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MAJA BARTOSZEK*, MICHAŁ JUSZCZYK**

SELECTED PROBLEMS OF BIM-BASED PLANNING OF CONSTRUCTION WORKS – CASE STUDY

WYBRANE PROBLEMY PLANOWANIA ROBÓT BUDOWLANYCH Z WYKORZYSTANIEM BIM – STUDIUM PRZYPADKU

Abstract

The article presents the problem of planning works based on the BIM model of a building. The authors briefly discuss the possibility of using BIM as a tool for planning works, and then present the case study. In the case study method in a synthetic manner the planning process presents works based on a model residential building construction. The advantages and opportunities as well as the problems of using BIM as a basis for the planning process of construction works are discussed and commented in the conclusions.

Keywords: BIM, scheduling, construction planning, BIM based planning

Streszczenie

W artykule przedstawiono problematykę planowania robót budowlanych na podstawie modelu BIM obiektu budowlanego. W zwięzły sposób omówiono możliwości wykorzystania BIM jako narzędzia do planowania robót budowlanych, a następnie przedstawiono studium przypadku. W syntetyczny sposób przedstawiono proces planowania robót budowlanych w oparciu o model konstrukcji budynku mieszkalnego. We wnioskach omówiono i skomentowano zalety i możliwości, a także wybrane problemy wykorzystania modeli BIM w procesie planowania robót budowlanych.

Słowa kluczowe: BIM, harmonogramowanie, planowanie realizacji robót budowlanych, planowanie oparte na BIM

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* Eng. Maja Bartoszek, Datacomp sp. z o.o.

** PhD. Eng. Michał Juszczyk, Institute of Construction and Transportation Engineering and Management, Faculty of Civil Engineering, Cracow University of Technology.

1. Introduction

Civil engineering is nowadays important part of, generally speaking, industry. To make construction process faster and more efficient engineers tend to invent more and more sophisticated methods both of buildings' design and constructing of the structures. A constant trend of improvement of construction planning and control through the whole period of works performed on a building site is needed and should be started from the very beginning of construction works start, or even before that time.

One of the most common problems associated with such situations is lack of communication and management systems, which are not effective enough to react instantaneously. The only way to get a solution of these types of problems could be usage of software which is more flexible, intuitive and comprehensive.

In this paper, there is Building Information Modeling (BIM) to be described as an irreplaceable tool in future construction management systems. It shows basic rules which need to be followed during BIM-based management of construction works. The aim of this article is to present concisely selected problems of the process of construction works planning. The case study for a certain structural model of a residential building is included in the paper. The starting point is the analysis of the model. The authors presented successive stages of the planning process (quantity take-off and scheduling) aided by the selected BIM tools (computer applications) which are currently developed in Poland.

This paper topic alludes to the previous works and research (i.a. [4, 7, 10] made by the academics from the Institute of Construction and Transportation Engineering and Management, Cracow University of Technology) in the field of widely understood applications of BIM in construction management.

2. BIM as a tool in construction planning and management

According to Smith [8] BIM (a building information model) "(…) is a digital representation of the physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle from inception onward."

"Building Information Modeling (BIM) is one of the most promising developments in the architecture, engineering and construction (AEC) industries. With BIM technology, an accurate virtual model of a building is constructed digitally. When completed, the computer-generated model contains precise geometry and relevant data needed to support the construction, fabrication, and procurement activities needed to realize the building" [2].

According to these definitions, on one hand, BIM is a process of modelling information, on the other collection of building information data, a spatial representation of a structure. Actually, BIM is all of it itself and even more.

The starting point is a 3D model of a building which contains geometry and other adjectives such as building components (walls, windows, stairs etc.) and its characteristics and parameters. However simulation of a building behavior is also possible on the grounds of those features.

According to another definition BIM can be related to as an intelligent simulation of architecture. According to them, there are six main characteristic of such simulation [east]:

– digital,
– spatial (3D),
– accessible,
– measurable (quantifiable, dimension-able, and query-able),
– comprehensive (encapsulating and communicating design intent, building performance, constructability, and include sequential and financial aspects of means of method),
– durable (usable through all phases of facility's life).

Those characteristic may seem idealistic and hard to be fulfilled at once. As a modern tool in construction industry, there is a belief that in the next few years all of the demanded features will be achieved.

