Creative Construction Conference 2016

Current Issues of BIM-based Design Change Management, Analysis and Visualization

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Abstract

The BIM-based design process is dynamic in its nature as the models typically need to evolve. This paper addresses the problems of a BIM-based design change analysis, design change management and visualization of the changes made to BIM models. A concise discussion of the general problems of design change management in terms of BIM is presented. The authors also briefly discuss the current advancement of native BIM tools and their functionalities dedicated specifically to design change management; namely, tracking and analysis of design changes on the basis of BIM models. Subsequently, a number of examples are presented to illustrate the results of recent developments in the visualization of design changes.

Keywords: design change management, design change analysis, design change visualization, BIM.

1. Introduction

BIM (Building Information Modeling) is currently an intensely discussed topic among professionals and scientists all over the world. A broad definition of BIM explains it as a collaborative platform for efficient information exchange and sharing among different disciplines [1]. "I", which stands for "information", is actually the key in understanding, implementing and using BIM. A thorough discussion and review of the ideas and approaches to BIM in the context of the information stored in the model and its processing in the course of a construction project is presented in one of the authors previous publications [9]. The goals of this paper include the following: to discuss briefly the problems of BIM based design change analysis and to present the authors' point of view to this problem, to present the current advancement of native BIM tools in the field of tracking and to analyze the design changes on the basis of models given in the IFC standard.

1.1. *Brief literature review*

The development and evolution of BIM affects the construction projects in all their areas and phases. Change management in the BIM context gains attention in many publications, as in the ones chosen to present here. One of such publications addresses the problem of change management in early design [6]. Its authors discuss the topic and problems of object versioning within BIM models given in the IFC standard. In another paper the flexibility of BIM tools towards design changes was studied, in which the authors evaluated and disclosed the drawbacks. It was concluded that BIM is efficient in adopting and promoting changes in the model; however, it suffers from certain shortcomings, such as the inability to produce a comparable design change deviation report, the unreliability of bidirectional links between the external analysis software and BIM tools, not having a powerful user interface and lacking enough artificial intelligence to analyze and offer alternatives to design [8]. The authors of another study propose an ontology of design changes [7]. According to them, the ontology explicitly defines a BIM-based structure to organize the changes. They complement the idea with the concept of an integrated framework the aim

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of which is to enable an information update process on a BIM model, and to facilitate information flow and exchange for energy efficient design [integr framework]. In a later study [5], the authors presented an automated model based on BIM, developed to aid the visualization of the design changes requested by owners after the completion of the design phase and before the commencement of the construction phase.

This paper is a continuation of its authors' diverse work, research and involvement in discussions concerning BIM in its various aspects, presented in earlier publications, for example [2], [3] and [9].

1.2. *BIM based design change management: basic information*

Design change can be defined as the alteration made to the hitherto proposed design solutions. Regardless of the reasons for design changes, they require re-design, or at least an introduction in successive revisions. In the traditional approach to design change management, the occurrence of which is considered inevitable in construction projects, attention is focused on the efficiency of the information and document flow, such as change requests and design revisions. Emphasis is put on reacting to the need for a design change, developing design change solutions and distributing design revisions among the participants of the construction project.

One of the general assumptions about BIM implementation in construction projects is that they will involve the reduction of design errors and, in consequence, reduction of the design changes forced by these errors (compare, for instance, [1]). However, even if BIM is applied to a construction project, it seems impossible to completely eliminate design changes. According to the results obtained by Malaysian researchers [8], the professionals that were investigated claimed that hardly any of the projects implementing BIM they had known was free of design changes. Another investigation [7] led to the development of a BIM-based ontology of design changes. The taxonomy developed included six classes explaining the nature of design change by its type, changed attributes of the altered component, dependencies between the components, the level of change effect on other components, timing (stage of the project when the change occurs), the impact on cost and schedule. The authors' proposal is to add one more class which would help to explain the cause of the change. In authors' opinion, the causes of the changes introduced in BIM models may be divided into two main subclasses. The first subclass should encompass the changes which occur as a natural consequence of model development that is, refining the model by the design-team, refining the model due to the analyses performed by engineers and consultants and redefining the model due to the client's requests. The second subclass should encompass the changes the occurrence of which is not a natural consequence of model development: removal of indefinable design errors, corrections due to unforeseen internal constraints of a construction project and corrections due to alterations of external conditions. The application of the taxonomy may provide the necessary structured information about the changes made to the model for further analyses and use.

