Building Information Model: advantages, tools and adoption efficiency

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Building Information Model: advantages, tools and adoption efficiency

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Abstract. The paper expands definition and essence of Building Information Modeling. It describes content and effects from application of Information Modeling at different stages of a real property item. Analysis of long-term and short-term advantages is given. The authors included an analytical review of Revit software package in comparison with Autodesk with respect to: features, advantages and disadvantages, cost and pay cutoff. A prognostic calculation is given for efficiency of adoption of the Building Information Modeling technology, with examples of its successful adoption in Russia and worldwide.

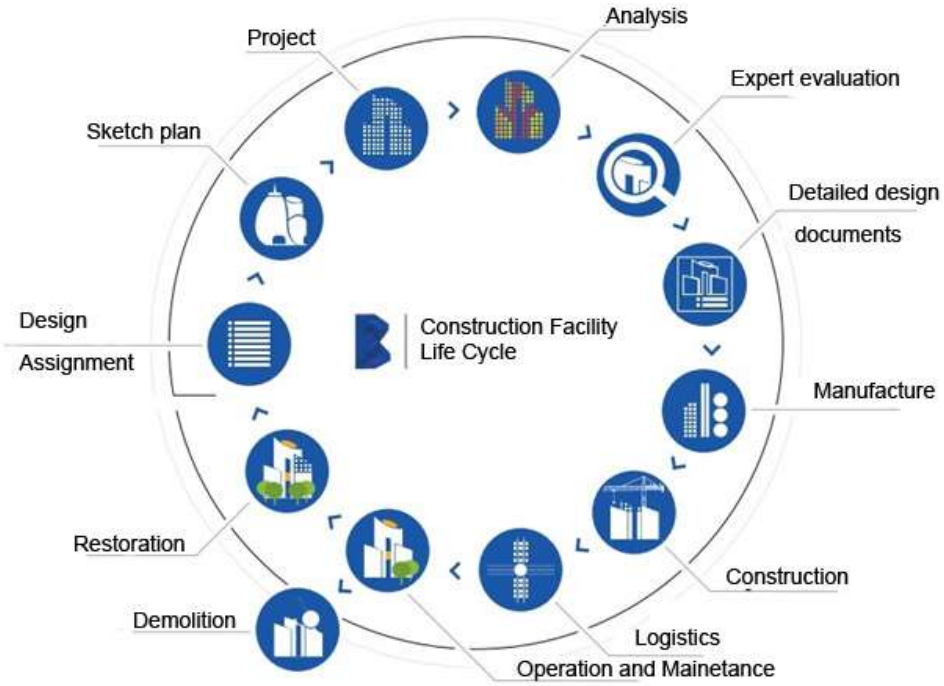
1. Introduction

Building Information Modeling (BIM) is a process of collective creation and use of information about a building, which forms a base for all the decisions during the facility's life cycle (from planning to design, issue of design documents, construction, operation and demolition). BIM is based on a three-dimensional information model, around which operation of an investor, a customer, a general planner, a general contractor and an operator are structured.

BIM (Building Information Modeling) is a complex software, using a three-dimensional base, common for the model and tools, which is developed and improved during design. The information model is a digital prototype of the facility, where each of its elements is unambiguously defined and logical relations are provided between the elements. This structure and designated relations are the main attributes of the information model. Thus, BIM is not a new software solution, it is not a 3D visualization, and it is definitely not just a pretty picture. BIM is a process of information creation and management.

2. BIM at different stages of facility's life cycle

BIM covers all the stages of a facility's life cycle (see Fig. 1): planning, preparation of building program, design and analysis, issue of detailed design documents, production, construction, operation and maintenance, dismantlement.



Fugure 1. BIM at different stages of facility's life cycle

The foundation of any design may be represented as *three summands of success*, see. Table 1.

