Implementation of BIM Technology into the Design Process Using the Scheme of BIM Execution Plan

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Abstract. Digital Revolution is one of the most up-to-date topics in the construction industry – and not even in that. According to the spreading of a new trend in Building Design, Construction and Facility Management – using of Building Information Modelling Technology and its Management, there are going to be many changes in the way to develop the design process and other phases of building life cycle. BIM Technology use is present in the whole life cycle of buildings and other constructions and is able to connect all participants of building process in effective way. BIM Technology as a new trend in building design reveals the need to set up effective processes, their parts, participants, their responsibilities, goals and the way to reach goals, etc. The main philosophy of BIM Technology´s implementation into the design processes lies in the BIM Execution Plan. This Plan should be specified for specific activities in specific environment and for specific participants in the whole construction process. These processes should be well conceived and managed. That’s way we can undoubtedly replace the “M” in BIM (Modelling) by the “M” as a Management. This paper contributes to the further thoughtful strategy for the specific process of the design – from the designer’s point of view and implementation of BIM Technology into this process in order to make the design process more effective. There are identified possible barriers for this implementation, their main causes, proposal to remove these obstacles and outlined a possible process of effective design using BIM technology and its principles. It is important to realize, that the implementation of BIM Technology in the design process will lead to a better virtual reality of the building and thus its transformation into physical reality will lead to a better construction and allow for greater cost savings not only during construction phase, but also in other phases of the building life cycle, especially during its use.

1. Introduction
BIM Technology is nowadays trend in way of managing knowledge, information and all processes connected to the whole building lifecycle. This technology offers wide range of possibilities for great effectiveness of every process connected with not only buildings itself, but also in infrastructures. Many researchers are solving problems within management of building design.

Building design, nowadays, has many faces. There are many different ways, processes and software used among designers. We can find a project documentation created in 2D software, also in 3D software. As in handwriting, every designer has his own way in building design: different tools, different graphics, etc.
BIM technology gives many new possibilities to model everything and that is why the processes in which BIM technology is used must be modelled and defined. According to the better comprehension, visualisation and communication between different software, the Industrial Foundation Classes (IFC) open BIM format is used in computer aided design (CAD). P. Barnes and N. Davies mentioned, “BIM permits everyone involved in the process (including the client) to have a clear understanding of the concept design by providing the ability to visualise (by way of a virtual 3D model walkthrough) what is actually to be built” [1].

2. Design process

Design of the building is at the beginning of building lifecycle. After the initiation of building lifecycle by investor comes the design which starts with a rough idea and ends with a detailed design and processing of the idea of a future reality. In construction industry, the range of materials used, technical requirements, hygiene requirements and environmental requirements complicates design. It is in creation of investment-intensive long-term objects. In construction, there are usually several viable solutions, and the designer should make the optimal solution decisions. As mentioned in [2]: “The efforts made on the project documentation created by using traditional technology and by using BIM technology are approximately the same (according to the area under the Mac Leamy`s curve [3]. But it differs in the amount of efforts made in different phases of building lifecycle”. Phase of design process seems to be the most divergent phase in the effort made on creation of project documentation.

Essentially, this means that the correct and detailed design of the building leads to its most efficient erection, both in terms of time, above all the low demands on the additional requests for information, and in terms of financial demands. The design of the building allows for the most accurate planning of the construction, the detection of collisions or the incomprehension of the individual professional parts of the documentation, leading to a small number of necessary additional changes or modifications in the construction project. The mistakes that come up when the project is erected are financially demanding and often involve a lot of additional work, time-consuming construction, thus delays, as well as often less aesthetic solutions.

2.1. Design process in traditional way of project model creation

Design of the building is traditionally based on drawings of architect or another designer, than it is further developed by other participants involved in design phase of building life cycle.

Comparison of effort and effect according to the Graphic Curve by Patrick MacLeamy from HOK [3] shows where the design phase lies within the building lifecycle. The traditional way of modelling and the design phase does not show the major effort which is made during the creation of building project. In design phase using traditional way, there is a low cost of design changes, but the high ability to impact cost and functional capabilities of building.

At the opposite site, design phase using BIM technology shows the major effort within the whole creation of building design. This effort includes more detailed idea development about the project.

