Employment of BIM technologies for residential quarters renovation: global experience and prospects of implementation in Russia

Alisa Vishnivetskaya 1* and Anna Mikhailova 1
1 Saint Petersburg State University of Architecture and Civil Engineering, Vtoraja Krasnoarmejskaja ul., 4, St. Petersburg, 190005, Russia

* E-mail: vishniv.alisa@yandex.ru

Abstract. Gradual integrating of BIM technologies into activities fulfilled by construction and investment companies takes place in Russia and abroad. Currently, particular attention is given to measures intended to integrate information modeling into practices of Russian companies belonging to construction sphere, inter alia, within the framework of state housing system renovation program. This paper is addressing the following issues: global experience of BIM technologies employment in the sphere of design, construction and operation of real property objects and investigation of specificity of BIM technologies employment for residential quarters’ renovation. Steps aiming to implement information modeling in Russia for construction industry in general and for housing renovation in particular were scrutinized herein. This paper is addressing factors impeding propagation of BIM technologies in Russia, evaluating the prospects of this discipline growth and defining first-priority measures which could eliminate the existing obstacles.

1. Introduction
Currently, due to the process of urbanization, about 70–90% of advanced countries’ population live in towns [1], therefore, actual problem for today is influence of construction activities not only on global economy but on socio-economic development of regions and countries as well. Urban sector in USA is reaching 81.4% of total population [1] and this fact is causing national administration to adopt respective state programs in the sphere of construction with consideration of negative influence of urbanization: construction projects include data on buildings' energy efficiency and environmental compatibility and give full information about materials and technologies used. Particular attention is given to construction wastes disposal and building operation including demolition phase [2]. Technologies and methods of investment-construction projects management which were applicable during construction of items intended for renovation could not satisfy today’s requirements.

Renovation in foreign countries is identified as urban renewal and understood as economic process of replacing the physically and functionally obsolete fixed assets with preservation of former territorial functions and institution of new ones and with the use of up-to-date technologies and materials [3]. Renovation of residential quarters in Russia is understood as simultaneous execution of technical and organizational rearrangement activities aiming to make territory under renovation comply with...
modern living conditions, improve its usability and create a unified and complete architectural appearance of the towns.

Charles Eastman, initiator of software designed to implement information modeling principle, created in early 1970's the so-called Building Description System (BDS) — a program which enabled the user to design a building out of architectural elements adding certain materials and suppliers thereof. In 1977 he updated the program by creating Graphical Language for Interactive Design (GLIDE) — a project with features used by today's platforms for Building Information Modeling (BIM) [4]. BIM abbreviation was first used by Phil Bernstein, Autodesk company employee.

BIM technologies were first used in the West in 1980's, however, active and throughout implementation of information modeling took place during recent decade. Based on expert estimates, in 2017 about 74% of British companies involved in construction projects were using information modeling, although, in 2011 this index was reaching only 13% (figure 1) [5]. It is necessary to point out the fact that BIM technologies are most frequently used during new construction, beginning from design phase, and cover entire phases of real property object life cycle including operation, repair, reconstruction and demolition [6].

BIM may be defined as process of creation, development and improvement of building information model at various phases of its life cycle. This kind of model aggregates real property object data which can be used for solving various problems [7]. Modern BIM technologies allow the user to automatically detect contradictions between different object elements with reference to works execution schedule (4D), bind information model with construction budget data (5D) and enable coordination of object technical maintenance upon construction phase completion (6D) [8, 9].

Advantages resulting from BIM technologies employment are verified by certain investigations [5, 10]: by year 2012, employment of information modeling in USA construction sphere allowed to reduce quantity of design follow-up revisions by 51%, quantity of mistakes and misprints by 52%, time spent for works execution cycle by 39% and personnel demand by 23%.

It should be mentioned that employment of BIM technologies for renovation purposes is considerably limited and is often presented in the form of object 3D-model creation by means of laser scanning without using the opportunities of information modeling which fact may be explained stipulated by specificity of reconstruction activities and by existing approach to renovation.

2. Global experience of BIM technologies employment

Foreign scientists are dividing BIM into a number of development levels (figure 2). BIM Level 0 is understood as object model presented in D2 format; object documentation is normally paper-based which fact is considerably complicating the process of data exchange among project partners. 3D appears at BIM Level 1 — dissemination of information is performed in digital format via shareable data environment. BIM Level 2 allows to aggregate data obtained from various specialists into a
common information model; at this phase of BIM technologies development it is possible to use 4D (time index) and 5D (budget estimate). **BIM Level 3** — updated version of preceding level allowing storing information in databases accessible via WEB-services. This enables the user to employ 6D and to efficiently fulfill projects with participation of foreign partners due to improvement of information model accessibility [11].