BIM-based design change management can be defined as a dynamic process providing identification of needs and reasons for changes, implementation of the changes to the model (while keeping its integrity and coherency), the flow of information about changes, analysis and assessment of the consequences of changes and minimizing the negative effects of changes while ensuring multioperability. The BIM-based design change management defined in this way needs appropriate tools and techniques that will ensure effectiveness of the process.

2. Development of native BIM tools in terms of design change

BIM is a technology which, if implemented in a construction project, can be immensely helpful in managing information and data. One of the greatest advantages of BIM in the context of design change management is that it allows to alter or modify the components of the model in real time. The information stored in the model is rearranged and the changes are available in every view. However, the problem is that for now the user "(…) is only able to see a change, and the newly-affected model, but not the ripple effect of that change" [5].

Literature analysis and discussion with BIM professionals helped to identify the need for a specific BIM-tool development. It was assumed that such a BIM-tool must be capable to visualize the changes made to the model in the course of the design process and to support the analyses of the consequences due to these changes. The basic assumptions for the tool are briefly presented below.

In the successive steps of the design process, that is, in model development, the subsequent versions of the model are introduced. These versions can be regarded as emanations of a dynamic design process. It must be stressed that they constitute a basis for a variety of multi-disciplinary analyses. In the successive versions of the model (later referred to as model revisions) a number of alterations can be made. These changes may be compared with each other and considered in many aspects. As a matter of fact, it may be necessary to compare several revisions of the model. Summarizing, the expectations were defined for the tool and it was agreed that it should allow to:

- compare two or more revisions of the model given in the IFC format,
- visualize (highlight) the changes made to the components of the model,
- differentiate the visualization of changes in terms of modification, addition and deletion of the component,
- highlight the changes made to the attributes of the model components,
- utilize the information about the changes in the cost and time analyses of the project,
- inform the user about the changes in a clear and understandable way.

It has been decided to implement such functionalities in BIMestiMate, a Polish BIM-based 4D and 5D analysis application. BIMestiMate is a computer application being constantly developed by Datacomp sp. z o.o. company from Poland. The program enables an almost full automatization of the quantity take-off process using its own calculation engine which is embedded in the IFC viewer attached to a calculation sheet. When a model is loaded into the program, both the model and a calculation sheet appear. The sheet's layout is based on a model's IFC structure. BIMestiMate also supports schedule preparation. The essential assumption was that implementing functionalities that support design change management in the BIM-based 4D and 5D system will enable not only visualizing the changes between revisions r_i and r_j but also the impact of these changes on cost and time. The comparison of the cost calculated on the basis of r_j revision and r_i revision would take into account only the changes, as there would be no need to prefer the whole estimation from the very beginning onwards.

Current advancements in the development of the functionalities listed are presented in the next section of the paper.

3. BIM based design change analysis: examples

As far as BIM is concerned, design change management seems to be one of the biggest advantages. BIM assures that any change made during each phase of the project will be revealed immediately on each view and those changes (improvements by default) will be proficiently managed by the participants of the construction project. Such idea looks exquisite by definition but making this a reality needs efficient tools on which BIM-users can rely.

These assumptions formed the basis for recent development of the functionalities and tools that aid change management within BIMestiMate application. The application enables to load and compare an unlimited number of versions of the same model, that is, revisions. In Figure 1 one can see a screenshot of the application window summarizing a revision list. Notes can be added for each revision and, if available, brief information about costs is displayed in the "Net value" and "Gross value" columns.