Furthermore, there are a lot of mistakes and misunderstandings about what actually the BIM technology is. First of all, BIM models must be not only 3D, but also represent other pieces of information (attributes), for example cost. What is more, BIM model must be equipped with parametric intelligence – it means that they must be equipped with a possibility to adjust their position and proportions. Those models cannot be inconsistent or uncountable. Also, they must reflect all changes on each possible view, not to confuse and inhibit the programming and working on the model.

From the perspective of construction works planning process BIM which is understood as model of a building, database or storage of important information, may serve as a source of knowledge necessary for quantity take-off analysis and then schedule development. It must not be forgotten that the use of BIM tools (that is software, computer applications) are inevitable to make the most of the information stored in the model.

3. Initial analysis of the model

The case study presented in this paper was carried out for the structural model of a residential building. Basic information about the building is set together in the Table 1. The model is presented in the Fig. 1.

Table 1

Basic information about the building under consideration

Building type:	– residential building – single family house, – small-size garage is integrated with the house structure.
Numer of storeys:	– no storeys below ground level, – two storeys above ground (ground floor and attic floor).
Foundations:	– foundation slab made of reinforced concrete, (below the slab, respectively styrofoam layer and sand-and-gravel bedding), – four spot footings in the corners of the structure outside the foundation slab (onto them, wooden frame as the part of the roof structure).
Walls:	– masonry ceramic load-bearing walls made of blocks of 25 cm in thickness (prefabricated lintels are to be installed above windows and entrance door), – cores in the load bearing walls made of reinforced concrete,
Slab:	– monolithic floor slab between ground floor and first floor,
Roof:	– gabled roof – collar-beam type of structure, – wooden frame as a part of the roof structure (posts made of glued wood).

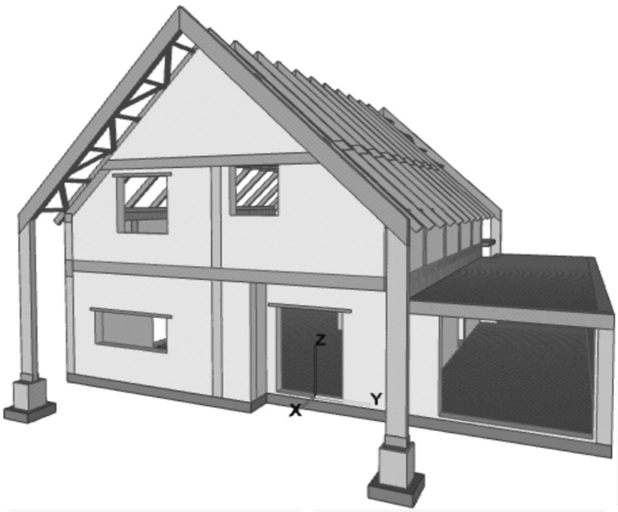

Fig. 1. The view of the model

The starting point for the planning process was the analysis of the model. The analysis revealed both some design and model correctness problems which may affect the process of construction works planning. The first issue was to rework and correct the model before the start of the planning. As the model was delivered as IFC file type, an IFC viewer (namely BIM Vision by Datacomp sp. z o.o.) has been used in order to check out the model. All the discovered deficiencies were presented to the design team and the model was corrected. Some selected problems revealed in the course of the analysis, are presented and briefly discussed below.

3.1. Internal structure of the elements comprising the model

Fundamental project structure division is presented in the Fig. 2.

So called "IFC structure" of the model was needed to be done for easier and more effective way of working on the quantity takeoff; such segregation has been added to the model. If it had not been done at this stage, each element of the construction (even every single reinforcing bar) would must be manually assigned to the adequate floor. Such a manual manner of work makes it unnecessary to use BIM technology – there is no improvement or automation in comparison with traditional way of project scheduling.

Adequate annotation of construction elements

From point of view of scheduling, proper management of construction works is essential. That is why a designer must be sure that every stage of the project execution is consequent and there is no doubt that all the structural rules are kept safely. Such a situation occurs clearly in case of starters – special reinforcing bars which are responsible for good connection and proper continuation of two construction elements designed to work as one system. An example is connection of the foundation slab and the columns on the ground floor. Comparison of rebar allocation is depicted in the Fig. 3.