Table 1. Summands of success for design

Summands of success	Nature	Output
Single design entity	all the participants of the project work with the same design solutions. If a design solution is changed, it is changed for all the project participants.	lower probability of a design error (collision).
Constant interaction of all the project participants	smooth communication, facilitating constant interaction between all the project participants	rework and corrections are minimized
Single structure for data storage and transmission	storing the files in one system	fast access to requested information

3. Significance and prospects for BIM adoption

Ministry of Construction of the Russian Federation is reflecting significance and prospective character of BIM technologies. Ministry's calculations have shown that taken as a percentage, reduction of construction and operational costs amounts to 30%, while reduction in design period approaches 50% see Fig. 2. According to plans of the Ministry of Construction of Russia, starting from 2019 , all the facilities constructed at public expense shall be designed with the use of BIM. In 2016, within the regulatory framework development, R&D Center Stroitelstvo developed 4 codes of practice for BIM, defining general principles of application for this technology.

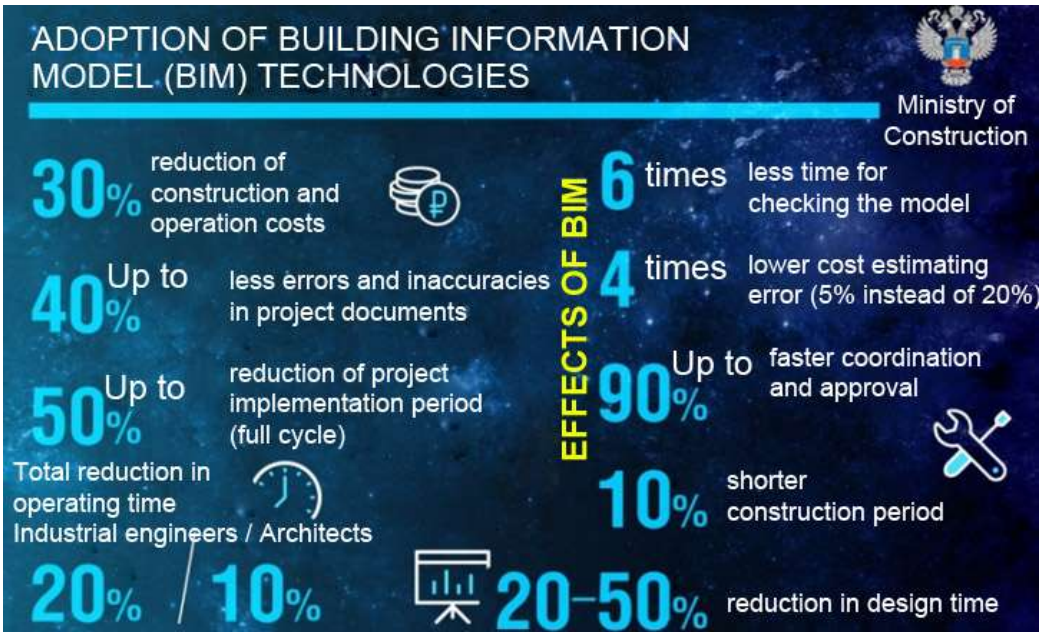


Figure 2. Effect of BIM adoption, data from the Ministry of Construction of Russia [2]

They will regulate requirements and standards in data exchange (interoperability) during design, construction and operation of buildings and constructions, requirements to information model components for facilities under construction, to software data exchange interfaces and content of transfered information, levels of geometric and attributive development of BIM components for buildings and constructions. Their approval is planned for 2017. They include: SP «Building Information Modeling. Code of Practice for Organization of Works in Operation and Technical Departments»; SP «Building information Modeling. Code of Practice for Data exchange between the information model of facilities and models used in software solutions»; SP «Building Information Modeling. Code of Practice for formation of facility information model at different life cycle stages»; SP «Building Information Modeling. Code of Practice for Description of Information Model components» [3].

Having surveyed executives of leading construction and design organizations, the authors highlighted short-term and long-term advantages from switching from CAD (Computer-Assisted Design) to BIM technologies (see Fig. 3).