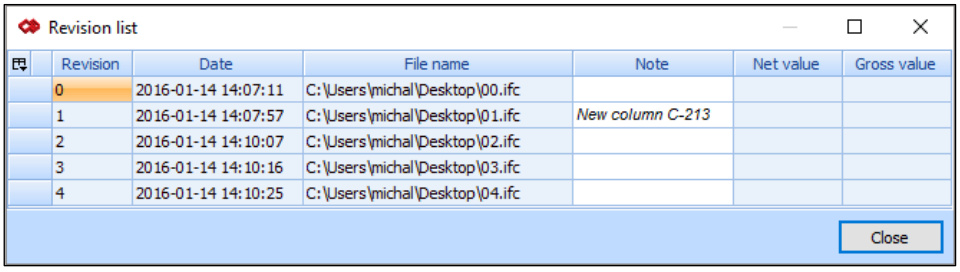


Fig.1 – Revision list - (source: own study)

Basically, the BIMestiMate functionality of design change management is composed of a few groups of functions. Figure 2 presents a screenshot of the application with available functionalities for selection, displaying and distinguishing between changes options. The user is able to display either modified, removed or added components. A graphical representation and filtering changes options are available – using color distinction the user can show the elements that have been modified regarding occurrence, geometry, classification or properties.

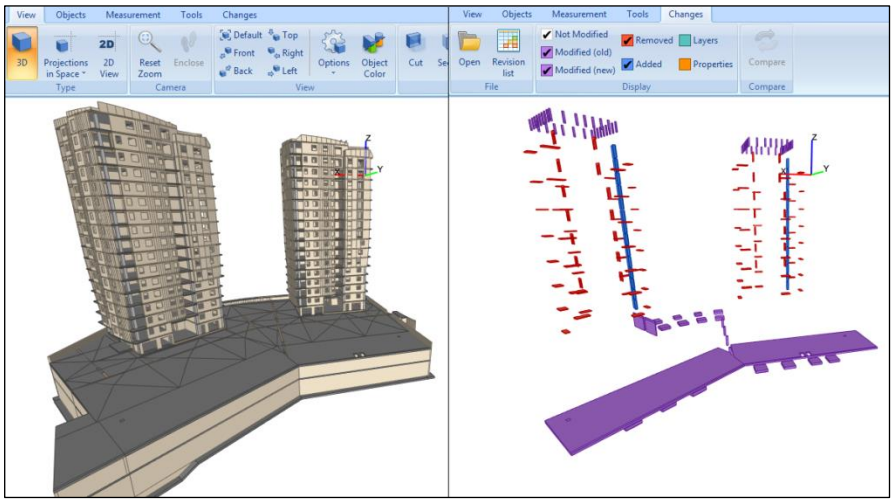


Fig.2 – A view of BIMestiMate embedded IFC viewer window – normal view (left side), tab with change management functionalities (right side) (source: own study)

The application functionalities make it possible to compare visualization and parameters of the chosen component of a model on the basis of two selected revisions, since the viewer can simply be switched between changed elements. The user can easily track the changes made to a certain component in the successive revisions by comparing the selected revisions. In the upper part of Figure 3 in the left window one can see the options for the choice of revisions to compare when in the right window ”Two latest revisions” have been selected. “Slide” enables moving the objects inspected closer and further from each other. Different views are also presented in the upper part of Figure 3.