**Figure 2.** BIM development levels [11].

Despite incremental implementation of information modeling, significant results were achieved during construction of infrastructure for 2012 Olympic Games. In 2011 Government Construction Strategy declared that beginning from April 1, 2016 all new construction, reconstruction and refurbishment projects involving state budget assets will be allowed to companies using information modeling technologies of minimum **BIM Level 2** [12].

Currently, information modeling is being used not only in projects fulfilled with participation of state but for fully commercial projects as well. Latest investigations show that construction costs reduce by 33% due to BIM technologies employment [5]. Furthermore, according to expert forecasts over 90% of companies will begin active using of BIM technologies [5].

In 2015 Great Britain prescribed the course of transition to **BIM Level 3** by year 2025 within the framework of projects implementation with participation of state. Thus, in the coming decade **BIM Level 2** (forerunner of **BIM Level 3**) will be employed by almost all investment-construction companies in Great Britain [13].

It should not go unnoticed that almost one third of construction industry costs structure is relating to reconstruction (not new construction) projects [14]. However, for renovation projects, information modeling is employed more rarely which fact is connected mainly with limited package of tools used.

Demonstrative example of BIM technologies application to existing buildings is reconstruction of Sydney Opera House, Australia. The duly developed object information model allowed fulfilling the project of reconstruction and thus achieving compliance with up-to-date energy efficiency and environmental compatibility requirements. Currently, this object is being actively operated; therefore, management thereof is also based on the model obtained. This unique object required development of complex model consisting of (I) main (structural-construction) part and (II) variety of sub-models for management, logistic and financial tasks [15].

Employment of BIM technologies proved itself to be efficient for renovation of residential quarter in California. Despite deficient initial design data and mistakes found in available documentation, renovation of buildings was carried out successfully and in due time. Design engineers developed technical documentation complying with requirements specification in the course of works execution; furthermore, discrepancies in data provided by engineering departments involved in renovation project were detected and eliminated [16].
Residential quarters’ renovation is understood as creation of proper social infrastructure as well. Renovation of residential quarters abroad, in particular, construction or reconstruction of educational institutions is also performed with the use of information modeling [17].

3. Specific features of information modeling during renovation

Main distinction of information modeling during renovation is absence of relevant full scope information about the building [18]. Even already constructed buildings are lacking complete documentation, furthermore, process of available information updating fails to keep pace with modern technologies development trends. In general, purpose of computer-aided modeling is to combine human’s outlook with potentials of modern technologies, i.e. intensive employment of 3D Laser Scanning for renovation purposes.

This kind of digital building processing allows not only to itemize the available drawings but to also recreate them where they are missing. As practice shows [6], this technology is used for complicated unique objects which were earlier improved with no records made in the documentation. Use of 3D Laser Scanning allowed reducing costs incurred during renovation; however this element of BIM technologies is not commonly used and needs prior agreement with the customer.

Another feature of information modeling in the process of renovation — lack of concern on the part of architects and engineers in using BIM technologies because renovation is not normally associated with creative ideas of project initiators. Design companies often consider costs associated with modern modeling technologies usage to be useless because, in their minds, standard and relatively simple projects may be used without them. On the other hand, employment of BIM technologies for standard objects renovation is deemed to be useful especially for large-scale projects like residential quarter renovation [6]. It is expedient to bind residential quarters with transport, social and engineering infrastructure using information modeling since it is necessary to take into account multi-aspect character of design, repair and reconstruction process.

Operation of information model-based residential quarter also allows to timely and efficiently perform repair of buildings and facilities, to improve ‘transparency’ of object management process and to provide monitoring (on the part of property owners) over activities performed by managing companies and contractors by means of information model access.

Example of project fulfilled with the use of BIM technologies and subsequent information model which was used for the purpose of object operation — construction of 5-storeyed (53 flats) residential house in Goteborg, Sweden. Efficient cooperation between construction-investment companies and owners began at the stage of construction which fact made it possible to take into account demands of various project participants [11]. Bostads AB Poseidon, a company which, by today, provided dwelling for over 50,000 persons in over 26,000 flats, took responsibility for aforesaid object construction [11]. Since 2015, when this company realized advantages of using BIM technologies at any stage of life cycle, it is using it in everyday activities.

Furthermore, investigations show that employment of BIM technologies allows to promptly evaluating energy efficiency of buildings and facilities where up-to-date technologies are being used which is a significant aspect for residential quarters’ renovation [19].

Renovation of residential quarters may include modernization of individual structural elements of building or facility. Thus, YIT company is using information modeling for renovation of existing residential buildings aiming to design and construct additional balconies and elevators [20].

Undeniable advantage of BIM technologies employment in renovation projects is involvement of all participants of construction into modeling process at early stages; cooperation between design and construction companies improves quality of solutions taken in the course of project implementation. Participants of renovation projects point out that information modeling is significantly improving efficiency of their activities: costs become more predictable, risks which are inevitably taking place during renovations are lowering; furthermore, it is possible now to explain and demonstrate renovation results to residents [21].
4. Prospects of BIM technologies employment in renovation projects fulfilled in Russia

Although there are certain BIM-employment steps undertaken in RF construction sphere we must admit that so far Russia is by several times behind the leading nations in the sphere of information modeling. Only 22% of RF construction-investment companies are using information modeling [22]. BIM technologies are more frequently used for construction of multi-apartment buildings, industrial and socio-cultural facilities (figure 3).

![Figure 3. Types of construction projects fulfilled with the use of BIM technologies [22].](image)

It was announced that beginning from 2016 RF construction industry will undertake transition to information modeling within the projects fulfilled with participation of state [23]. Such decision was taken with reference to foreign experience of information modeling employment because execution of state programs with the use of BIM is the reference point from which BIM technologies begin to spread all over the construction market. Beginning from 2014, BIM technologies began to enter the practice of RF construction companies and, subsequently, information modeling standards development began [24]. By the middle of 2019 it is planned to perform full-fledged transition to information modeling at any stage of capital construction object life cycle including renovation of residential quarters [25].

Currently, only 18% of total number of residential quarter construction projects was fulfilled using BIM; however, it should be understood that this index cannot reflect the percentage of renovation of this type of facilities [22].

Over latest decades, numerous attempts to perform renovation of residential quarters (standard panel buildings built-up in 1950–1970’s) were made. Beginning from 2008, targeted program entitled Development of built-up areas in Saint Petersburg is ongoing; according to this program, 1089 residential houses in 23 quarters are subject to reconstruction [26, 27]. Within the aforesaid program a three times increase of housing density is planned; this is causing citizens’ discontent because this scenario is leading to increase of population from 110,000 to 350,000 persons and subsequent deficiency of infrastructure, green zones etc. Many citizens would like to have quarter renovation without demolition thereof; however, development and implementation of building modernization needs detailed scrutinizing. We have to admit that currently cooperation between renovation participants (even in the issues regarding houses demolition) is not efficient; scope of completed works is 1.5% [27], therefore, development (by analogy with foreign experience) of individual solutions at current stage of program implementation is practically impossible. Logical solution for renovation of the aforesaid quarters — employment of BIM technologies which enables the user to
give consideration to all variants of reconstruction and, should there be no demolition-free options, to evaluate consequences of new construction within the said territories. Moreover, development of information model of the quarter will allow evaluating advantages resulting from the possibility to execute building management with the use of modern technologies and will create the basis for entire construction sphere transition to BIM technologies.

Program of Moscow residential sphere renovation was initiated in 2017 and one year later some of the owners entered the new apartments [29]. This program is referring to Saint Petersburg experience in solving legal issues regarding renovation of residential quarters; however, renovation method selected is the same — demolition. Experts evaluate consequences of demolition undertaken within the program of renovation as negative [30], this is why, employment of BIM technologies at the stage of renovation method selection could, in our opinion, be an expedient step on the way of creating of comfortable and safe living environment. It is known that 11 residential quarters in Moscow will be put under renovation with the use of BIM technologies [31], however, it will be mandatory to employ the said technology not only for newly designed buildings instead of demolished ones but to continue implementing BIM technologies during subsequent phases of residential objects life cycle. Moscow program of renovation involves over 5,000 houses and about 500 quarters [32], this is why information modeling implementation shall not be limited to a number of projects.

Solution regarding BIM technologies implementation through mandatory employment thereof during fulfillment of projects with participation of state, in particular, for residential areas renovation, is concordant with demands of construction-investment companies. Investigation results show that namely demand and readiness of any customer, even a state-owned company, will inevitably lead to BIM technologies introduction in any everyday activity of construction-investment companies [22]. Another obstacle on the way of BIM technologies implementation is construction sphere conservatism since most of construction companies cannot fully realize advantages of information modeling; this issue could be solved by gradual expansion of BIM employment via stimulation on behalf of state.

5. Discussion

BIM technologies are spread abroad almost throughout and construction industry development in this direction is projected to rise. However, it should not go unnoticed that despite evident advantages of information modeling usage at various phases of construction object life cycle, BIM is normally used either for construction of new or reconstruction of complicated or unique objects.

According to western classification, BIM technology in Russia belongs to BIM Level 1 and transition to higher level is the first-priority task for digital economy development process.

Advantages of using the BIM technologies are evident: reduction of works execution time, mistakes and follow-up revisions, project costs all of which result in project efficiency increase.

Russian practice shows that renovation of quarters, including residential ones, is performed within state programs whose purpose is to impose information modeling. Moreover, creation of standard housing base will help to more efficiently and promptly fulfill renovation of similar quarters.

On the other hand, motivating of investment-construction companies exclusively on the part of state will never give significant results because obstacles on the way to implement up-to-date technologies still exist. One of most hardly avoidable obstacles is companies’ non-readiness to change accustomed way of doing job because of failure to understand all advantages of BIM employment. Lack of specialists capable to operate information modeling tools is also preventing companies’ management from using BIM.

Solution to employ information modeling for any stage of capital construction object life cycle demands complex approach. State stimulating, changing of legal and regulatory framework with consideration of new requirements, development of state norms and standards for information modeling, training and requalification of personnel aiming to ensure proper handling of BIM tools — all these measures will help to increase BIM technologies implementation degree. Existing residential quarter renovation programs represent possibilities for construction industry developing in modern technology directions: BIM in these projects may be used at any stage of object life cycle.
There are several directions within the Program entitled *Digital economy of the Russian Federation*: improvement of legal and regulatory environment; establishment of standards corresponding to society demands occurring in digital economy sphere; training of skilled personnel capable to employ modern information technologies; creation of information infrastructure and scrutinizing of information security issues [33]. Employment of information modeling is directly linked with transition towards digital economy, however, by today there is no available mechanism of BIM integrating into investment-construction companies’ activities.

Provision of construction sphere with required norms and standards is the most efficiently fulfilled direction; by 2018, there have been established seven GOST R and four Sets of Rules providing information modeling with required legal and regulatory base. From the viewpoint of real property objects renovation, use of these standards will allow to maintain cooperation between direct participants of design and renovation stages. Nevertheless, most important part in such projects is inhabitants who own their houses; therefore, it is important to regulate their interrelations with other participants of renovation projects. This stage of residential quarter renovation program in Russia is characterized by lack of efficient exchange of information between government authorities, investment-construction companies and apartment owners [27]. Implementation of BIM may not only improve design-and-construction companies’ performance indices but can also create full-pledged cooperation between citizens, state authorities and design-and-construction companies.

6. Conclusion
 Turning to Digital economy program, we can point out that Federal government information territorial planning system (FGIS TP) and Information system designed for city planning (ISOGD) are being gradually integrated into information infrastructure development framework. These systems provide the users with information about this or that territory or program, however, for the time being, participation of citizens in formation of such resources is not yet possible. Employment of BIM for the projects of residential quarters renovation will allow to develop the system of cooperation within each individual quarter and within the program itself and will give dwelling owners the possibility to receive not only strategic information about the progress of renovation from public information systems but may give access to latest information about their property.

Russian dwelling renovation programs are large-scale and long-lasting. Taking into account RF demand for import substitution and for entry into international market with own digital technologies it is evident that approbation of Russian software used for residential quarters renovation may be considered as a possibility to improve already available products like *Renga* BIM-platform.

Furthermore, employment of BIM technologies for quarters renovation will allow to create a data library containing information about technologies used during construction phase which may become a significant contribution into the newly established all-Russian database of materials and structures.

Therefore, renovation of residential quarters with the use of BIM technologies will allow creating a platform of digital cooperation having no comparable counterparts in Russia. Integrating of BIM technologies into large-scale projects of renovation being the objects of interest for state, investment-construction companies and dwelling owners is the basis for revealing the shortcomings which occurred during formation of legal and regulatory framework with a purpose to successfully implement information modeling for entire sectors of RF construction market.

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