Lp.	Model	Nr	Podstawa	Opis robót
1	☑		Kosztorys	⊟ Czestochowa
2	☑	1	Rozdział	⊟ Roboty budowlane
3	☑	1.1	Grupa	⊟ Undefined
4	☑	1.1.1	Grupa	⊟ Single-family house (dom jednorodzinny)
5	☑	1.1.1.1	Grupa	⊟ Foundations (fundamenty)
6	☑	1.1.1.1.1	Element	⊞ Reinforcement (zbrojenie)
154	☑	1.1.1.1.2	Element	⊞ Slabs (płyty grube)
156	☑	1.1.1.1.3	Element	⊞ Footing (ławy i stopy)
161	☑	1.1.1.1.4	Element	⊞ Frame mounting (mocowanie ramy gł.)
174	☑	1.1.1.1.5	Element	⊞ Columns (słupy)
179	☑	1.1.1.2	Grupa	⊞ Ground floor (parter)
411	☑	1.1.1.3	Grupa	⊞ First floor (piętro)
505	☑	1.1.1.4	Grupa	⊞ Roof (dach)

Fig. 2. IFC structure of the model

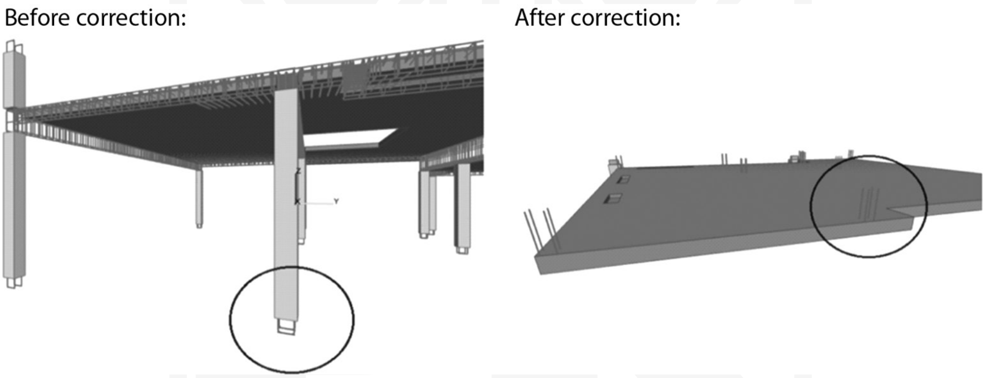

Fig. 3. Example of corrections made to the reinforcing bars assignments

When the schedule is to be done, design team must ensure that the starters are installed on the level of foundation slab (they must be prepared as the part of slab reinforcement, in spite of the fact that they are not actually the construction element of the slab). The same situation has been observed on the upper floor. After those rebar remarks have been launched (with great care of static part of calculations and design of reinforced concrete structure) also technological order of works execution could be conserved.

Practical approach to concrete placement

The figure shows how the model has been changed in order to facilitate concrete placement process. On the left of the Fig. 4 – proper execution and creation of strong enough bonds between neighbouring concrete elements (slabs, beams and columns) demanded by designing rules would be impossible. On the right of the Fig. 4 (after model corrections) – concrete placement will be easier and a gain of technological properties unquestionable.

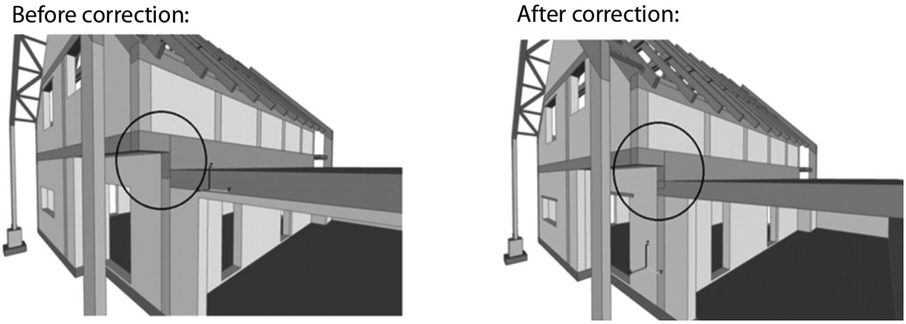

Fig. 4. Example of corrections made in the concrete elements' connections

The problems revealed in the course of the analysis might be related to unavoidable human errors or usage of repeatable blocks of elements during the model development process. (In the light of the analysis results the choice of IPD (Integrated Project Delivery) approach seems to be a promising option. Early involvement of contractors, consultants, fabricators and other specialists in the design process is expected to reduce errors and deficiencies on the very early stage of design process. More details about the IPD can be found i.a. in [3] and [9])

4. BIM-model-based quantity takeoff and schedule

Two next steps described in the following chapter are the actual parts of the planning process. The first step was the quantity takeoff and the second step was the scheduling. The most important advantage of the BIM model usage is the ability to get automatically or semi-automatically the quantities of construction works (compare with e.g. [2]). "All BIM tools provide capabilities for extracting counts of components, area and volumes of spaces, material quantities and to report these in various schedules" [2]. However it must not be forgotten that the degree of accuracy depends on the model itself and the way it is developed. A list of the elements with their quantities read directly from the model is a starting point to scheduling.