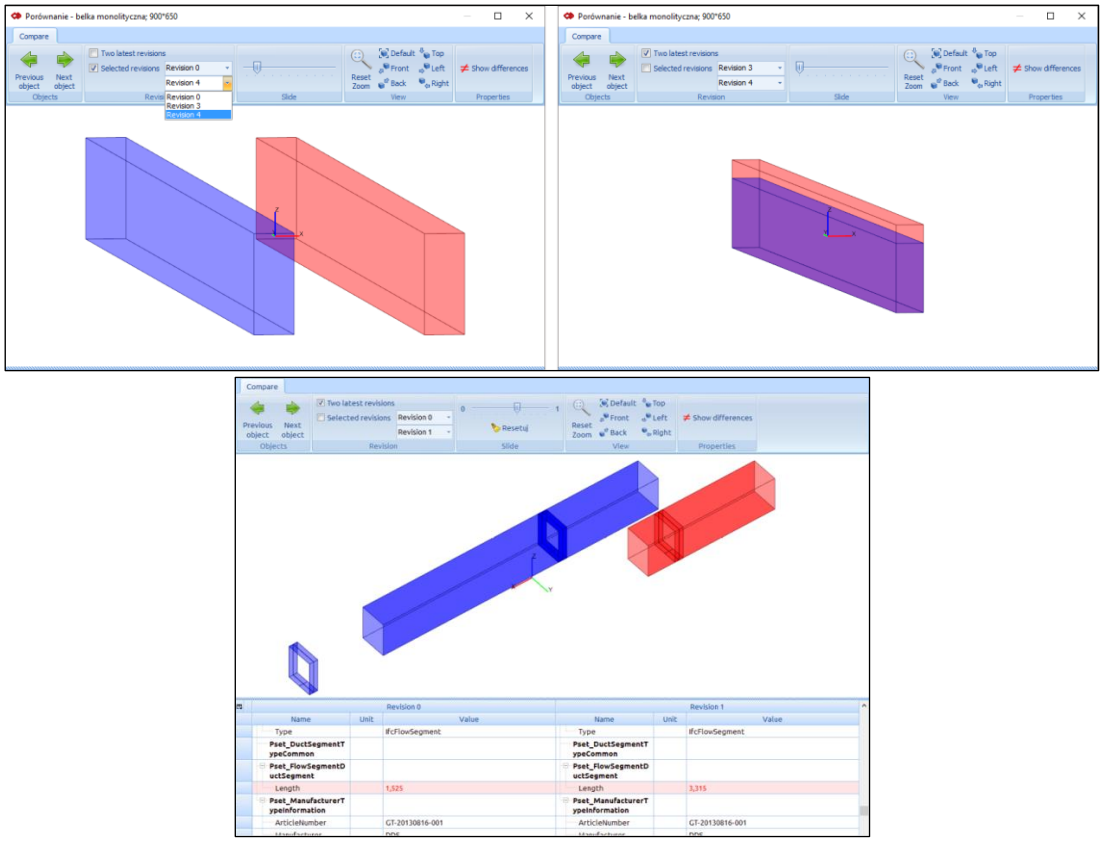
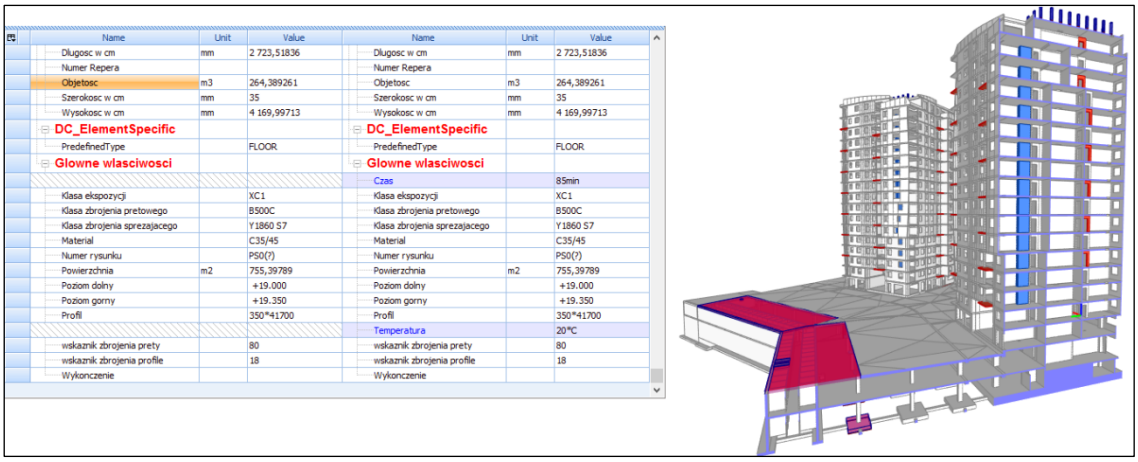