2.2. Design process performed within the principles of BIM Technology

Design process performed within the BIM Technology ranges from a simple design of matter to a precious detailed design of a building. There are many participants, who are entering to the design phase in building life cycle. At first, the architect comes and provides a rough design. Than other participant enters design process and they are adding more and more detailed information according to individual professions. Work of all these participants is done in a single environment, in a single model. Every participant gradually enriches the design, the virtual reality of the construction, with new graphical and non-graphical data.
The process of design creating is very demanding to plan correctly the entry of the individual participant into the model with their professional focus. Every participant entering the design process has his own request for information from others and subsequently, based on the information received, moves the entire project forward with his new additional information and inserted data. This process should be well-planned. For this planning, within the BIM Technology, as for planning of other phases of building life cycle, the BIM Project Execution Plan is very helpful. Well-developed BIM Project Execution Plan help the success of BIM project.

3. Case study: design of apartment building in the legislative conditions of the Czech Republic

Design process of apartment building is quite simple case for determination and demonstration of communication, which is needed to be performed.

According to the legislative conditions of the Czech Republic, the content and form of the project documentation must comply with Ministry for Regional Development’s Decree no. 499/2006 Coll., on construction documentation (as no. 62/2013 Coll.). In this Decree, the division and content of project documentation is determined. If we compare traditional way of modelling and BIM technology, the condition to meet the requirements of this Decree do not change. Difference between using these two approaches to project documentation lies in the way the project documentation is created. The output is the same, but with using BIM Technology, digital model with current data is create and the processes by which the documentation is created are simpler, clearer and easier to coordinate among the participants, not only in the design process.

Decree no. 499/2006 Coll., on construction documentation (as no. 62/2013 Coll.) provides conditions for project documentation in many stages. For our case, we will focus on the stage called “Documentation for building permission”. There is a BIM common language called Level of Development (LOD). LOD consists of Level of Information (non-graphical information) and Level of Detail (graphical information). American Institute of Architects (AIA) has developed LOD Specification, which is a detailed interpretation, and which defines visualized model element characteristics in various levels of development [4]. This stage of project documentation, “Documentation for building permission”, corresponds to the LOD300, according to work of Active working group WG#03: BIM & Implementation from Czech BIM Council “Level of Development draft assignment to the individual stages of project documentation in the Czech Republic” [5].

Project documentation according to Decree No. 499, Attachment No.4 [6], project documentation for building permission is divided in many parts:

- A. Covering report
- B. Comprehensive technical report
- C. Situation drawings
- D. Documentation of objects and technical and technological equipment
- E. Document part

In the phase of design, we will focus on part D. Documentation of objects and technical and technological equipment, further part D.1. Documentation of a building or engineering building. It has these parts:

- D.1.1. Architectural and building design solution
- D.1.2. Construction design solution (Static solution)
- D.1.3. Fire Safety solution
- D.1.4. Technics of building environment
Medical-technical installation,
- Air conditioning and heating, cooling
- Measurement and control,
- High voltage electrotechnics,
- Electronic communications,
- and other

For every part mentioned above, different participants, the professionals, of building design process are responsible for the solution. Every part of a documentation has two parts:

- **Text part** with a verbal description of the solution, solution specifications, used materials and other non-graphical information
- **Technical drawings** with graphical information, element’s dimensions, etc.

3.1. **Case study: design of apartment building using traditional way of modelling in the legislative conditions of the Czech Republic**

As mentioned above, design process is the part of building life cycle where most efforts lie. In design phase, there is usually a cooperation of many participants within the project. In order to create design, which is regarding all technical requirements, hygiene requirements and environmental requirements. There is a need to coordinate all these participants.

At first, for each building design, the investor is the initiator of the launch of the whole life cycle of the building. Investor is the first participant within a design process. Investor provides a basic mass solution for the construction, purpose of the building and layout requirements. In cooperation with architect, he tries to define the rough design of the building. This rough design of a building is an output of investor’s part of a design and, at the same time, is the input for architect, who forward the project development during his work on design phase and create an architectural study as an auxiliary documentation.

Designer, also chief designer and architect in one person in this case, develops investor’s proposals according to all technical requirements, hygiene requirements and environmental requirements according to legislation. It means that designer forms the basic drawings (ground plans, sections, views and 3D views). The output from designers work at this stage is a completion of mentioned drawings, which are the input for work of other participants. These drawings are basics for the D.1.1. part of project documentation (first version).

Other participants, who enter in to design phase, are professional designers of: construction design solution (static solution); fire safety solution; medical-technical installation; air conditioning and heating, cooling; measurement and control; high voltage electrotechnics; electronic communications; and others.

After the chief designer, at first, designer of static solution enters the project design. His goal is to check solution designed by designer (basics for part D.1.1.) from the perspective of static solution, make suitable changes in project and further develop the project by adding more information. Usually, designer of static solution uses his own data model (drawings) – in different software according to his own habits in documenting, or just the different data model in the same software, which is further developed. It means, that designer of static solution should to announce the necessary changes in project to the designer, because of work on different model. Than he adds further information about the construction design solution, e.g. the reinforcement of concrete parts, profiles of wooden elements, etc.,
according to the technical requirements from the view of bearing capacity. He reveals the D.1.2. part of the project documentation. This further developed project design should be returned to the chief designer, who is responsible for drawing any changes in his data model, which is simpler, hence poorer, than the data model (drawings) of designer of static solution. Chief designer needs to modify the data of part D.1.1. to record any changes in mass solution of the building, layout requirements and plotted building elements, e.g. the elements thickness, profiles, etc., according to the static solution D.1.2.

In next phase, chief designer usually gives this output (D.1.1. drawings modified according to requirements of designer of static solution) to the designer of fire safety solution, who, same as a designer of static solution, may use his own data model (drawings) – in different software, or just the different data model in the same software. He develops the project further by adding requirements and information about elements within the project to fulfil the requirements for fire safety set in legislation. Than his output (drawings with fire safety solution - part D.1.3.) needs be returned to the chief designer, who, same as in the previous step, modify his documentation (part D.1.1.) according to the changes made by designer of fire safety solution.

Than chief designer usually gives this output (drawings modified according to requirements of designer of static solution and of designer of fire safety solution) to other professionals (creators of the part D.1.4. project documentation) at the same time, because major changes are not expected in the project design already made. These professional designers are: designer of medical and technical installations; air conditioning designer and heating, cooling; designer of measurement and regulation; designer of heavy current electrical engineering; electronic communications designer; and others. These professional designers use these drawings as an input for their work. Same as designer of static solution and fire safety solution, they may use their own data model (drawings) – in different software, or just the different data model in the same software. They add further information according to their profession, the part of documentation. Designer of medical and technical installations design the solution of water and sewerage systems. He usually draws new lines into existing drawings (from chief designer) and adds further information about installations. The same work other professional reveal.

After all this work, chief designer gets the outputs from all participants. He needs to identify all solutions from all participant work that are conflict with his prime project design and make the appropriate editing of the project design. E.g., when designer of medical and technical installations designed the pipes leading through the building foundations, he needs to create transitions in the foundations. If he does not do so, the absence of transitions will be revealed during the construction process and it will have to be constructed additionally, which increases the demand for the performance of construction, the time and the cost of the construction.

It means that the chief designer, as a responsible person for compliance of project documentation, needs to develop many efforts for coordination of all participants who are involved in the design of the building. Chief designer needs to forward the information-relevant changes to the project to all other participants to record these changes in their parts of project documentation and thus to produce the final versions of the individual parts of the documentation. This process, in traditional way of building design, seems to be very time-consuming and mainly it has very high demands on the psychic activity of the chief designer and misunderstanding between participants or inattention of participants may cause many failures and discrepancy of the documentation [3]. We can find from different to contradictory information in different parts of the documentation and this is undesirable.
The process described above is carried out in figure 1. The process is presented using Business Process Model and Notation (BPMN) standard [7], [8].

![Figure 1. Process Map of Case study: design of apartment building using traditional way of modelling in the legislative conditions of the Czech Republic.](image_url)

Figure notes:
- Type A – oral / email presentation
- Type B - auxiliary documentation
- Type C – project documentation according legislative
3.2. Streamline the building design process for BIM technology

According to the process map of case study above, obviously, the traditional way of modelling offers huge environment for making mistakes, because there is a lot of partial processes and data sharing between all participants. Every process or data sharing offers space for error in project design. Between participants, data sharing is usually base on 2 types of data: Type C – project documentation according legislative and Type A - oral/e-mail presentation, which helps to share, record and respond to changes provided by previous participant. The output of all these processes should be the most compliance project documentation – part D.1. Documentation of a building or engineering building.

The main issue of chief designer is coordination activity when participants are using different data models within the same software or within different software. It means that chief designer has to be able "read" different data models or drawings and compare them manually, to provide final check compliance of project documentation. BIM technology offers using software by all participants in different layers and levels of information. All participants entering in to the project design are adding information - project further developing - from their profession into one single data model. This model is capable of detecting collisions and make them visible to users of this model. In this model, each participant can work with specific data relevant for their part of design in order to provide clear documentation of professional’s part and, at the same time, the model contains all information from all participants in order to detect collisions and work with one right information. It reduces from different to contradictory information in different parts of the documentation. The coordination of all participants is much easier for chief designer within the BIM Technology. That’s why the creation of project documentation using BIM Technology is more reliable, time and financially less demanding.

Last, but not least, advantage is for investor, who always has access to the actual virtual reality of his planned building work. He is allowed to control the respect of his proposal and comments, in the next stages of the building life cycle, he is allowed to control observance of the time schedule of the construction or have access to the virtual reality of the current form of construction during its operation and use.

4. Possible barriers for using BIM technology

The use of BIM technology means to change completely the approach not only to the design itself but also to the processes linked to the entire building life cycle. The main barriers from the perspective of the designer is the use of the appropriate tools that support the BIM technology, which may be time-consuming when using new software starts. It is not just about using the new software tools by all participants, but also about working with data, the accuracy of their input, the content and amount of information they have entered, as well as their sharing between participants. BIM technology forces all participants in the design process to work more closely and more carefully than they have been forced so far into the traditional approach to building designing. It is important to note that the increased efforts made by using BIM technology has a return especially in the next stages of the building’s life cycle, thus during the realization and especially during the use and management of buildings.

Other important barrier is absence or insufficient implementation of BIM into legislation. Nowadays, in many European countries is BIM in some phase of implementation into legislation. The support of BIM technology by the legislation will certainly lead to its wider use, saving many resources (time, cost, environment, etc.) and better quality of buildings and other constructions.

Other barriers may be cost of implementation (software and training) in building design offices, continuity of supply chain, ownership and intellectual property, etc. [9].

5. BIM Project Execution Plan in design phase

For proper using of BIM Technology, there is a need to define all the participants in the process, their responsibilities and sub-goals. BIM Project Execution Plan, according to Publicly Available
Specifications (PAS), is defined as a “plan prepared by the suppliers to explain how the information modelling aspects of a project will be carried out” [10].

Basic principles of BIM Project Execution plan lie in definition of participants and goals, proposals of processes within the BIM project, definition of the information exchange and definition of infrastructure helping the implementation of defined processes within the project. Well-prepared BIM Project Execution Plan leads to successful implementation of BIM Technology into whole processes provided in the entire building life cycle.

6. Conclusion

As revealed in the chapter 3, traditional way of building design and creation of project documentation has very complicated workflow. There are many partial processes, which are not well-defined. This leads to misunderstanding between participants, time and cost consuming collisions and discrepancy of final project documentation. This is a cause of many failures during the building construction and other time and cost consuming activities performed to failures corrections.

BIM Technology offers to find the optimal workflow with precise, high quality and effective sharing of information that leads to a correct and sufficiently detailed design. Next to that, it will reduce the demands and work pressure on the main designer, will provide better project documentation and thus better construction and saves many resources (time, cost, environment, etc.).

In order to achieve desired results, it will be necessary to modify currently used processes according to possibilities that offers BIM. Transfer from traditional way of building design to BIM technology has many barriers from many perspectives. For proper using BIM Technology, many key issues still need to be solved, e.g. technical standards, content of BIM documentation, ownership and intellectual property, electronic building permitting, implementation in to education and many others.

Acknowledgment

This work was supported by the Grant Agency of the Czech Technical University in Prague, grant No. SGS16/200/OHK1/3T/11

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