sciendo

BUILDING INFORMATION MODELING FOR HOUSING RENOVATION - EXAMPLE FOR UKRAINE

Nikolai Siniak, asst. prof., PhD.
University of Information Science and Technology "St. Paul the Apostle", Macedonia
e-mail: nikolai.siniak@uist.edu.mk

Sabina Źróbek, prof., PhD.
University of Warmia and Mazury in Olsztyn, Poland
e-mail: zrobek@uwm.edu.pl

Vsevolod Nikolaiev, prof., Dr.Sc.
National Academy for Public Administration under the President of Ukraine, Ukraine
e-mail: vsevolod@irpin.com

Sergey Shavrov, Asst. prof, PhD.
Belarussian State Technological University, Belarus
e-mail: shavrov@ipps.by

Abstract

Building Information Modelling (BIM) is the latest software technology used widely by many construction businesses - big and small - particularly within the Architecture Engineering Construction (AEC) sector. Besides being a design and documentation tool, building information models (BIM) provide a platform for enhanced knowledge base collaboration, the potential to manage modification, and therefore the capability to provide information support throughout the lifecycle of an apartment building. A big share of the eastern European construction industries remains excluded from BIM technology and the potential advantages it will hand over to their business, particularly for renovation projects. It requies the involvement of all stakeholders to realize higher-level coordination, productivity, visualization and value efficiencies. The advantages of BIM exploitation for renovation projects are considered in the article. Tendencies in the development of BIM technologies throughout the globe and in eastern European countries on example of Ukraine are shown. Examples of the exploitation of local building information systems in realizing renovation processes are given, and proposals for policymakers in terms of applying BIM technologies in housing renovation activities and facility management are formulated.

Key words: *BIM, housing renovation; information system; building and facility management; spatial management.*

JEL Classification: *C13, R10, R30, R32.*

Citation: Siniak N., Źróbek S., Nikolaiev V., Shavrov S., 2019, *Building Information Modeling for Housing Renovation - Example for Ukraine*, Real Estate Management and Valuation, vol. 27, no. 2, pp. 97-107.

DOI: 10.2478/remav-2019-0018

1. Introduction

Digital transformation is a mainstream economic and technological trend concerning all of us. No industry can escape the digital transformation taking place throughout the world, with the AEC sector being no exception as an integral and essential part of the global economy. Digital technologies and advanced analytics are helping businesses across industries improve customer experience, boost sales and increase operational efficiencies. Digital transformation is necessary for the built environment, construction and real estate sector to survive and provide economic growth. Architects, designers and engineers are sourcing and implementing construction technology and software solutions in preparation for this growth. BIM acts as the centerpiece for the digital transformation of the industry (*An Action Plan*… 2018). In the nearest future, BIM is anticipated to change the common situation of the AEC business. Companies are managing the completion milestones of their projects based on BIM rather than traditional computing methods.

Building Information Modelling (BIM) is currently considered as collaborative process in which AEC professionals involved in a project use an intelligent 3-7D (scheduling (4D), cost (5D), sustainability (6D) and operations and maintenance (7D) model-based design application that provides the insight and tools they need to design, construct, and manage buildings and properties throughout total assets' lifecycles (*Advances in* … 2018).

The acronym BIM stands both within the industry and within the academia for building information modelling and model (TURK 2016, *Society for Marketing Professional Services* 2015) and represent physical and functional characteristics of buildings or facilities forming a reliable basis for decisions during their life cycle (*NBIMS* 2010).

When describing BIM, engineers and architects often resort to a paradigm known as structure-function-behavior, dividing the definition of BIM into three facets: structural , functional and behavioral (DE KLEER, BROWN 1983; GERO 1990).

Structurally, BIM is a structured representation of a building and is defines how it is organized, what parts it has, and how they work together. Ideally, the structure of BIM would be that of an object-oriented database with special requirements, which include sharing data in a multiuser system, support for multiple views of data, controlled data redundancy, enforced integrity, restricted unauthorized access, data independence, transaction processing, backup and recovery (WATT 2014; BJORK, PENTTILA 1989).

Functionally, BIM is a communication backbone during its entire life cycle, as well as a shared source and destination of information required, and the outcomes of BIM describe how such interaction can prove useful (*What is BIM* 2013).

The behavior of BIM is described how interacting, interrelated, or interdependent elements or parts of a socio-technical system function together and respond to their environment to accomplish a goal (*The Free Dictionary*, KENNETH 1956).

Some benefits of BIM include enhanced efficiency, reduced time and construction costs and ctr. (SHEN, ISSA 2010; SUCCAR 2010). BIM technology is a promising way of exploring how BIM will beneficially support sustainable real estate development (PENG, WU 2015; BALDWIN et al. 2008), facility management (WANG et al. 2013), housing renovation (JOBLOT et al. 2017; AAPAOJA et al. 2013), and the refurbishment as well as maintenance of the built environment (KHADDAJ, SROUR 2016; PAVLOVSKIS et al. 2017).

BIM is an exhaustive research topic in the field of construction informatics or computing in building engineering (TURK 2006) and mainly applied today in the new construction industry. The future of BIM is determined by ongoing research and software development that has been summarized in several studies (VOLK et al. 2014; AZHAR et al. 2015).

A fully digitized built environment could have a greater impact, optimizing all services based on the built environment and help citizens to make better use of communications and infrastructure.

The AEC industry started to implement BIM in projects in the the mid-2000s, and implement it widely in practice in 2014, in spite of the some important research having been conducted in the late 1970s and early 1980s (AZHAR et al. 2015). The Directive of European Parliament from January 2014 encouraged the adoption of BIM and electronic tools in public work contracts in European countries (*Directive of European* … 2014). The creation of the EU BIM Task Group in 2016 Handbook for the Introduction of Building Information Modelling by the European Public Sector released in 2017 was also particularly important.

Currently, BIM methodology and software solutions are in high demand in the US and Western Europe, helping to enhance efficiency, productivity and collaboration across the entire project lifecycle, reducing time, waste and cost and drive business competitiveness and new levels of digital business innovation. According to experts, design, construction and facility management using BIM technology are more efficient and provide, in the EU countries, expected annual savings from the use of BIM-technologies at the design and construction stage of more than 20%.

BIM adoption and implementation in different fields in Eastern countries has been slow, despite its many advantages.

Building Information Modelling is growing in popularity of implementation in Poland, and helping to facilitate and accelerate work, to organize information throughout the life cycle of the asset, to facilitate communication between designers of different industries working on the same object, to avoid collisions and to speed up the quantity takeoff process (JUSZCZYK et al. 2015).

In Belarus, starting in 2022, all construction projects that are created at the expense of the republican budget will be built on BIM-technologies. To fulfill this task, which has been set by the state, a working group has been set up, which includes designers, contractors, analysts, representatives of the housing and utilities sector.

In comparison, Spain has a BIM Commission sponsored by the Ministry of Public Works for BIM to be applied in buildings in 2018 and in infrastructure in 2019. In Denmark, there will be a mandate for all projects in 2022, and in Germany, the government will require a mandate for public infrastructure projects by 2020 (AZZOUZ et al. 2018).

Work to assimilate BIM software in the Belarusian civil engineering industry has been in progress since 2012. Only in one of the universities in Minsk, can one get an education on how BIM-platforms operate for purposes of advanced training and retraining of personnel. Some institutions, such as Belgosproekt, Belpromproekt, Gomelproekt, Minskgrazhdanproekt, Minskproekt, Minskkinzhproekt, and a number of private construction companies have already completely switched over to BIM-design. Today, the construction of the Dynamo stadium has been completed with the use of BIM technologies, while the Belarusian NPP, the Minsk Metro, and the gas supply network are under construction.

Experts in the field of land administration in Belarus propose to reengineer the business processes of the administrative procedure "registration of creation /change of capital structure" on the basis of the executive BIM model. The executive model is BIM, which corresponds to the capital structure adopted in operation. They are looking for ways to integrate GIS and BIM, taking into account CityGML OGC standards to create 3D-cadastral digital maps.

Russia and Kazakhstan are also busy assimilating BIM technologies for new construction projects.

A national roadmap was developed for the BIM adoption in the Former Yugoslav Republic of Macedonia. The goal is to achieve a significant reduction of the energy bills of the buildings through BIM methodologies in the phase of operation and maintenance of a building.

The implementation of BIM-technologies in design and construction will become mandatory in Ukraine starting from 2019. Unlike many Western countries, Ukraine must still create the preconditions of such implementation. These preconditions must include the following actions: conduct extensive works on the alternative digital approaches regarding the transition of the construction industry in Ukraine to BIM-technologies, clear classification of all information on the environment of the construction industry and automated exchange of information and databases in an open format in line with international standards, ensuring the implementation in school curriculums for training and retraining qualified specialists for training and practical use BIM-technologies, interoperability of all public organizations and associations, business partners when implementing BIM-technologies in Ukraine. Implementation of these preconditions has no chance without proper attention being paid to professional associations and NGOs, investors, heads of design, contractors, manufacturers and suppliers of inputs for construction (ROMANENKO, CHAPLAI 2017).