BIM technology offers a number of opportunities:

1. It allows consolidating all the information already at organization's disposal with new knowledge appearing due to switch to BIM.
2. It provides data exchange between existing systems of an enterprise and a BIM model.
3. Information model becomes a data source for procurement, scheduling, project management, internal ERP and other systems of an enterprise.

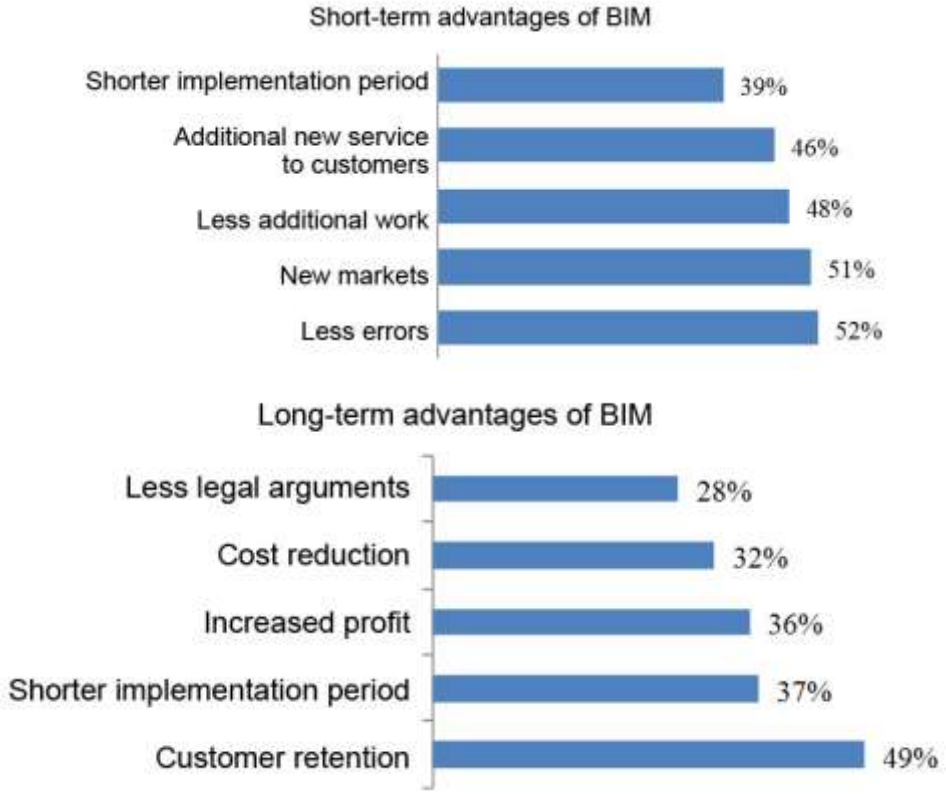


Figure 3. Short-term and long-term advantages of BIM

BIM technology is a process of information model formation, the model being a digital prototype of a designed facility; it is a 3D model complete with information on the subject.

4. Analytical review of software solutions

Information modeling systems have been in development since the 1980s. Among the leaders and founders of the movement is Autodesk Inc., whose achievements jump-started an alliance for interaction between different graphics platforms. «Alliance of Interoperability» includes 12 largest software developing companies, including Autodesk (Revit, Autocad), Tekla, Graphisoft (Archicad), Trimble (Sketchup) and others.

Let us analytically review Revit software solution in comparison with Autodesk, as a tool for implementation of Building Information Modeling on the following criteria: features, advantages and disadvantages, cost and pay cutoff.

Revit is a stand-alone application supporting BIM workflow, from concept development to construction. Purpose of Revit: creation of accurate project models, performance optimization, efficient interaction between project participants.

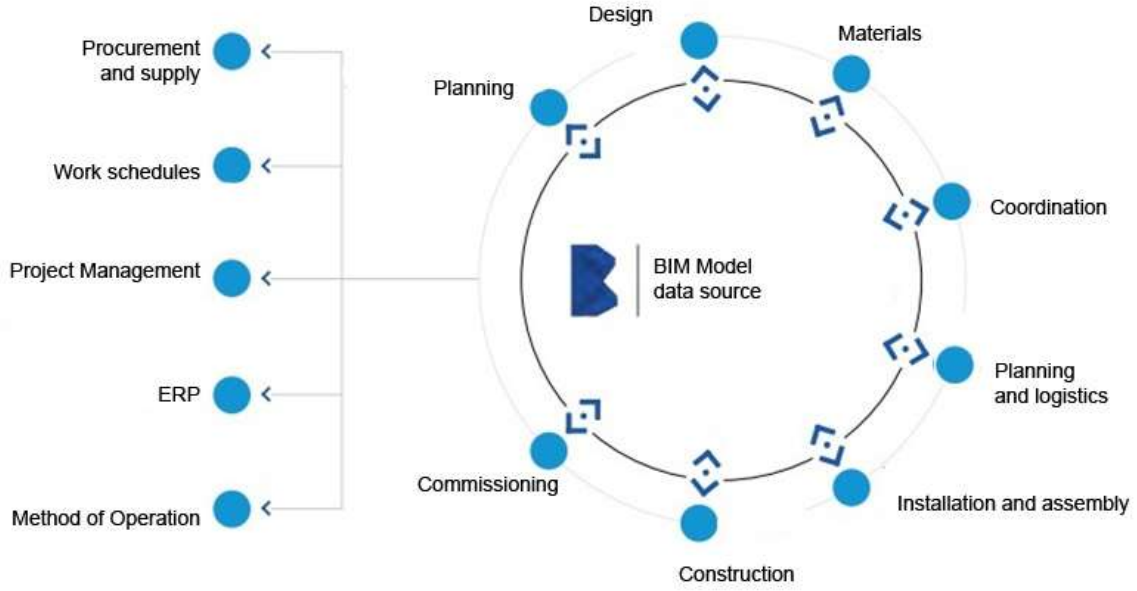


Figure 4. Use of BIM data for different systems

Revit software for BIM provides tools for engineering of architectural elements, utilities and building structures. These tools allow for better coordination of specialists from different disciplines. The software has a very wide range of features, it allows unifying work of people participating at different stages of the Project Life Cycle (PLC), see Table 2.

Table 2. Analysis of Revit features

Features	Nature
	Platform
Improved performance	More efficient operation due to faster software.
Article I. Interaction with BIM technology	Possibility to import, export and set links to data in universal formats DWG™, DXF™, DGN and IFC. Besides, it is now possible to export a building or construction site model complete with metadata into infrastructure engineering software AutoCADCivil 3D and import models from AutodeskInventor, software for 3D engineering of mechanisms.
Bidirectional associations	Parametric changes the management mechanism of Revit automatically harmonize introduced changes in views, drawings, layout plans, specifications and section drawings.
Parametric components	Design intent may be expressed with maximum detail with the help of parametric components.
Teamwork	Specialists of different disciplines may work with the building model simultaneously, saving the results in a common storage file.
Specifications	Specifications may be created at any stage of the design process. If changes are introduced into a project, influencing a specification, such specification is automatically updated accordingly.
Revit Server	With the help of RevitServer, project teams may cooperate in work with Revit models over the global network.
	Architectural design
Conceptual design tools	Preliminary sketches may serve as a basis for further work while creating a project of a facility.