Fig.3 Options of visualizing and displaying information of alterations in two chosen revisions - (source: own study)

In the lower part of Figure 3, apart from the view of the changed component, one can see displayed information related to the changed parameters of the component according to the two chosen revisions of the model. A readable

list of changes attached to the viewing window allows to display and highlight the alterations of the properties or values for an easy detection. Figure 4 presents the view of the model with the displayed and highlighted components that have been changed (on the right) and a list of properties and their values for a chosen component. The application provides convenient viewing and setting the zoom and camera configurations.



Name	Unit	Value	Name	Unit	Value
Dlugosc w cm	mm	2 723,51836	Dlugosc w cm	mm	2 723,51836
Numer Repera			Numer Repera		
Objetosc	m3	264,389261	Objetosc	m3	264,389261
Szerokosc w cm	mm	35	Szerokosc w cm	mm	35
Wysokosc w cm	mm	4 169,99713	Wysokosc w cm	mm	4 169,99713
DC_ElementSpecific			**DC_ElementSpecific**		
PredefinedType		FLOOR	PredefinedType		FLOOR
Glowne wlasciwosci			**Glowne wlasciwosci**		
			Czas		85min
Klasa ekspozycji		XC1	Klasa ekspozycji		XC1
Klasa zbrojenia pretowego		B500C	Klasa zbrojenia pretowego		B500C
Klasa zbrojenia sprezajacego		Y1860 S7	Klasa zbrojenia sprezajacego		Y1860 S7
Material		C35/45	Material		C35/45
Numer rysunku		P50(?)	Numer rysunku		P50(?)
Powierzchnia	m2	755,39789	Powierzchnia	m2	755,39789
Poziom dolny		+19.000	Poziom dolny		+19.000
Poziom gorny		+19.350	Poziom gorny		+19.350
Profil		350*41700	Profil		350*41700
			Temperatura		20°C
wskaznik zbrojenia prety		80	wskaznik zbrojenia prety		80
wskaznik zbrojenia profile		18	wskaznik zbrojenia profile		18
Wykonczenie			Wykonczenie		

Fig.4 – View of the model changes - model view and a readable list of parameters - (source: own study)

On the basis of the detected and processed changes BIMestiMate supports cost analyses. The application provides the possibility of creating cost estimation variants resulting from successive revisions (alternative or improved versions of the model). In consequence, it allows either to prepare an analysis of changes impact on cost or to build a cost simulation for alternative design proposals or solutions. It makes the decision process for the final design better informed. Figure 6 depicts a cost calculation sheet beside the view of the model where the changes made to the model are highlighted both in the list and in the model view.

