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## Building Information Modelling as an opportunity and risk for stakeholders involved in construction investment process

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### Abstract

The requirements to apply Building Information Modelling (BIM) in public investments worldwide are currently very high. Significant interest (sometimes formulated also as a requirement) in BIM technology can be observed also among private investors. Design technology that applies BIM is supported by many private investors due to its numerous advantages. A growing group of construction designers (steel, concrete and reinforced concrete among others) and installation designers, producers of prefabricated elements (steel and reinforcements), engineers, architects, construction companies, developers, contract managers and investors in Poland and worldwide notices opportunities offered by using BIM technology in preparation and construction phase, as well as building management. At the same time experts in construction industry draw attention to the low level of competitiveness of Polish construction companies in global and European market caused, among others, by insufficient application of modern technology and innovation, as well as lack of public investor's initiative in promoting the application of BIM. It is difficult to assess the level of BIM implementation in Polish companies (due to lack of wider research results). The goal of this paper is to present the results of initial research regarding the level of knowledge of BIM and the scope of its implementation in Polish construction companies. The goal of the research was also to establish the level of interest and ability to implement BIM by public investors, architecture and construction companies. The paper also presents the scope of actions undertaken by the state, in the context of public investments using BIM.

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## 1. Introduction

Organisations involved in public procurement area globally have very high requirements for designers and contractors regarding the use of Building Information Modelling (BIM) framework. Surge in interest in BIM technology can be also observed within the private sector, to a point of requiring BIM implementation. Engineering technology using BIM is supported by government and private investors due to its multiple advantages [1]. A growing group of construction designers (steel, reinforced concrete or concrete among others), installation engineers, components manufacturers (made of steel, as well as prefabricated reinforcements), engineers, architects, contractors, real estate developers, contract managers and investors in Poland and globally notices the multitude of opportunities created by using BIM during design, construction and operation of a building. Simultaneously construction industry experts raise the still low level of competitiveness of Polish construction companies in European and global market caused by insufficient use of modern technologies and innovation, as well as lack of initiative on the side of public investors in promoting BIM.

The numerous advantages of using BIM have been noticed by the authorities in many European countries. In countries where BIM application is actively developed the state acts in order to encourage its implementation and development. The most advanced in this area are the United Kingdom and Scandinavia, where BIM implementation is centrally guided by the government and its agencies (since 2016 in the UK BIM has to be implemented in all centrally financed public projects) that assign significant financial resources for this effort. Actions on the state level with regards to public investment can be recently observed in Europe. For example [2]: the 2014 directive of the European Parliament and Council on public procurement [3] encourages all member states to implement BIM in order to maximise value in public projects, in France a Directorate for Digital Construction has been created within the Ministry of Housing and a National Plan of Digitalisation promoting BIM has been announced, in Germany the Construction of Major Projects Reform Commission created a BIM Working Group in order to create a BIM strategy for Germany and increase its implementation in projects, in Austria the Austrian Standards of BIM have been published.

Recommendations regarding the use of BIM, created at EU level, convince organisations interested in this technology to start modernising their software, improve the processes and bear the cost of introducing BIM. Currently a trend can be noticed in global construction industry to use BIM at design and construction stages, as well as building maintenance. A lot of companies implements BIM to achieve competitive advantage and increase efficiency. Numerous studies confirm rapid implementation of BIM in construction projects worldwide [4].

## 2. General assumptions of BIM framework

According to the National Institute of Building Sciences the Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition. Information is defined from the initial conceptual phase of the project all the way to demolition. The basic assumption of BIM is close cooperation of all stakeholders involved in the investment project (including the investor, architects, contractors, equipment suppliers, components manufacturers, construction materials suppliers, technology suppliers and property managers) at every stage of the project's lifecycle. Their cooperation facilitates collection, entry and update of current information that is important for each stakeholder to support their decisions [1,5]. The main advantage of the system is digital storing of all characteristics of the building. It is based on specification of parameters of each element comprising the building. Their definition includes material and geometric parameters (size, location, scope of integration with surrounding elements and with the whole building), used in construction analysis of the building; it also includes definition of cost and time factors specific to each element (for example single reinforced concrete pillar, window, ventilation pipe, equipment) that have not been before defined in such high level of consolidation [1].

The scope of BIM possible use is strictly linked to the course of construction process. BIM framework assumes that a building is perceived as a product with its lifecycle [4].

Another concept widely used in the context of BIM is Integrated Project Delivery (IPD); its main assumption is integration of people, systems, structures and business practices in the construction process, using skills, experience

and knowledge of all team members in order to optimize resources and efficiency in all phases of design and construction.