4.1. Quantity takeoff

The quantity takeoff was prepared with use of Zuzia BIM application (BIM software tool which is being developed by Datacomp sp. z o.o.). The process itself is very easy – selected construction element or group of elements has been automatically counted (area, length of chosen edge, volume or weight) and assigned to the element or group of elements presented on the model. Such an operation has been performed on the entire model. Not only each level of construction (foundations, ground floor, first floor, roof structure) has been described directly on the basis of quantity survey, but also automatically each variant of construction element has been registered and summed up (e.g. for the entire building, posts with dimension of 25 × 25 cm comprises 2.886 m^3 of concrete). The exemplary part of the work is depicted in the Fig. 5.

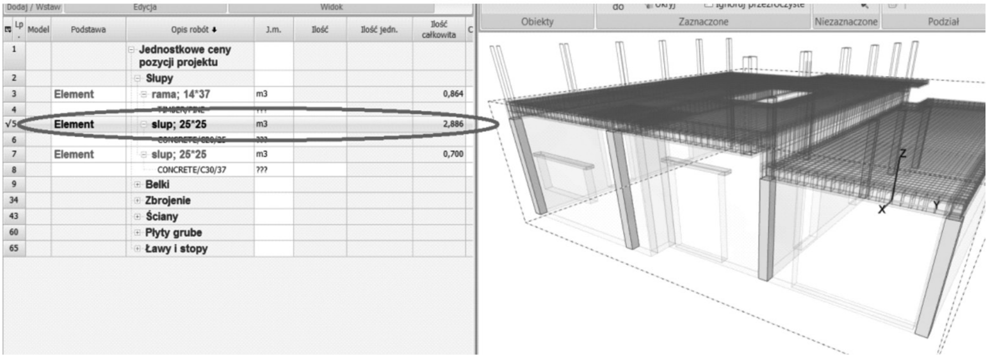

Fig. 5. Transfer of the quantity information from the model – example for RCT columns

There were few challenges met during quantity takeoff determination. As no BIM specific rules of measurement have been yet developed in Poland it was necessary to make the most of the catalogue base which is traditionally used in the process of cost estimation.

When all the quantities have been revealed in quantity takeoff, direct assignation of resources and their normative consumption connected with each type of an element has been determined.

4.2. Development of construction works schedule

Development of the schedule was continued with use of Zuzia BIM application. It noteworthy that an arrangement of an IFC-structure of a model (i.a. definition of stroeys/levels and elements assigned to the levels/storeys) in the model directly determines tasks which are to be carried out during construction phase. There is a possibility however to group any types of element and the elements themselves. Nevertheless, its usage for schedule arrangement is hard to be launched and unclear and there is the threat, that merging of position causes disintegration of the model and the quantity takeoff.

The most complicated case occurs for reinforcement. On grounds of clarification of construction elements, such a classification could be made regarding bar diameter. The division facilitates distinction of similar bars' properties on each level of the building. Then the quantity takeoff appears more understandable and transparent. Unfortunately, it does not help to plan more accurate schedule of construction works. It would be like that if the division has been made into parts of the foundation reinforcement (for example group 1: footing, group 2: slab, group 3: columns). The more the groups, the more accurate schedule may become.

It must be emphasized however, that this type of classification (regarding e.g. bar diameter) is very troublesome during planning phase. In order to prepare precise schedule such a division must be made by a designer of a model. From point of view of a person constructing the schedule only classification regarding similar location is reasonable.

The durations of the tasks was assumed as deterministic and assessed on the basis of the simple formula (compare with [1, 4]):

$$D = \frac{TA}{ns} \tag{1}$$

where:

D – duration of an activity (here in days),

A – quantity of a construction work,

T – the time required to complete a unit of work by a standard crew (measured in man hours or machine hours per measurment unit of a construction work),

n – the number of workers or machines assigned to the task,

s – number of working hours per shift.

The details of the duration assessment is depicted in Fig. 6.

Nr	Nazwa	Widoczny	Il. godz. pracy	r-g koszt.	r-g	Il. prac.	r-g / prac.	m-g	m-g / sprz.	Il. dni liczona	Ilość dni rob.	Czas trwania
1.1.1	⊟ **Single-family house (dom jednorodzinny)**	☑										53
1.1.1.1	⊟ **Foundations (fundamenty)**	☑										47
1.1.1.1.1	⊞ Reinforcement (zbrojenie)	☑	8		152	5	**30**	21	21	4	4	
1.1.1.1.2	⊞ Footing (ławy i stopy)	☑	8		3	1	**3**	1	1	1	1	
1.1.1.1.3	⊞ Slabs (płyty grube)	☑	8		16	2	**8**	3	3	1	1	
1.1.1.1.4	⊞ Columns (słupy)	☑	8		7	1	**7**	1	1	1	1	
1.1.1.1.5	⊞ Frame mounting (mocowanie ramy gł.)	☑	8		0	2		0	0			
1.1.1.2	⊟ **Ground floor (parter)**	☑										17
1.1.1.2.1	⊞ Walls (ściany)	☑	8		295	7	42	48	**48**	6	6	
1.1.1.2.2	⊞ Reinforcement (zbrojenie)	☑	8		146	5	**29**	20	20	4	4	
1.1.1.2.3	⊞ Columns (słupy)	☑	8		35	4	**8**	4	4	1	1	
1.1.1.2.4	⊞ Beams (belki)	☑	8		226	10	**22**	15	15	3	3	
1.1.1.2.5	⊞ Slabs (płyty grube)	☑	8		249	10	**24**	13	13	3	3	
1.1.1.3	⊟ **First floor (piętro)**	☑										19
1.1.1.3.1	⊞ Walls (ściany)	☑	8		155	5	**31**	25	25	4	4	
1.1.1.3.2	⊞ Reinforcement (zbrojenie)	☑	8		11	3	**3**	2	2	1	1	
1.1.1.3.3	⊞ Columns (słupy)	☑	8		22	3	**7**	2	2	1	1	
1.1.1.3.4	⊞ Beams (belki)	☑	8		85	10	**8**	6	6	1	1	
1.1.1.4	⊟ **Roof (dach)**	☑										7
1.1.1.4.1	⊞ Columns (słupy)	☑	8		19	3	**6**	1	1	1	1	
1.1.1.4.2	⊞ Beams (belki)	☑	8		122	6	**20**	7	7	3	3	

Fig. 6. Table with details of duration assessment for the tasks in the schedule

For the tasks enlisted in the Fig. 6 value of the nominator in the formula (1) has been calculated automatically on the basis of the information extracted from the model (quantities) and obtained from the catalogue base (normative consumption of man-hours [r-g] or machine-hours [m-g] for a certain construction work). Assumptions about the number of working hours per shift and number of workers assigned to a certain construction work had to be made in the course of planning process.

4.3. Final arrangement of construction works schedule

The work starts with foundation reinforcement preparation and placement. As there is a lot of rebar, the task takes four days with man power of five reinforcement fixers. When it is finished, both footing and foundation slab is to be poured with concrete. Technological delay is required, that is why ground floor walls are planned to be constructed nine days after the slab execution and the week no. 2 may be recognized as a gap week. When the process of walls bricking up is nearly finished first stage of ground floor reinforcement (column's reinforcement) preparation is planned to be started. Columns are located between masonry walls and are to be constructed after them, what reduces amount of needed formwork. Two-sided one is to be mounted and concrete placed in order to create the columns. Another part of the schedule is the roof structure construction. Main frame made from wood comprises columns mounted on the foundation columns (placed onto the spot footing) and beams. Execution of the rest of roof structure is planned to be finish at the same time as frame, but the frame does not require the gable wall in contrast to beams comprising roof truss (collar-ties, rafters, cross-beams and other wooden and metal elements). Final arrangement of the tasks in the schedule is presented in the Fig. 7.