Features	Nature
3D project visualization	Use Revit 3D visualization capabilities for deeper understanding project features before its implementation.
Construction site planning tools	Formation of construction site relief directory within Revit and transfer of layout solutions to engineers.
Structural design	
Reinforcement connectors	Provides additional detail level in modeling and documenting reinforcement by means of completely adjustable reinforcement connectors by family basis.
Dead load analysis	Possibility to perform calculations of load flow with visualization of vertical loads being transferred from the top of the model to its foundation.
Reinforcement detailing	Creation of detailed and accurate reinforcement projects. Creation of project documentation for reinforcement, including rebar specifications.
Bidirectional link with different calculation software	Parametric change management technology provides coherence of all views of the model and its construction drawings.
Analytical model of structures	Analysis with an analytical model, automatically generated whenever a physical model is created in Revit.
Utilities engineering and manufacture	
Detailing for manufacturers	Use Revit to create ready for manufacturing models using date from AutodeskFabricationCADmep, FabricationESTmep and FabricationCAMduct to improve coherence between models intended for manufacturers and detailers.
HVAC — engineering and delivery	Engineering and modeling of air ducts and pipelines with the help of mechanical engineering element. Preliminary calculations for heating and cooling loads and tools to determine sizing of ducts and pipelines. Engineering of complex air duct systems in coordination with other disciplines and building structures.
Engineering of electric systems and development of documentation	Engineering and modeling of the electrical system with its components. Installation of cable trays and channels, tracing of electrical loads throughout the electrical distribution system.
Engineering of sewage systems and development of documentation	Creation of sewage systems with sloped pipes. Manual or automatic arrangement of a pipeline system, connection of instruments and equipment items.
Cooperation with architects and building construction engineers	Increased efficiency of cooperation with architects. No collision with load-bearing beams and framework. Coordination and more efficient cooperation thanks to tools intended for engineers and project designers specializing in machinery, electrical and sewage systems.
Construction Activity	
Construction modeling	Possibility to divide facilities, e.g., walling layers and concreting stages and further manipulations, thus allowing for more accurate reflection of construction methods.
Building construction manufacture	Revit provides building construction engineers with data on detailing and manufacture of concrete reinforcing elements.

Usage of a product is always followed by discovery of its advantages and disadvantages, which were arranged in Table 3.

Table 3. Advantages and disadvantages of Revit software

Advantages	Disadvantages
1. 3D design of Building Information Model (architecture, construction, HVAC)	1. The software is produced abroad, thus it does not take cue from peculiarities of engineering design in Russia
2. Automatic generation of sections, facades, specifications, nodes	2. Low compatibility with Russian standards. Almost all nomenclature requires some changes.
3. Bidirectional associations (changes in one location are implemented automatically throughout the project)	3. Poor choice of features for working with specifications. Specification standards are not supported.
4. Cooperative and coordinated operation of all design engineering sections of Revit in a single file or with the help of upload	4. Weak features for working with Steel Structures, Steel Structures Details and Timber Structures sections
5. Any parametric element of the library may be created by a user	5. Generation of Building Information Model is a rather long and work-intensive process, viable only for large-scale projects.
6. Links to computational software Robot, Scad, Lyra (Revit contains analytical model of frame, loads and anchoring within its project, with possibility to transfer it to other software)	6. When modeling buildings subject to total renovation, filling the system with information on structural defects requiring building reinforcement is unexpectedly hard.
7. Working with any materials with possible transfer to 3dsMax	7. Even for pilot projects created within the framework of a state-sponsored program, a lowering of workforce productivity was noted.
8. Intuitive interface and fingertip control.	
9. Automation of many processes allowed reducing time required for project documentation development	

Due to the fact that the software covers a vast set of possibilities for all project participants at all project stages, it is worth noting separate groups of specialist, directly linked to the project in a certain period of time and following a task-solution approach demonstratively express significant improvements and work flow acceleration through stages from concept to commissioning (see Table 4).

Table 4. Advantages of BIM technology for different participants in construction facility life cycle

Targets	Considerations
Investor, customer, developer	
1. Optimizing investments, reduce project costs	1. Reducing design and construction time thus optimizing cash flow and credit periods to additionally reduce construction costs.
2. Determining project estimates at the groundbreaking stage to calculate its profitability.	2. At early stages, estimating scope of work and material supply, cost of construction on the basis of BIM-supplied model.
3. Obtaining complete information on expenditures during the project, giving accurate predictions of cash flows at any stage, from design stage to construction and operation.	3. Creating accurate and vivid visual construction schedules, allowing for planning of cash arrival periods.
4. Cutting construction budget by optimizing construction site logistics.	4. Checking for spacial and time collisions at the construction site, analyzing and optimizing construction machinery availability period on the basis of BIM-supplied model to reduce construction period and costs.
5. Obtaining information about the project	5. Using modern communications based on BIM processes and

Targets	Considerations
necessary for decision-making in a convenient and descriptive form.	BIM model.
6. Creating high demand for the construction facility at its groundbreaking stage.	6. Using BIM tools to create conceptual 3D model, which is a close match to the future facility. Using it for marketing allows for better communication with a client.
Project Organization	
Project	
1. Obtaining new orders / enlarging company's business.	1. Proposing BIM model-based solutions in accordance with market demand, including that from state customers.
2. Issuing high quality documentation on time.	2. Cutting errors by over 30% due to coordinated work of all the project participants working with the BIM model.
3. Increasing productivity – by finishing more projects in less time.	3. Speeding up design process by more than 30%.
4. Avoiding employee turnover and keeping key personnel.	4. Increasing attractiveness of one's own company for the most prospective employees wishing to raise their professional competence by working with BIM technology.
Head of CAD/IT department	
1. Investing optimally, getting maximum return on each and any investment.	1. 90% of companies get positive results from adopting BIM, 50% of companies show ROI over 25% (McGrawHillConstruction).
2. Facilitate increase in company's profits with IT tools.	2. BIM technology allows speeding up design by up to 30%, reducing incidence of errors (from experience of Russian users of the technology).
3. Providing neat and smooth production of final product — detailed design documents.	3. Correctly organized adoption of BIM technology allows keeping the speed of documents delivery during the implementation. In the future, as per Decree 87, the whole set of documents may be issued on the basis of BIM model.
Architect	
1. Creating unique high quality projects.	1. Automating of routine operations, thus allowing more focus on creativity.
2. Complying with timeframes and budget of the project.	2. Increasing quality and reducing design period by means of early discovery of collisions; minimizing incidence of correction in the project at the stages of detailed design documents preparation and construction.
3. Complying with special customer requirements, including those concerning energy consumption of the building.	2. Increasing quality and reducing design period by means of early discovery of collisions; minimizing incidence of correction in the project at the stages of detailed design documents preparation and construction.
4. Selecting optimal solutions early in the project and agreeing them with the customer.	4. Providing the customer with descriptive variants of project solutions, complete with exhaustive arguments.
Structural Designer	
1. Meeting the requirements for safety of complex projects.	1. Performing calculations on the basis of BIM model ad different stages of design, including conceptual design stage.
2. Management of a large number of project changes.	2. Supporting cooperative work within the framework of the information model allowing for automatic update of all the parts of the project following introduction of a change.
3. Coordinating work with other departments, including engineering and architectural.	3. Discussing project solutions at any stage of design with the help of software feedback tools.
4. Reducing period for development of analytical model.	4. Creating a simplified model and supplying it with loads for further transfer into computational software without excessive modeling and changes into main model.
Engineer	
1. Selecting the optimal variant of an engineering project.	1. Variation of engineering on the basis of BIM model.
2. Excluding collisions between different	2. Organizing cooperative work, including efficient

Targets	Considerations
engineering systems and architectural design. 3. Delivery of high quality project documentation according to schedule	coordination of works between all project participants. 3. Reducing the period of design by means of automated search for collisions and their resolution early in the project.
Master Planner	
1. Finding the optimal variant of the project schedule. 2. Creating a site grading plan, calculation of earthworks and execution of an interpretative map. 3. Development of a combined plan of utility networks. 4. Creating a site improvement plan.	1. Automation of labor-intensive processes of scope estimation and Bill of Material development on the basis of BIM model. 2. Automation of changes to the model and all its linked drawings on appearance of changes in the project. 3. Issuing drawings in compliance with Russian and corporate standards on the basis of pre-configured templates. 4. Developing the site improvement plan with the help of unit libraries and automatic summary for pre-configured templates.
Construction Organization	
1. Accurate estimation of construction cost before bidding. 2. Reducing risks of cost overrun. 3. Controlling the stated construction time of a facility.	1. Reduced error in construction cost estimation on the basis of BIM modes with accuracy of 5-10%. 2. Modeling the construction process on the basis of BIM model, generating the construction schedule, optimizing availability time of expensive construction machinery, exact definition of contractors' involvement periods, optimization of amounts of building materials. 3. Controlling plan/actual works of all construction participants on the basis of BIM model, including with the help of mobile devices on site.