BIM implementations for different issues are generally of a complex nature, and a range of organizational and technological barriers for BIM implementation have been analyzed in some research (LIU et al. 2015; BUI et al. 2016).

In recent Ukrainian publications, attention is drawn to the fact that, first of all, BIM requires the transition of the construction industry to the principles of life cycle management and market pricing (KUBIDA et al. 2018). The latest attempts in developing the concept of the reformation of the construction industry have been confronted precisely with this first issue.

BIM implementation barriers range from the lack of a BIM framework, low awareness of BIM benefits, high initial investment costs, staff's resistance to change and cultural misfits (MIGILINSKAS et al. 2013; EADIE et al. 2014; JUNG, JOO 2011).

Providing players in the AEC value chain with the right motivation and understanding of BIM's benefits could serve as the foundation for faster adoption. The evolution of BIM in the direction of the needs of the housing renovation industry and its specificity is a promising approach to tackling and managing the complexity of the renovation and facility management process.

This paper aims to present the initial research results on BIM understanding for housing renovation and its adoption in some Eastern European countries on example of Ukraine. To realize the BIM benefits, an active role in guiding based on understanding BIM in the context of developing countries and examples of its implementation must be taken into consideration (ARAYICI et al. 2011; ARAYICI et al. 2009).

2. Information technology in the reformation of the construction industry in Ukraine

In programs of reforming Ukraine's economy, the investment and construction industry were unfairly bypassed. This was counterproductive seeing as how it is through their mechanisms that all capital investments are realized - both in production and social spheres.

There are a lot of problems with construction in Ukraine. Upon reviewing the official statistics, one might ask himself, "what kind of industry is this if its enterprises have been working at a loss for so many years?" In 2017, for example, the volume of construction in financial terms amounted to 105.7 billion hryvnias, but the losses of enterprises amounted to 5.0 billion hryvnias. Approximately the same picture was presented in previous years. It is highly likely that not everything is transparent in the activities of these numerous construction firms. Professionals are well aware of "cheating" on costs in estimates, and "kickbacks" for land plots and outsourced contracts, not to mention scams connected with the construction of housing for the use of the population with its absolutely artificial pricing and unknown quality of materials and design solutions.

It appears the construction of buildings is the only goal of this industry. The more new meters are commissioned and the larger the amount of money, the more successful the work of our builders is considered to be, and vice versa.

It was proudly noted that, in 2017 in Ukraine, more than 10 million square meters of housing were commissioned, this being 8.,9% more than in 2016. Therefore, the demand has increased and the market came back to life (in 2018 the market had fallen by 15%). At the same time, however, it has been forgotten for some reason that housing stock wears down and is destroyed, and the addition of new objects does not correspond to their improved technical standard, thus this situation will not last long, especially if the buildings are not given proper maintenance.

The consumers have had questions about the quality of the buildings, the unreasonable prices and the low efficiency of using real estate for a long time. Unfortunately, the future owners of these houses know only the price per square meter, without the costs of renovation, and see only the advertised image of the house. In reality, however, they do not know what they are buying and what they are paying for, e.g.: what materials the house is built from, who produces these materials and what their quality is like, the length of the service life of the house, its components and its engineering systems, and how much maintenance and renovation will cost or how often such works should be carried out. The owners of previously built houses and apartments are also unaware of the frequently critical condition their houses are in, the huge financial investments required to carry out urgent capital renovations, or the short remaining life expectancy of the buildings.

At the same time, by reviewing the state of the construction industry abroad, it is clear that consumers and authorities in developed countries show an interest mainly in the efficiency of buildings: how well the facilities are designed, their quality and price, and the conditions of facility management.

Today, opportunities for improving the efficiency of the industry, construction enterprises, as well as facility management are connected with building information modelling, which is provided by the current industrial revolution.

It is not difficult to see that the problem is not merely building design but the entire construction and facility life cycle. At the same time, it is not only the cost of construction which is determined, but all of the expenses, incomes and value over time for the customer or future owner. For this purpose, information accumulated over the years on the costs of such houses during the construction and management period is used. Such data finds its way into the information databases of reliable reports of builders and property managers.

It is not only architects and design engineers who take part in the design process, but also the investor (the commissioning party and, possibly, the potential buyer), the contractor and the main suppliers. This is a single team whose members can work online on a common information model using appropriate software products, some of which are known in our country as 3D design. The goal of the team is to create an object that will satisfy the customer and future users as much as possible, and hence to receive remuneration in proportion to their contribution to the final results.

In the design process, the object is combined from components with known physical, price, operational and environmental characteristics. Products are designed, ordered and delivered in the form of pre-manufactured components, which minimizes work on the construction plot and construction waste. All information is provided by manufacturers and suppliers, and accumulated in the industry information databases. It then is put to use by the owner and facility manager of the building.

Thus, both the builder and future users can find all the necessary data in the model for the effective construction, maintenance and facility management of the building.

But what do we get in the end besides 3-D images of the object on a computer screen?

Firstly, a reduction in the time and cost of construction; secondly, the assurance of quality, not only of the construction work but also of the materials used, the products, the various equipment and the engineering systems; thirdly, we are provided with the most transparent and real price. Fourthly, recommendations on the timing and cost of future renovations and future utility bills of the housing are obtained.

This, however, is not all. Let us take a broader look at the advantages: the use of BIM in the public sector, as the experience of western countries has shown, provides for a reduction in construction costs by 15-20% or more, and facility management by 50%. This, of course, is based off the level achieved by the industry today.

The cost of urgent major repairs of 400 million square meters of residential area in Ukraine is estimated by us at $ 20 billion, with the cost of design work - up to $ 1 billion. The application of the BIM will make it possible to save up to $ 4 billion on design and construction.

Compared with the international practice of BIM, with respect to planning, adoption, technology and performance, Ukraine is lagging behind the majority of developed countries. According to experts, in Ukrainian realities, the benefits of BIM can be 20-50% at the design stage, and up to 40% at the construction stage. This is possible, among others, due to the price transparency, the factory production of building components, the elimination of inconsistencies and alterations, and a clear timetable for the construction and delivery of supplies. In order to start the movement towards "information construction", we need to, on the one hand, legally ensure the provision of all the necessary data by all participants in construction and facility management as well as the accumulation of these sets of data in industry information databases. On the other hand, we need to include, in all the standards and rules of design, the requirements for the new composition and quality of documentation using modern methods and means of information modelling. Obviously, we need to think about the staff, because not a single domestic university prepares specialists in real estate management, engineering and surveying.

Ukraine is noticeably behind schedule when it comes to the introduction of BIM. Starting from now, let us think about and act on the implementation of the relevant industry program and pilot projects.

3. Pilot housing reconstruction project

The cost of preparing and carrying out urgent renovations is estimated at an average of 40-50 USD per sq. m of the total area of an apartment, or more than 1000 USD per person. On a national scale, this may amount to about $20 billion, with the cost of survey and design work estimated at about $1 billion.

At the same time, the income of 91% of the population of Ukraine is below 5 USD per day (poverty level), and 18% of the people do not earn more than 2 USD. It is obvious that the tenants do not have sufficient funds for renovation, especially the poorest families concentrated in the worst dwellings.

Under these conditions, local authorities in some cities offer financial assistance of up to 50-70% of the costs of house renovation, in particular those organized by building owner associations. To obtain this type of assistance, however, residents of each dwelling must provide project documentation and design and cost estimates. They, however, have no funds for this. There are also organizational difficulties in joint decision-making by co-owners of houses, which hold back the process of renovation. There is an illusion of low demand for renovation work and the adequacy of the necessary funds in local budgets. As a result of this situation, the condition of the housing stock is rapidly deteriorating.

Under these circumstances, it is necessary to organize, at the expense of local budgets, surveys and designs for chosen standard dwellings. On this basis, it is necessary to identify and effectively use the limited financial resources of the population and municipalities, as well as identify the problems and the extent of ageing of the housing stock of cities to justify the need for state support.

An obstacle to solving this problem is an imperfect system of design, pricing and management in construction and facility management, which increases the real need for funds. Thus, project documentation, design methods and technology are outdated, technical and organizational decisions are irrational, and the normative estimated renovation cost can be distorted and sometimes too high. During facility management, there may be no original project documentation for the residential building, which is required for restoration for the purposes of management.

With the above scale of the required renovations, the artificially high cost can be measured in billions of dollars. At the same time, the effectiveness of design decisions and management during subsequent facility management is not guaranteed. The qualifications of managers for the control of such works is insufficient, and corrupt practices are possible.

There has been a proposal to prepare standardized and effective design solutions for the renovation of standard buildings using innovative approaches and possibilities of BIM on the example of a city with subdivisions of buildings that were popular during the Soviet period. Electronic models of residential buildings, electronic passports and 3-D projects of major maintenance works will contain effective design, technological and organizational solutions, comments and methods for adapting them to specific buildings, as well as instructions for facility management companies on the use of the models in further facility management operations.

Attempts to apply BIM to existing facilities began almost simultaneously with the widespread introduction of BIM, but continue to be underestimated. However, it is in the application of BIM to existing facilities that the advantages of BIM become even more obvious, including: the ability to simulate changes in the building structure, design the building with new equipment, bring its performance up to the present level of requirements, track the current state of the building and take timely renovation measures, and competently exploit the existing facilities, both technologically and economically.

If there is an information model of the building, then the management company can be continuously aware of what the schedule of maintenance and replacement work on each structural element is, the quantity of materials needed for major renovation of the building, the cost of the work, where to find quality materials at a reasonable price, how long such works will take, etc.

It is equally important to be able to obtain accurate information in the event of possible accidents or failures. This clearly requires information databases and special computer programs.

Project Information

The urban design part of the project assumes the electronic visualization of the urban development indicating, by color, the placement of residential buildings of various types, with comments regarding the property rights and management, construction time, the necessary major renovations and technical condition, etc.

For this purpose, data from GIS-based property surveys are processed using BIM software in the context of GIS used in urban planning.

The building design part assumes:

1. The choice of representative residential buildings according to standard buildings and the creation of their 3D models based on the “lifting” of 2D drawings.
2. Parallel development of design solutions for individual building systems for major renovation, modernization and reconstruction works, linking them in a common model.
3. Schedules of works
4. Calculation of estimates in market prices.
5. Organization of the project: selection of contractors, structuring of cost estimates by contractors and deadlines for work (making payments)

6. Preparation of comments on the model usage for typical building applications.
7. Formation of the electronic passport of the residential building in the context of its structural elements, square meters of the buildings and owners, with the appropriate characteristics for the purposes of facility management, to be used for the accumulation of data on the costs of facility management (utility payments).

Periodically carried out paper "certification" of residential buildings to determine the need for renovation is very laborious and inefficient, since it requires all of the previously collected information to be explored and clarified once again after a period of time. In such a situation, it would be logical to replace paper passports of buildings with their information models.

The use of an information model of a building instead of the usual passport allows us to electronically store, search, and then analyze the collected information. As a result, the exact condition of each building is known, rather than the total percentage of the depreciation of a building that is currently used.

The developed model allows for a renovation project of a typical dwelling in a multi-family residential building to be carried out.

Thus, the use of BIM technology makes the project:

- exact (the number of design errors is reduced to almost zero),
- transparent (the project itself and all stages of its implementation are available at any time for control by both the contractors, residents, management companies and authorities),
- economically calculated (according to the model, an exact estimate is made, which is easily changed when the project is adjusted),
- allows the renovations themselves and the supply of the construction site with materials to be organized, while precisely specifying all of the relationships with the suppliers,
- allows for accurately managing the funding phases of work and work schedules,
- makes it so that, upon completion of the works, all information regarding them remains in the information model of the building (electronic passport of the house) and can be taken into account during further operation of building,
- is more flexible in the case of making any changes,
- is easy to replicate for other houses of similar types.

4. Methodical part and information base

On the basis of building classification codes, there is an intention to create a template for presenting data on the characteristics and costs of resources, contractors, and the cost of renovation works on structural elements to a regional information base (library). Such a template should form the core of the local BIM information base for other types of construction.

Structurally, BIM is a structured representation of a building; for example, it is an object-oriented representation of a building. The phrase "object-oriented" should be understood as in object-oriented analysis, design and programming with an object-oriented database. The requirements of a database, in general, include (WATT 2014) sharing data in a multiuser system, support for multiple views of data, controlled data redundancy, enforced integrity, restricted unauthorized access, data independence, transaction processing, and backup and recovery. Interestingly, this is, in fact, a superset of early requirements for product models of buildings (BJORK, PENTTILA 1989).

The development of the database causes the evolution of informational structures of the database, which includes four directions:

1. Better database schema and features.
2. Progress in database coverage - lower use of information storage outside of a database.
3. Development beyond the object-oriented data model.

Structurally, there is progress in the objects, which are richer (more attributes and functions) and more complex (more relations to other objects). There are volumes of estimations that argue that it is not possible to predefine information about renovation of buildings that someone would like to receive and data structure.

Improving the database features of BIM, as standard in proper databases with several users simultaneously changing the database having restricted unauthorized access, support for multiple views of data, controlling data redundancy and independence, and transaction processing (VENUGOPAL et al. 2012; TURK 2016). All actions within the pilot project should be analyzed and reflected in the appropriate methodology for use for other purposes such as: civil engineering, by constructors, architects, designers, subcontractors, building owners, repairs specialists, developers, suppliers of electricity, and property managers. Comments on the drafts of projects by a coordinating authority are also expected.

Therefore, the BIM model provides details of the actual existence of buildings, including geometric information, physical information and information about their legal status. It also provides for possible states after the project is modified. The complexity of most modern buildings is typically beyond the capacity limit of the staff involved, who are unable to grasp all the necessary information without relying on technology and equipment. BIM and its supportive optimization functions provide for the possibility of complex project optimization. From the project-planning perspective, BIM could integrate both project design and cost analysis so that the impact of design changes on the costs could be calculated in real-time. For more difficult construction issues, BIM could optimize designs and simulate construction, which brings about significant improvements in terms of duration and costs.

5. Results and effects of BIM

When spreading the results of the pilot project to other typical buildings and in different cities, relatively smaller funds from local budgets or residents will be required, compared to the costs of a survey, design and renovations for each building separately. The savings of residents and city budgets at these stages can be at least 30% (up to $15 per square meter, $300 per person or $600 million nationwide).

The project will provide management companies with information models (life cycle passports) of houses in a form that is convenient for subsequent management, detection and elimination of defects, planning the timing and costs of renovations, monitoring the use of space, etc. with corresponding effects.

The proposed approach will also allow, for the first time, to form, from the "core", an open regional information database on renovation and construction products, construction works and services, as well as their current market prices. Such a base can be expanded in the future to all construction products and all regions, thus creating the possibility for the spread of innovative BIM technologies with the corresponding effects.

The proposed approach will also allow for assessing, forecasting and planning the needs of cities in financing the renovation of the housing stock, especially where the main part of the housing has existed for many years and requires urgent and particularly intensive renovation, possibly with government support.

In general, the project can be extended to cities and other post-Soviet countries where typical housing stock is being renovated.

To realize the benefits of this type of digitized built environments, governments need to coordinate with the industry to develop a BIM adoption strategy, roadmap, action plan, standards and specifications.

6. Conclusions

Building Information Modelling (BIM) lies at the heart of digital transformation across the global economic and infrastructural sectors.

BIM technology and tools based on basic BIM methodology are developing rapidly, but their effective and fast use in practice is constrained by existing project frameworks and teams involved in the process, who typically resist changes that require them to deploy new BIM concepts and technologies. Therefore, it is necessary to raise awareness regarding the benefits of BIM methodology and technologies through training and education in addition to legal instruments, to collaboratively organize the project and achieve optimal results.

This leads us to conclude that more work is needed to develop new BIM solutions that will be addressed to local construction and building renovation industries in developing countries like Ukraine. The transfer of technology, that is seeking to import technology, standards, and collaborative approaches from developed countries to the context of developing countries, is necessary.

In Europe and various Eastern European countries, like Poland and Belarus, the usage of BIM is encouraged by political pressure and legal frameworks, such as public tendering, while in other countries, its application is still lagging behind.

For future development, a deeper comparison between developed and developing countries is required.

For the construction industry, a major part of the Ukrainian economy, it provides a critical opportunity to significantly improve performance. Ukraine has all the prerequisites for the rapid and successful implementation of BIM-technology. The authorities should lead the way as the main developer, accelerating cultural changes in design and construction. Innovative project delivery approaches have built a collaborative environment for constructing new buildings where the designer, contractor, subcontractors and suppliers work for the overall benefit of the owner. Renovation of existing buildings requires the development of similar contractual agreements, which, in turn, encourages the usage of BIM tools.

The lessons learned from the example project described in the article provide evidence to support the potential benefits of cost-oriented arrangements of construction activities optimized via BIM (i.e., how BIM can be utilized to improve value for money). It is believed that BIM can facilitate design and renovation phases by encompassing various stakeholders involved in the renovation process via the automated simulation of cost activity information. The implementation process of housing renovation projects must be based on reliable information, effective procedures and project teamwork relying on decision-making and BIM methodology.

At the government level, BIM adoption requires adaptation of legal and organizational frameworks as well as long-term commitment and innovative financing to get the technology into the hands of stakeholders who need to standardize the implementation of BIM tools in housing renovation.