BIM introduces multiple challenges for construction and IT industries. This technology, being further development of computer-aided design (CAD), includes also methodology of key digital information management during consecutive phases of the building creation and lifecycle. To implement the concept mentioned above the tools and technology used must adhere to the assumptions listed [6,7]:

- Interoperability of the digital presentation of the object (independent of any specific software),
- The building model contains information that can be automatically processed by all stakeholders of the investment process through data stored in Industry Foundation Classes (IFC) standard, created by Building Smart Alliance (BSA) and being an open file format used for exchange of data and information between various applications,
- Information in the model is up-to-date (every design change is reflected in the model) and reflects reality (construction fully matches to the digital model),
- The digital model accompanies the building throughout its lifecycle, thanks to using the COBie (Construction Operations Building Information Exchange) standard; the standard includes storing data regarding materials used and equipment installed (including name and data of the manufacturer and supplier, technical parameters, product specification, warranty information, list of spare parts, maintenance schedule) and other documents necessary for proper use and maintenance of the element,
- Information stored in the model is accessible (within appropriate scope) for all stakeholders and the model functions as an area of cooperation for all stakeholders involved in the project – in line with the IPD concept,
- Elements of the model contain information stored on specified Level of Development (LoD), available for all stakeholders.

### 2.1. Multidimensionality of BIM

The building model created in BIM technology can be generated on various dimensions (3D – 7D), depending on information required by the architects, engineers, contractors, surveyors, owner, or building manager. For example, parametric description of material and geometric characteristics on 3D level makes the model useful for companies involved in manufacturing of precast concrete elements, or creating virtual walks to assess functionality of the future building and for marketing needs for interiors visualization. 3D BIM model can be used by engineers for calculations and analysis of static and dynamic strength [8].

4D level in BIM framework refers to the time of construction. Model defined this way may be used for planning of the construction phases, based on construction schedule, as well as actual time management during construction, as a logistics support tool (deliveries, construction site management, equipment rental, traffic organization and health and safety management). Time schedule can be visualized as animation, as well as sequential phases reflecting milestones, taking into account the critical path and dependencies between processes, representing also the model-schedule relation [8].

5D allows for processes related to engineering costs – generating the bill of quantities, later the priced bill of quantities including all changes made to BIM model. It is also possible to create and analyze various financial scenarios for the project, as well as conduct the current analysis of estimated and actual expenditure, for partial payments.

Dimensions 6D and 7D are used in the management of completed facility. 6D relates to sustainable development i.e. estimating and optimizing energy consumption and costs of use and maintenance of the building. The essence of 6D in BIM is the monitoring and verification of the building for LEED (Leadership in Energy and Environmental Design) certification, assessing location and type of land for the investment, energy and water consumption, the quality of internal environment, type and durability of materials used and innovation.

7D is related to the building management and includes procedures and user manuals, renovation and modernization planning, inspections and safety procedures (for example fire procedures). The main part of 7D level



is COBie. Effective use of 7D requires constant updates to the model during construction, because only an up-to-date model can be used to make decisions regarding building maintenance in the long term [8].

### 3. Stakeholders interested in introducing BIM – range of the system possibilities

In the building investment process there are many stakeholders that are, for various reasons, interested in introducing BIM framework. Beneficiaries of using BIM technology include: public and private investors, engineers, contractors, building owners, property managers [9].

Investor – in order to make an effective investment decision investor requires mainly information regarding profitability of the planned investment. Profitability is defined as the entire cost of the investment (price of 1 m<sup>2</sup> of usable space or 1 m<sup>3</sup> of the building's volume), including also additional factors: investment attractiveness, location, usability (infrastructure such as roads or trains, finishing standards etc.). When using BIM it is possible already at the initial phase to verify the investment profitability and by controlling the budget it is possible to control the building parameters to increase profitability [9].

Engineer – the digital model increases the possibilities to modify the building design, shortening design phase, eliminating collisions and mistakes that currently (when using traditional design techniques) generate significant costs. Increased model operability allows for changes to be introduced also on later stages of design, for flexible work and adjustments of the designed and constructed building to changing investor requirements. The possibility of constructors and installation designers working in parallel (starting with architectural concept all the way to trade design and detailed construction design), as well as automated generation of technical documentation are important elements that help shorten the design process. This is possible due to IFC standards and hierarchical access that allows for full coordination and maintaining consistency of the design during parallel modifications using the central model [9].

Contractor – if the digital model is created using information from levels 4D and 5D the contractor can generate the schedule of works and priced bill of quantities, depending on the current need for those documents. Flexible format of automatically generated documents can be used for example for partial payments or to assess the costs of additional works that were not initially planned. Other important aspects are the logistics and technology and the possibility of using BIM in this respect. Using software integrated with BIM the contractor can obtain information regarding possible placement of cranes, detailed deliveries schedule, scope and timelines of prefabrication of atypical elements or construction erection using specialized equipment [9].

Advantages of using BIM are noticeable even if only the basic aspects of the framework are implemented. Information generated on each level can be used separately, depending on the current needs of each stakeholder. Every piece of information stored on a given level of the model affects information scope available on the next level and at the same time is integrated with specific phase of building's lifecycle.

#### 3.1. Opportunities arising from the implementation of BIM framework

BIM technology that currently helps to improve the state of construction industry in many countries is the natural direction of the industry's development.

BIM including the entire programming and design process, allows the stakeholders for better understanding of the project, as well as efficient, fast, accurate and effective work through integrating work of many individuals (thanks to using IFC model), introduction of changes and analysis of alternative scenarios [10]. Thanks to high effectiveness of information shared between the stakeholders of the construction investment process, BIM eliminates mistakes, collisions, repetitions and omissions in the project documentation at the initial stages of investment design; it provides solutions addressing the needs of all stakeholders (if environmental aspects are included – also at the stage of building operation), and the quality of actions taken. The simulations and analysis done timely, based on up-to-date data, help to minimize the risk of delays and cost increase and manage project changes effectively [11].

Using BIM gives contractors significant and lasting benefits, including building a good image and increasing their attractiveness by offering a new service, which in longer term helps to acquire new and retain old customers, resulting in higher number of contracts. Wide spectrum of BIM application throughout the building's lifecycle



results in a large group of beneficiaries. This technology in the near future will be the standard used in investment projects globally, comparable to Computer Aided Design (CAD).

According to [12] the benefits of implementing and using BIM framework include:

- Reduction of extra-budgetary spending and costs generated by changes by 40%,
- Accuracy of cost estimates reaching 3%,
- Reduction of time spent on creating priced bill of quantities by 80%,
- Savings up to 10% of contract value thanks to identification of collisions in the initial stages of the project,
- Shortening the time of the project completion by around 7%.

### 3.2. Risk related to BIM introduction

Despite many undisputed advantages BIM technology also includes risks. Using BIM allows for significant shortening of design phase, which in result eliminates from the market the smaller companies (engineers, architect studios), which work based on ‘traditional’ solutions.

To achieve the benefits of common and current arrangements and generate identical and up-to-date information, all stakeholders (investor, engineer, and contractor) have to use the open format used for data exchange between various applications (IFC), they also have to be experienced BIM users. Lack of experience in this field may result in errors in building model.

An additional issue may be the lack of interest among engineers in using IFC format (one of the reasons for this is that it is still not perfect). ‘Natural formats’ (.dwg, .fvt, .tsc, .nwd, .ams) are still considered as sufficient for exchanging documentation among stakeholders of the construction investment process [1]. Therefore in practice the approach mentioned may cause problems for investors, engineers and contractors in implementing and using this solution.

It should be stressed that public sector requirements regarding BIM implementation focus mainly on complex and long-term projects. Using BIM technology involves implementation of specific guidelines (regarding the format of data etc.), change of organizational procedures regarding planning and certain financial investments. Construction industry stakeholders (engineers, architects, contractors) have to adjust to constantly growing number of regulations and requirements regarding using BIM in Europe and globally, otherwise they risk losing contracts [2]. Those requirements should be defined by Polish investors in a clear and transparent manner. Lack of clearly formulated expectations regarding using BIM, by organizations managing public funds in Poland, results in sceptical attitude towards BIM among engineers, architects and contractors, and in them delaying spending required to implement BIM.

Designing in BIM technology involves using a library of structural elements with previously defined geometrical and material parameters. It needs to be highlighted that currently there is lack of complete information base to build complex and atypical models of future buildings. Current resources that are the basis of BIM allow building simple and standard models (both in the aspect of construction and installation design, as well as schedule and pricing of specific elements or works). The possibilities of digital representation of physical and functional features of the future building are also limited. The scope of information stored in the database does not allow for unique and innovative design solutions, in such cases the information about the building in generated model is limited and incomplete not sufficient to make informed decisions during the building lifecycle. Some imperfections have also been noticed with regards to cross trade coordination.

Problems may also arise in associating current prices (including certain level of works aggregation) with the library of BIM elements, resulting in issues with pricing construction works and associating the correct prices to model elements created by architects, engineers and installation designers.

Another important element may be the human factor i.e. team integration on organizational and legal level. It involves implementing organizational and legal changes (copyright agreement etc.) that will bind all stakeholders into one complementing team. Team cooperation should be based on the appropriate software that will assure hierarchical access to documentation, at the same time assuring timely notification about changes and updates and allowing monitoring the actual progress of works [1].



#### 4. Current state of BIM technology implementation in construction industry in Poland

Taking into account the advantages of using BIM, the current state of construction industry in Poland and the direction of European legal regulations related to public investments, in the perspective of few years Polish organizations involved in construction projects will be have to implement and use BIM framework.

In the next part of this paper authors present result of a study, carried out via survey in the fourth quarter of 2016 among 32 organizations (55 organizations were selected for the study, but only 32 have provided answers) organizations preparing and executing public investment projects, regarding the level of knowledge about BIM technology (Table 1).

Table 1. Companies that participated in the study.

Type of company	Number of companies
Investors – institutions and public organizations	7
Architecture studios	17
Construction contractors	8

Source: own data

The purpose of the study was also to identify the level of interest, possibility and ‘readiness’ of the subjects for BIM implementation.

The study has shown that only 37% of public investors have come across the concept of Building Information Modelling and 89% of them have no knowledge about it. It has been established that only 61% of representatives of public institutions participating in the study was aware of the resolutions of Directive of the European Parliament and of the Council of 26 February 2014 on public procurement [3] and none of the investors plans to use electronic tools (which is facilitated by the directives) during preparation for public tender process.

The study results, conducted among architecture studios, have shown that 84% has come across the concept of BIM and 55% of them assessed their level of knowledge in that regard as medium. It has also been confirmed that 47% of architecture studios participating in the study can generate digital model with details at LoD 350.

Among construction companies participating in the study, representing general construction contractors, 64% has come across the BIM concept, 36% assessed their knowledge of the subject as medium or low. Only 23% of surveyed companies had skills to coordinate construction process using levels 4D and 5D.

The best results regarding knowledge and possibilities of BIM implementations have been noted among architecture studios. This is probably a result of the requirements of private investors operating in Polish market that are interested in using new technologies.

#### 5. Conclusions

Complex and multi-faceted character or the widely defined construction investment process requires detailed definition of the responsibilities and expectations, rules of cooperation and obligations of all involved stakeholders [13]. Lack of precision in those areas resulting in conflicts arising during recent public investment projects in Poland, was the cause of numerous claims and litigations [13]. To avoid the mistakes that occurred during public investment projects co-financed by EU in recent years, EU has provided specific solutions for investments for 2014-2020 cycle, they are included in the Directive on public procurement of 26 February 2014 [3,14,15], [16,17]. Numerous recent amendments of Polish law [18], also in the construction sector, are directly related to the Directives adopted by European Parliament. Among those are also regulations significant for implementation of BIM concept in Poland.

Development of information technology significantly affects all industries. Therefore also construction industry has to adjust and adapt to the possibilities offered by digitalization. The concept of BIM is a compilation of previous experiences, including various aspects of construction process (time, cost, technology, quality, building operation), compiling them in a compact digital model. An important element of complete implementation of BIM framework



is unrestricted access of all involved parties to the complete transparent model generated in the appropriate format (for example IFC).

The conducted considerations and analysis of initial research results regarding the level of knowledge about BIM, its implementation, the level of interest and abilities of public investors, architects and construction companies with regards to its implementation support the below observations and conclusions.

- The advantages of BIM implementation are not recognized widely by Polish public investors and are not implemented by construction companies. The best results regarding the knowledge and ability to implement BIM have been observed in architecture companies. It should be noted that the level of knowledge and ability to implement BIM in Polish construction companies is generally low. In the near future it may cause significant disproportions (lack of competitiveness and decrease of efficiency) between local construction companies and their European and global counterparts.
- Research results confirm also the lack of BIM specialists. In order to correctly and permanently implement BIM in Poland the trust has to be built between stakeholders of construction process to allow them to share information, this can be achieved, among others, by the new approach of design teams made aware of the advantages of long term investments in knowledge and skills.
- One of the factors raised by interviewees was the lack of external impulse, such as market need of the new technology and lack of encouragement from public investors to apply modern working methods. The concept of Building Information Modelling is the natural direction of development of the construction industry. Its effective implementation and application includes also change in the way of thinking by all participants of the construction process, especially public investors that initiate large projects, regarding the rules of cooperation, advantages of current information exchange and flow (for example for discipline of public finance), ability to generate and analyse scenarios to support decision making process, risk management [19,20] and alternative approach to project management. In practice the large delay in BIM implementation can result in significant decrease of Polish market attractiveness for investors and increased activity of foreign construction companies, instead of the local ones.

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