5. Efficiency from switching to BIM technology

For BIM technology to manifest its potential, the company shall execute detailed and comprehensive planning of an adoption procedure. Financial results of information modeling adoption are in direct dependence on depth of such adoption and its level of maturity in the company. One of the more important indicators of BIM adoption efficiency is return on investments (ROI), a profitability coefficient, calculated with the following formula:

$$\mathrm{ROI} = \frac{\text{Gross Profit} - \text{Investment}}{\text{Investment}}$$

As evident from practice, the profitability coefficient increases depending on depth of BIM adoption, as shown in Fig. 5.

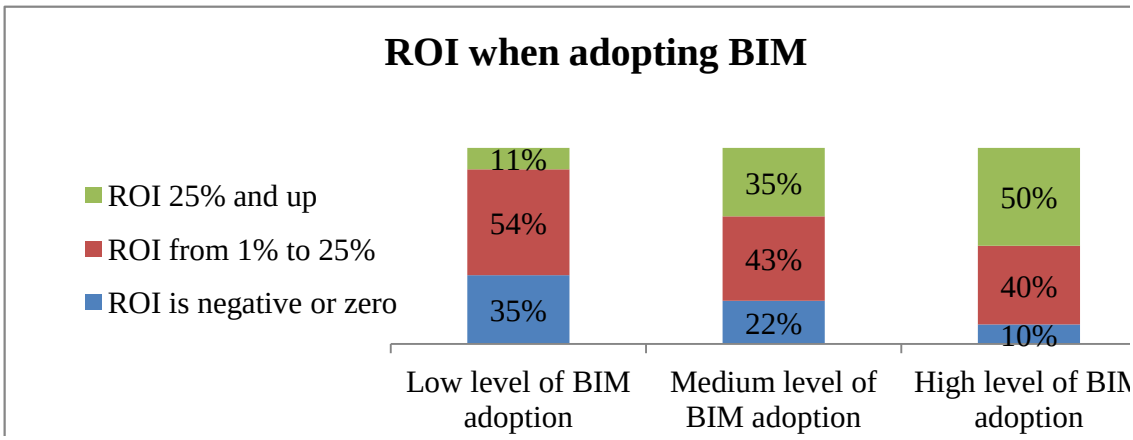


Figure 5. ROI when adopting BIM

Despite all the advantages of BIM technology as a whole and Revit software solution, in particular it is largely a question of infrastructural, project, and long-term investment.

Currently, taking into account the highest efficiency of BIM application, that is, when all the specialists switch to new software, total amount of investment is 2,786,600 roubles, as of the beginning of 2017; this amount includes investment into software and personnel training costs. [2]

Adoption of new software is accompanied with recline in productivity (training period), then it gradually rises, attaining a level higher than that with the old software.

Some prognostic indicators of net profit (NP) and net present value (NPV) for three years since adopting BIM technology (see Table 5).

Table 5. Prognostic calculations for net profit and net present value following adoption of BIM technology

Property	1 year	2 years	3 years
Net profit before adoption of BIM technology, roubles	3,224,960	3,224,960	3 224 960
Net profit after adoption of BIM technology, roubles	3,920,000	5,808,000	5,808,000
Difference in profit ϕ_t, roubles.	-3,221,040	2,583,040	2,583,040
Net profit, roubles.	-3,221,040	-638,000	1,945,040
Discounted profitability index a_t	1	1.0875	1.183
$\phi_t x a_t$, roubles.	-3,221,040	2,809,056	3,054,848.4
NPV, руб.	-3,221,040	-411,984	2,642,864.4

As predicted, values of NPV for the third year are positive, investments into BIM technology as a replacement for CAD may deem to be efficient. To prove this fact, one may cite examples of successful adoption of BIM in different areas of construction, both in Russia and abroad.