7. References

AAPAOJA A., HAAPASALO H., SODERSTROM P., 2013, *Early Stakeholder Involvement in the Project Definition Phase: Case Renovation*, ISRN Industrial Engineering, DOI: http://dx.doi.org/10.1155/2013/953915

Advances in Production Management Systems: Smart Manufacturing for Industry 4.0, 2018, MOON I., LEE G.M., PARK J., KIRITSIS D., VON CIEMINSKI G. (Eds.): IFIP WG 5.7 International Conference, APMS 2018, Seoul, Korea, August 26-30, 2018, Proceedings, p. 256.

An Action Plan to Accelerate BIM Adoption, 2018, World Economic Forum, Switzerland, 2018, p.4, available at: http://www3.weforum.org/docs/WEF_Accelerating_BIM_Adoption_Action_ Plan.pdf.

ARAYICI Y., COATES P., KOSKELA L., KAGIOGLOU M., USHER C., O'REILLY K., 2009, *BIM Implementation for an Architectural Practice*, Managing Construction for Tomorrow International Conference, October 2009, Istanbul Turkey.

ARAYICI Y., KIVINIEMI A.O., COATES S.P., KOSKELA L.J., KAGIOGLOU M., USHER C., O'REILLY K., 2011, *BIM implementation and adoption process for an architectural practice* , in: FIATECH Conference, April 2011, USA, available at: http://usir.salford.ac.uk/id/eprint/20928.

AZHAR S., KHALFAN M., MAQSOOD T., 2012, *Building information modelling (BIM): now and beyond*, Australasian Journal of Construction Economics and Building 12 (4), pp. 15-28, DOI: https://doi.org/10.5130/AJCEB.v12i4.3032.

AZZOUZ A., HILL P., PAPADONIKOLAKI E., 2018, *Which countries have the highest levels of BIM adoption in Europe?* 13 June 2018, [cit.2018-11-09], available at: http://www.bimplus.co.uk/people/which-country-most-bim-mature-europe/.

BALDWIN A., SHEN L., POON C., AUSTIN S., WONG I., 2008, *Modelling design information to evaluate prefabricated and pre-cast design solutions for reducing construction waste in high rise residential buildings*, Automation in Construction, 17 (3), pp. 333-341.

BJORK B.-C., PENTTILA H., 1989, *A scenario for the development and implementation of a building product model standard (1978)*, Adv. Eng. Softw. 11(4), pp. 176-187.

BUI N., MERSCHBROCK C., MUNKVOLD B.E., 2016, *A Review of Building Information Modelling for Construction in Developing Countries*, Procedia Engineering, 164, pp. 487-494, DOI: https://doi.org/10.1016/j.proeng.2016.11.649.

DE KLEER J., BROWN J.S., 1983, *Assumptions and Ambiguities in Mechanistic Mental Models*, in: Gentner D., Stevens A.L. (Eds.), Mental Models, Lawrence Erlbaum Associates, New Jersey, pp. 155-190.

Directive of European Parliament and of the Council 2014/24/EU of public procurement and repealing Directive2004/18/EC, [cit.2018-11-14], available at: http://eurlex.europa.eu/legalcontent/en/txt/

pdf/?uri=celex:32014l0024&from=en.
EADIE R., ODEYINKA H., BROWNE M., MCKEOWN C., YOHANIS M., 2014, *Building Information Modelling Adoption: An Analysis of the Barriers to Implementation*, Journal of Engineering and Architecture, 2, pp. 77-101.
GERO J.S., 1990, *Design prototypes: a knowledge representation schema for design*, AI Magazine, 11(4), DOI: https://doi.org/10.1609/aimag.v11i4.854.
JOBLOT L., PAVIOT T., DENEUX D., LAMOURI S., 2017, *Literature review of Building Information Modeling (BIM) intended for the purpose of renovation projects*, IFAC-PapersOnLine, 50(1), pp. 10518-10525, DOI: https://doi.org/10.1016/j.ifacol.2017.08.1298.
JUNG Y., JOO M., 2011, *Building information modelling (BIM) framework for practical implementation*, Automation in Construction, 20, DOI: https://doi.org/10.1016/j.autcon.2010.09.010.
JUSZCZYK M., VÝSKALA M, ZIMA K., 2015, *Prospects for the use of BIM in Poland and the Czech Republic – Preliminary Research Results*, Procedia Engineering, Volume 123, pp. 250-259, DOI: https://doi.org/10.1016/j.proeng.2015.10.086.
KENNETH E., 1956, *Boulding, General systems theory-the skeleton of science*, Manag. Sci. 2 (3), pp. 197-208.
KHADDAJ M., SROUR I., 2016, *Using BIM to retrofit existing buildings*, Procedia Engineering, 145, pp. 1526-1533, DOI: https://doi.org/10.1016/j.proeng.2016.04.192.
KUIBIDA V, NIKOLAIEV V., NIKOLAIEVA T., SICHNYI S., SUDAK V., 2018, *Building information modeling in facilities life cycle cost management: monograph*, Ivano-Frankivsk, Yaryna, p 128.
LIU S., XIE B., TIVENDAL L., LIU C., 2015, *Critical Barriers to BIM Implementation in the AEC Industry*, International Journal of Marketing Studies, 7, pp. 162-171, DOI: 10.5539/ijms.v7n6p162.
MIGILINSKAS D., POPOV V., JUOCEVICIUS V., USTINOVICHIUS L., 2013, *The Benefits, Obstacles and Problems of Practical Bim Implementation*, Procedia Engineering, 57, pp. 767-774, DOI: https://doi.org/10.1016/j.proeng.2013.04.097.
NBIMS, *National Building Information Modeling Standard*, 2010, [cit.2018-11-04], available at: http://www.wbdg.org/pdfs/NBIMSv1_p1.pdf.
PAVLOVSKIS M., MIGILINSKAS D., ANTUCHEVIČIENĖ J., URBA I., ZIGMUND V., 2017, *Problems in reconstruction projects, BIM uses and decision-making: Lithuanian case studies*, Procedia Engineering, 208, pp. 125-128, DOI:10.1016/j.proeng.2017.11.029.
PENG C., WU X., 2015, *Case Study of Carbon Emissions from a Building's Life Cycle Based on BIM and Ecotect*, Advances in Materials Science and Engineering, vol. 2015, Article ID 954651, 15 pages, 2015, DOI: http://dx.doi.org/10.1155/2015/954651.
ROMANENKO Y.O., CHAPLAI I.V., 2017, *Public administration by the modern information technologiesin construction of Ukraine* // Публічне урядування, 2 (7), [cit.2018-11-03], available at: https://cyberleninka.ru/article/n/public-administration-by-the-modern-information-technologiesin-construction-of-ukraine.
SHEN Z., ISSA R.R., 2010, *Quantitative evaluation of the BIM-assisted construction detailed cost estimates*, Journal of Information Technology in Construction, 15, pp. 234-257, available at: http://www.itcon.org/2010/18
SOCIETY FOR MARKETING PROFESSIONAL SERVICES, 2015, "Evolution of Technology: Innovations in Building Information Marketing", [cit.2018-11-03], available at: https://onlinelearning.smps.org/products/evolution-of-technology-innovations-in-building-informationmarketing.
SUCCAR B., 2010, *The five components of BIM performance measurement*, Part of Proceedings: W096 — Special Track 18th CIB World Building Congress (combined with W104), May 2010, Salford, UK, University of Newcastle, NSW Australia, 2010.
The Free Dictionary, [cit.2018-11-09], available at: http://www.thefreedictionary.com/system.
TURK Ž., 2006, *Construction informatics: definition and ontology*, Adv. Eng. Inf. 20 (2), pp.: 187-199, DOI: https://doi.org/10.1016/j.aei.2005.10.002.
TURK Ž., 2016, *Ten Questions Concerning Building Information Modelling*, Building and Environment, 107, pp. 274-284, DOI:10.1016/j.buildenv.2016.08.001.
VENUGOPAL M, EASTMAN C.M., SACKS R., TEIZER J., 2012, *Semantics of model views for information exchanges using the industry foundation class schema*, Adv. Eng. Inf. 26 (2), pp. 411-428.
VOLK R., STENGEL J., SCHULTMANN F., 2014, *Building Information Modeling (BIM) for existing buildings. Literature review and future needs*, Automation Constr. 38, pp.: 109-127, DOI: https://doi.org/10.1016/j.autcon.2013.10.023.

WANG Y., WANG X., WANG J., YUNG P., JUN G., 2013, *Engagement of facilities management in design stage through BIM: framework and a case study*, Advances in Civil Engineering 13, pp. 1-8, DOI: http://dx.doi.org/10.1155/2013/189105.
WATT A., 2014, *Database Design*, [cit.2018-11-04], available at: https://opentextbc.ca/dbdesign/
What is BIM, 2013, Parsons Brinckerhof [cit.2018-11-09], available at: http://www.wsp-pb.com/en/Who-we-are/In-the-media/News/2013/What-is-BIM/.