Nr	Nazwa	Ilość dni	Wartość
	Czestochowa	53	
1	**Roboty budowlane**	53	
1.1	**Undefined**	53	
1.1.1	**Single-family house (dom**	53	
1.1.1	**Foundations (fundamenty)**	47	
1.1.1	Reinforcement (zbrojenie)	4	
1.1.1	Footing (ławy i stopy)	1	
1.1.1	Slabs (płyty grube)	1	
1.1.1	Columns (słupy)	1	
1.1.1	Frame mounting (mocowanie ramy gł.)	0	
1.1.1	**Ground floor (parter)**	17	
1.1.1	Walls (ściany)	6	
1.1.1	Reinforcement (zbrojenie)	4	
1.1.1	Columns (słupy)	1	
1.1.1	Beams (belki)	3	
1.1.1	Slabs (płyty grube)	3	
1.1.1	**First floor (piętro)**	19	
1.1.1	Walls (ściany)	4	
1.1.1	Reinforcement (zbrojenie)	1	
1.1.1	Columns (słupy)	1	
1.1.1	Beams (belki)	1	
1.1.1	**Roof (dach)**	7	
1.1.1	Columns (słupy)	1	
1.1.1	Beams (belki)	3	

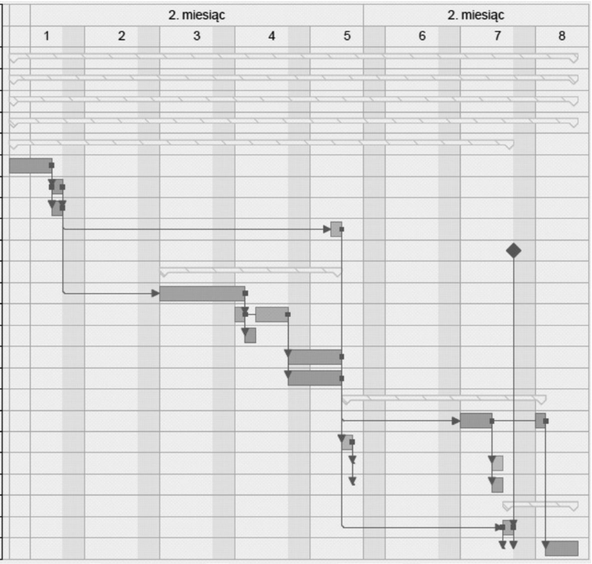

Fig. 7. Final arrangement of the tasks in the schedule – plan of construction works

5. Summary and conclusions

Implementation of BIM provides numerous number of possibilities concerning all the building engineering matters. BIM is especially beneficial in the field of construction project management. The models developed as 4-, 5- or even 6D constitute a collection of the data (database information) related to the successive construction stages, moreover they can also be a basis for maintenance and operating system long after the construction process is finished. Any type of building element can be launched into the model – every type of installation, architectural consideration or even a landscape planning.

The starting point for the quantity takeoff, cost estimation and planning is a model. Preparation of a model that ensures sufficiently precise, consistent and well organized information is a task which requires a discipline, experience and skills from the design team. On the one hand, each building structure may be composed of millions of elements, on the other hand division of those element into groups can be infinitely long process, actually not

this much important for designers as for people responsible for planning. Some requirements for the models as a basis for quantity takeoff and schedule can be listed as follows:
– elements in the model structure should be ordered in a way which allows for generating adequate work breakdown structure for the purposes of planning and schedule,
– distinction of the storeys/levels in the building's structure and assignment of the building's elements to the storeys/levels is essential,
– the elements in the adequate storeys/levels should be ordered in a way which reveals the technological order of execution of construction works,
– adequate model-based work breakdown structure is a condition for proper planning and schedule,
– quality of the schedule depends on the quality of a model.

The software exploited by the authors in the course of planning process (ZuziaBIM) allows to improve some of the possible deficiencies of the model. It is possible to correct the structure of the model's elements in the scheduling module to some extent. The way of operating on the model seems to be rather intuitive. For these people who met the concept and the tools for a building designing and construction management before, usage of BIM should not be troublesome. Such a program as ZuziaBIM (well-known cost estimation tool on Polish market) has been developed recently in order to operate on *.ifc files. (BIM software backgrounds is described i.a. in [6].)

The future of the construction management seems to be strictly connected to BIM-based solutions. It must be emphasized however, that none of program or concept is able to replace a reasonable human who is able to evaluate the given assistance (in a form of software), reject unnecessary gadgets and take advantage of the modern world's opportunities for the most efficient project management outcomes.

Acknownlegdements

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