A project is an ultra-modern business center in the city of Kazan. In the end of 2014, State Unitary Enterprise «Tatinvestgrazhdanproekt» (TIGP) was tasked with design engineering works for a business center, an ultra-modern 11-storeyed office building. The task included four underground and seven overground parking garages, a conference hall, public service areas, catering area and recreation zone. The starting point for the specialist of Tatinvestgrazhdanproekt was issued as a sketch plan, prepared by a third-party company in AutoCAD. Autodesk Revit was selected to develop the information model of the business center; all the design disciplines were completed in it: Architectural Solutions, Reinforced Concrete Structures, HVAC, Water Supply and Sewage, Operation. Presentation materials were prepared in Autodesk 3dsMax and Autodesk Revit. Autodesk Design Review and Autodesk Navisworks were used for information exchange on the project with the customer. To create a possibility for virtual excursion through the building, a team headed by Dmitry Polkovnikov (Head of BIM department in Taninvestgrazhdanproekt) used a Revizto software solution.

Renovation of Luzhniki Swimming Center. UNK project Co. was awarded a tender for renovation of Luzhniki Swimming Center against 42 other participants, both Russian and international architectural bureaus. The relatively small building of the center (42 000 m²) is very rich in features: there is a technical level, two-level parking, several retail space levels, three connected swimming pools, a waterworld, several levels occupied by the Boxing Academy, a fitness center and spa.

Preparation of project documentation for Rubin Sports and Concert Complex. In the late 2012s, SBE-NIPIGS group was awarded a tender for development of project documentation for construction of Tyumen-Arena Sports and Concert Complex. In accordance with its technological and operational parameters, the facility was deemed to become one of the leading ice stadiums of the country, with design capacity of 12,500 spectators in hockey mode and up to 15,000 for concert events. According to the design assignment, the scope of work included development of project documentation for four facilities: a multifunctional arena building, a technical unit, a roofed parking and a hotel, as well as site improvements for a 19 ha area. Autodesk Revit was selected as a main design tool. About 150 variants

of the main arena building were developed, thanks to parametric geometry of forming elements and automatic calculation of technical and economic indicators.

Opening Arena Stadium. The AECOM, an international company, had got an order for concept and design development of project documentation for home stadium of FC Spartak (currently – opening Arena Stadium) in Moscow in 2009. An initial plan indicated a design capacity of 35,000, however, when Russia won a right for Football World Championship 2018, the capacity was raised to 42,000 as per FIFA requirements. To guarantee successful expert evaluation and keeping within the budget, the stadium was designed in Autodesk Revit with BIM technology. Less than a year was spent on developing the concept, and a year and a half was spent on developing detailed design documents.

Shanghai Tower is known as the second tallest building in the world; the Shanghai Tower is both a spectacular example and a magnificent result of BIM application in design, construction and operation of a building.

In Bronx Lebanon Hospital Center in New York, specialists from WASA/Studio completed a complex project of Bronx Lebanon Hospital Center and put together different disciplines of the project with the help of Revit.

Unlike the traditional approach, BIM gives an opportunity to shift the principal body of work concerned with changes of the project to its FEED stage and Development of the Design Documentation stage, thus reducing cost of each design error. While using the traditional technologies, the main body of collisions are found and corrected only at the Detailed Design stage or during the Construction stage.

Companies adopting BIM bear different non-comparable and non-uniform costs. The conclusion is that it is impossible to make decisions exclusively on the basis of monetary terms of investments, like in calculating ROI.

BIM adoption shall be considered on a case, with considerations of a concrete project at hand. The all-or-nothing approach is incorrect here. In some cases, CAD systems show more efficiency, while BIM may find only limited application (e.g., 3D modeling).

Adoption of SP standards for Information Modeling shows support and approval of the BIM technology from the government.

Despite some issues, the process of development and adoption of BIM technology in Russia is irreversible.

6. Acknowledgment

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