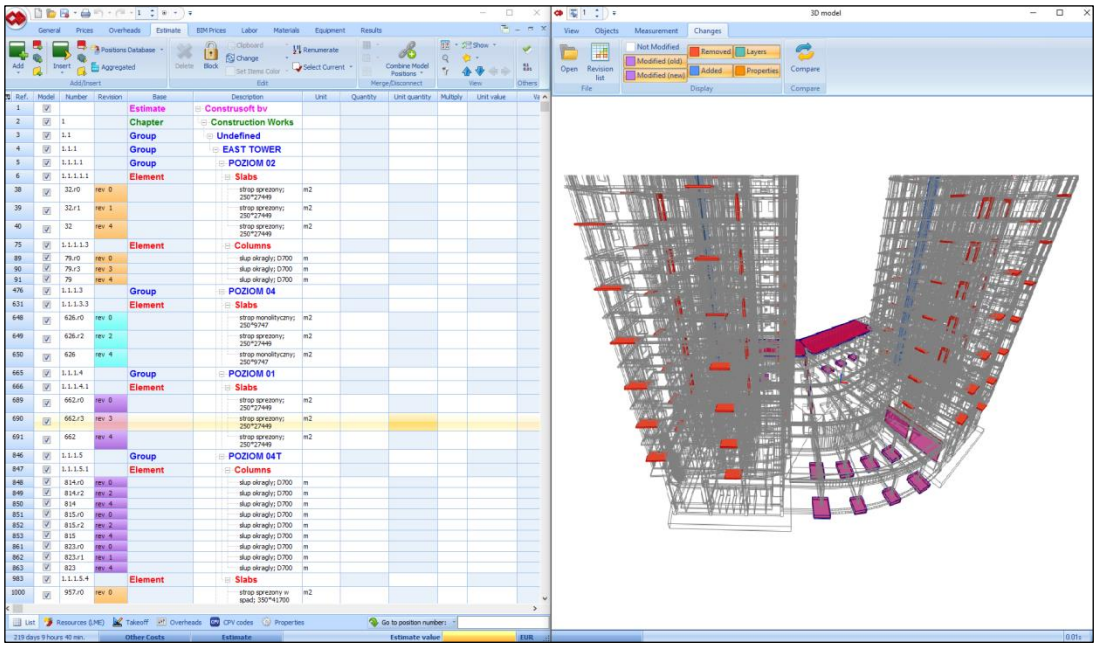


Fig.6 - Revisions-based cost analysis process - (source: own study)

BIM, in terms of a model, constitutes a shared database of information about the construction object. The database evolves during the design process as changes are made to the model. Due to the automation of quantity take-off, support of the cost estimation process and functionalities which allow to find and process the changes made to the model, which are implemented in BIMestiMate, all the participants of the project are able to investigate and compare the impact of model alterations or variants on project costs.

For now the application presented in this paper supports BIM-based scheduling. In the near future the development of the functionalities that allow to assess the impact of the changes on project tasks and the whole project duration is planned.

4. Summary and conclusions

Despite the fact that one of the goals of the BIM implementation in construction projects was to reduce the number of design errors, design changes seem to be inevitable in the process of model development and improvement. BIM, as a technology, should provide both the possibility to present and analyze the consequences of the changes. The potential of BIM should be used to automate or semi-automate the execution of analyses.

The development of BIM tools that allow to implement BIM-based design change management in an efficient way seems to be both actual and challenging task. Such functionalities as quantifying, visualizing and analyzing changes made to models would provide benefits for all participants of the construction project. Currently, successive revisions of models usually do not highlight the alterations of information, component attributes or relations between the components caused by the changes made to the model. These limitations are being consistently overcome along with the development of the BIM tool introduced in this paper. One of the goals of BIMestiMate development is to provide an efficient and automated BIM tool that supports BIM-based design change management process: a method for collection, distribution and processing information concerning changes among the participants of a construction project. Depending on the current advancement of work, for now BIMestiMate allows the user to:

- load and process several revisions of the model given in the IFC format,
- compare two revisions of the model given in the IFC format,
- visualize and display changes made to the model in successive revisions, both in terms of alterations made to the components and the parameters or values of the component attributes,
- utilize the information about the changes in the cost analyses.

Further research and development of the tool will include testing the tools by the BIM specialists, improvements of the existing functionalities and the implementation of new ones. Planned development directions are as follows: increasing the information detail level that may be compared and developing the analyses capabilities, especially in terms of automation of the processes.

Acknowledgements

The authors wish to thank M.A.D. Engineers sp. z o.o. (team of BIM specialists) for providing a number of models used in analyses and tests of the tools and functionalities presented in this paper.

References

[1] C. Eastman, P. Teicholz, R. Sacks, K. Liston (2008) BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors, Wiley Press, 2008

[2] M. Juszczyk, M. Vyskala, K. Zima (2015) Prospects for the use of BIM in Poland and the Czech Republic–Preliminary research results, Procedia Engineering, Elsevier, 2015, pp. 250-259

[3] M. Juszczyk, K. Zima (2015) The Use of Building Information Modelling in Construction Cost Management, in E. Plebankiewicz (ed.) Recent Advances in Civil Engineering, Monografia 480, Politechnika Krakowska, