomes significantly simpler at all its stages as well as becomes more thorough due to real-time analysis and monitoring. The final variant of the object digital model comprises an exact geometry of the structure and all necessary data for procuring materials, manufacturing structures and execution of construction work [10]. The main information that passes through BIM and is of direct relevance to it is shown in figure 1.

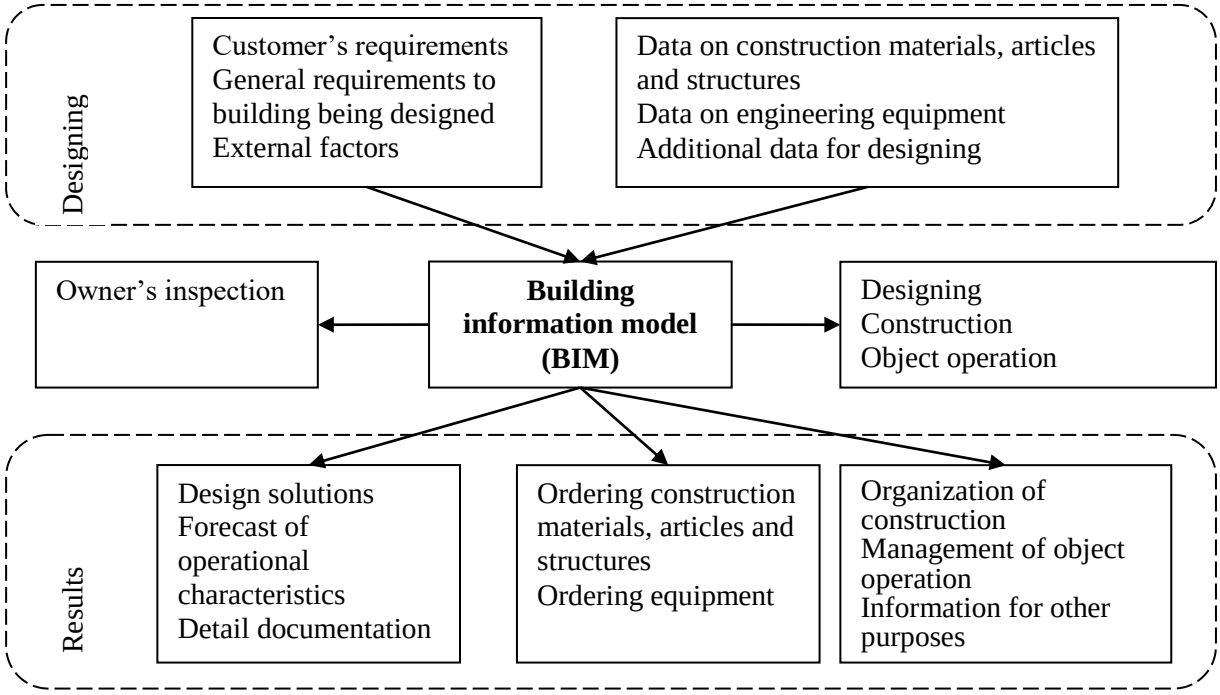

Figure 1. Building information model (BIM) [12].

Due to use of BIM technology the participants of the investment and construction project are able to reveal and eliminate errors of the traditional 2D designing; improve lines of communication between a project manager and designers; reduce the number of project modifications; reduce the estimated construction cost; monitor costs more accurately online; accelerate construction [11, 12].

3. The problems of *inefficient energy consumption at the stage of operating objects of capital construction* can be solved by using innovative construction materials intended to increase energy saving.

The use of nanotechnologies in energy saving is also promising.

A semi-transparent coating accumulating solar energy has been invented in the Shanghai Center of Science and Technology. This coating can be applied to the walls of the buildings, windows and doors, at that, electric power saving is attained [2].

A transparent nanogel (aerogel) with the increased heat- and sound insulation to be used in the energy-saving roofing systems was invented in the early 21st century in Stockton (California, USA).

Cool-Colors coating protects window structures against heat effect. This coating reflects about 80% of infrared rays due to a specific pigment preventing structure overheating. The colored window can be heated up to +50°C at temperature of +25°C. In case of protecting premises against overheating and protecting windows against exposure to sun the expenditures for air conditioning get reduced, while a useful life of structures increases [7].

3. Contemporary Russia: barriers on the way of innovative technologies and methods of overcoming barriers

The basic problem of the domestic construction sphere is a technological underdevelopment of construction operations, the use of obsolete technologies of the construction operations and labor organization. It results in the reduced efficiency of management of material and technical resources in the course of construction and installation operations, violation of safety precautions, due dates of putting objects into operation. The insufficiency of innovative technologies is felt particularly keenly under present-day conditions of severization of requirements to the quality of real-estate objects. This situation is dramatized by high prime cost of construction, low quality of construction produce and low efficiency of construction operations. A number of problems related to the resource saving can be also encountered at the stage of real-estate objects operation.

1. In order to solve the specified problems at the stage of designing, some big Russian construction companies have begun to incorporate technologies of information modeling. The difficulties with application of BIM technology consist in the resistance of design organizations to innovative changes in the system of designing buildings and structures, as well as in the shortage of knowledge and personnel able to work with BIM, since this technology is not taught at higher educational institutions. The cost of incorporation is quite high for a majority of construction companies, since the software, expenditures for personnel training and consulting support are costly. At the same time, at the initial stages of implementation, staff productivity decreases. BIM software also needs improvement so far, since the design documentation is not always compliant with the existing standards.

2. The obsolete technologies are the essential *problems related to inefficient organization of construction operations* in Russia. However, a trend has emerged currently to step-by-step solution of these problems in practice.

The technological innovations making it possible to minimize negative effect of the external factors and severe environment at the construction sites are efficient at the stage of construction and installation operations. The challenging engineering-geological and hydrological conditions as well as geological processes emerge time and again at the construction sites or in the territories adjacent thereto in the course of developing territories for construction of infrastructure facilities (road-transport, railway, hydro engineering, oil-and-gas) [2]. In order to minimize the influence of geological and engineering-geological phenomena on the pavement surfacing in service, it is necessary to use the innovative technical solutions, which help improve the quality of the used substructures for construction of infrastructure facilities. Both the traditional technologies for strengthening and reinforcing substructures (replacement, soil compaction, piling systems, etc.), and the up-to-date ones: utilization of geosynthetic materials on the basis of high-strength raw materials are used for this purpose [13]. The geosynthetic materials are used in construction, reconstruction as well as repair of motor roads in Russia. They feature high strength, chemical resistance, low material content, low weight, longevity (operation period thereof extends up to 100 years), resistant to high temperatures.

The geosynthetics fulfills such functions as reinforcement, drainage, protection and strengthening of the road structures [13]. The application of geosynthetic materials makes it possible to improve quality of the construction work; reduce the volumes of used materials, time limits and expenditures for roads construction; extent periods between repairs; increase durability of road pavements; reduce wheel tracking formation. Currently the investigations and developments of geosynthetic materials are aimed at the assessment of properties thereof in case of prolonged exposure to those or the other environments, e.g., in soil.

The incorporation of innovations in the road construction is possible due to use of colored bitumen-concrete mixtures. The colored bitumen is identical with respect to composition to the classical grey variant of pavement surfacing, and it is also fabricated using the basic production processes. The difference of the colored surfacing consists only in the addition of a filling agent for imparting a definite color: yellow, red, brown, green, violet and orange, providing an additional attractiveness for consumers. Following the process of fabrication the colored bitumen can be applied onto usual

bituminous concrete in a thin layer (less than 1 cm); laid in the form of in situ blocks into cavities specifically cut in the existing pavement surfacing for highways striping; cast in the form of hot solution into prepared shallow cavities. The advantage of bitumen surfacing is its specific strength, versatility of application and a relatively low price, while the disadvantages include its high toxicity, bitumen starts melting at high temperatures emitting poisonous vapors; bitumen placement also needs knowledge, experience and special tools.

The nanocomposite pipes have been developed in Russia, which operating characteristics significantly exceed the analogs; therefore, they can be used in the systems of heating, gas- and water supply. The new pipes are also quite cheap [11]. Thus, they just begin to use the innovative developments in the field of nanotechnologies in the construction operations. The new types of pipes, concrete, steel, innovative coatings, nanofilms for transparent structures – all innovative solutions are promising for utilization.

One more innovative line of development of construction operations is the arrangement of roofing, which characteristics (reliability, longevity, aesthetic qualities and other) influence significantly the quality of objects being built. The multilayered tile, the up-to-date roof covering, the so-called "flexible roofing" is used as the innovative material. It is safer, more dependable and aesthetic as compared with the traditional (single-layer) flexible tile [15].

The innovativeness of multilayered tile consists in the fact that the individual single-layer tile shingles get firmly adhered to each other during production of this material, at that, the upper layers feature a different cutting shape, which helps to get a new bulk-structure material with preservation of reliability and water-proofing parameters. The multilayered tile is entirely resistant to wind rushes and exposure to water, which increases moisture resistance and longevity of the roof [15].

3. A problem of *inefficient energy consumption by the commissioned real-estate objects* is relevant for the domestic construction sphere. The innovative technologies acquire a special relevance at the stage of operation. The construction produce furnished with novelties becomes a subject of physical wear and gets gradually obsolete at the stage of operation. Those novelties that have been relevant in due time, need replacement in accordance with the new demands, while under market conditions these demands and the methods of satisfying thereof can be distributed in quite a wide range. In this case what it involves is the use of up-to-date innovative (from the point of view of eco-friendliness, aesthetic qualities, safety, efficient performance, dependability and other indices) construction materials and technologies used in the course of current and major repairs of buildings and structures, and the equipment of objects under consideration with fundamentally new technical facilities making the operation thereof easier.

This can be exemplified by the use of resource-saving technologies (saving water, electric energy, man-hours in the process of operation), ecologically sound materials as well as installation of automated systems of "Smart home" buildings control, which are commonly referred to for the moment as "green technologies".

The use of "green technologies" makes it possible to optimally satisfy the household requirements of the real estate users and reduce to operational costs. For instance, it is possible to optimize the costs of electric energy used in the building for different needs by means of installation of solar cell panels or special wind-driven devices on the roofs of houses. In case of shortage of water it is possible to use systems collecting rainwater for watering plants at the territory adjoining the house or for the other needs of house tenants [16].

The "green technologies" are used in Russia more and more frequently in construction operations, however, the share of this type of innovations increases insignificantly. The international experience testifies to the fact that, e.g., the construction of houses with the use of "green technologies" increases 2 times per annum in China, while the annual increase amounts to about 20% in the USA. At that, the number of finished objects in Russia equals tens of units only [16].

The automated systems of "Smart home" building control correspond to the systems of dispatch control of the building utilities (power supply, heating, ventilation, air conditioning, telephony, lighting, security system, water supply system, IT-infrastructure, process equipment and processes).

The use thereof makes it possible to save energy, create comfortable conditions for staying in the building, provide safety, effect monitoring and control of the processes, quickly find and eliminate troubles in the engineering subsystems of the building.

The use of the reviewed innovations in the construction operations increases the cost of the object. So, the cost of the building built with the use of "green technologies" exceeds the cost of the building of traditional construction by 10–15% [17, 18]. Though, the expenditures for the object maintenance and operation become lower in this case. In particular, the installation of automated systems of "Smart home" control helps reduce: expenditures for energy saving – by 30%, heat- and water supply – by 20%; expenditures for salary of the attending personnel –by 60%; expenditures for repairs or replacement of operational equipment – by 50%. These indicators are attained due to use of environmentally clean materials as well as keeping utilities in good condition and extending useful life due to automation and dispatching control departments [19].

The innovative technologies in construction make it possible to stimulate the economic growth of the state owing to the use of hi-tech means of production and technologies. More efficient construction machines and mechanisms, production of high-performance eco-friendly construction materials, articles and structures are the present-day developments, which application increases quality characteristics of the construction produce and minimizes expenditures for construction operations.

The following can be attributed to the basic problems impeding incorporation of innovative developments and technologies in construction operations of Russia:

– significant part of using import construction materials and insignificant share of domestic manufacture, in particular, of roofing and finishing materials, façade systems, glass, fittings, high-grade heat-insulating materials;

– deficit of skilled personnel in the construction sphere due to deterioration of quality of industry-specific education, reduction of universities faculty resulting in insufficient development and use of innovative technologies in the projects;

– insufficient government support to science and technologies in the construction sphere for its intensive development, stimulation of energy saving, stimulation of using innovative developments and technologies, nanomaterials, up-to-date equipment.

The main problem in the course of incorporating innovations in construction in Russia is the absence of consistency, as well as insufficient efficiency of the used organizational solutions. In this regard incorporation of innovations is fragmented rather in practice and the effect will not be attained in full.

The solution of specified problems in Russia requires development and implementation of a complex program of incorporating technological and organizational innovations in construction with the system of indicator of social and economic effectiveness. It is also necessary to provide training on innovations in the construction universities. It is reasonable to offer the following advanced lines of innovative development of construction operations:

– improvement of regulatory and legal framework and particular managerial solutions in the construction sphere aimed at promoting development of innovations and innovative management in construction;

– stimulation of introduction of innovations in designing, organization and carrying out construction and installation operations, operation of buildings at the legislative level;

– stimulation of development of market of energy-efficient technologies and technologies involving low energy intensity, use of innovative materials with high operational and consumer properties;

– legislative support of transition to mass construction of autonomous and income-generating accommodation with the use of renewable energy sources and "green technologies";

– improvement of institutional relations in the construction industry, prompt incorporation of managerial innovations based on the advanced global experience;

– incorporation of innovative developments into designing of construction equipment more efficient and cost-effective from the point of view of construction operations and operation of mechanisms, acceleration of implementing investment and construction projects;

– involvement of skilled blue-collar and white-collar personnel of construction discipline to the industry.

4. Conclusions

The complex approach to incorporating innovations in the construction sphere is aimed at increasing operational characteristics of capital construction objects due to attainment of synergizing effect from the use of technological and organizational innovations.

The innovations in the construction operations are aimed at increasing efficiency and stability of the construction sphere due to using new improved technical facilities, technologies, materials and manufacturing methods in the production process that are fundamentally different from the traditional organization and technological solutions used earlier.

The construction requires incorporation of technological innovations, at that, in Russia this process significantly lags behind the world trends. The main components of the process of construction operations (construction materials, method of production process organization and management) have gained a considerable traction in the recent years. The development and incorporation of innovative materials and technologies into construction sphere are promising due to physical and chemical properties thereof as well as a necessity of ensuring efficient use of resources, abiding by the requirements of state regulatory authorities to environmental safety and energy efficiency of infrastructure facilities and residential buildings.

The incorporation of innovative technologies or materials in the construction operations makes it possible to reduce manufacturing expenses, minimize expenditures for operation of capital construction object, increase energy efficiency of the building, useful life of construction materials and structures and the entire object, improve environmental content without any detriment to the main performance properties of materials and capital construction objects.

The development of innovative technologies depends first of all on the state and prospects for science development. Construction is a science-intensive sphere utilizing digital technologies in designing buildings, structures and in the course of construction and installation operations. The innovative construction development requires support and provision of national economy development. Thus, the prospects of improvement of scientific and technical progress in Russia in the construction sphere require closer attention on the part of the state. It is necessary to develop the programs of science development, financing, involvement of venture capital for conducting research activities. The innovative developments shall be inextricably linked with practice, which produces a social and economic effect.

References

[1] Pavlov K V 2017 *Chasopic Ekonomichnykh Reform* **2** 24–32

[2] Kaverzina L A and Rodivonova E V 2017 *Role of Contemporary Science in the Development of Innovative Technologies in Construction. Innovative Processes: Potential of Science and Goals of the State* (Penza: Nauka i Prosveshcheniye)

[3] Gendlina Yu B and Martynova T S 2013 Influence of Innovations on Real Property Management, http://www.konspekt.biz/index.php?text=56875

[4] Agarwal R, Chandrasekaran S and Sridhar M 2016 Imagining construction's digital future, https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/imagining-constructions-digital-future

[5] Probst L, Monfardini E, Frideres L, Moujahid S and Luxembourg P 2014 Smart Living: Advanced building materials, https://ec.europa.eu/docsroom/documents/13407/attachments/3/translations/en/renditions/native

[6] The Boston Consulting Group 2016 Shaping the Future of Construction. A Breakthrough in

Mindset and Technology, http://www3.weforum.org/docs/WEF_Shaping_the_Future_of_Construction_full_report__.pdf
[7] Kulatilake P 2000 *Built-Environment. Sri Lanka* **1** (2)
[8] Winsun 2016 Demonstrating the Viability of 3D Printing at Construction Scale, http://www3.weforum.org/docs/WEF_Shaping_the_Future_of_Construction_full_report__.pdf
[9] Grakhov V P, Mokhnachev S A and Borozdov O V, 2014 *Fundamentalnye Issledovaniya* **11-12** 2673–2676
[10] Gerbert P, Castagnino S, Rothballer C, Renz A and Filitz R 2016 *Digital in Engineering and Construction. The Transformative Power of Building Information Modeling* (Boston: The Boston Consulting Group)
[11] Parvan K 2012 Estimating the Impact of BIM Utilization on Building Project Performance, http://hdl.handle.net/1903/13063
[12] World economuc forum 2018 An Action Plan to Accelerate Building Information Modeling (BIM) Adoption, http://www3.weforum.org/docs/WEF_Accelerating_BIM_Adoption_Action_Plan.pdf
[13] Geosynthetics 2017 Roads. Innovations in Construction, http://www.techinform-press.ru/images/stories/pdf/roads59/59.pdf
[14] Dmitriev I I 2016 *Construction of Unique Buildings and Structures* **10** (49) 35–58
[15] "TekhnoNIKOL" 2016 Multilayer Roof Tile: Innovation on the Market of Roofing Materials, https://realty.tut.by/news/building/520007.html
[16] Moore M, Shrader S and Bowles S 2010 Introducing Innovation into the Home Building Industry: Advice for innovators and inventors, http://newportpartnersllc.com/PDFs/Newport Publications/hsg_innovation_Jan2010.pdf
[17] Global Construction 2015 *A global forecast for the construction industry to 2030* (Hampshire: Global Construction Perspectives and Oxford Economics)
[18] Skvortsov M 2013 "Green" Technologies: Realities and Prospects, http://zagorod.spb.ru/articles/3586
[19] Boston Consulting Group 2016 Case Study as part of the Future of Construction Project at the World Economic Forum Demonstrating the Viability of 3D Printing at Construction Scale, http://www3.weforum.org/docs/WEF_Shaping_the_Future_of_Construction_full_report__.pdf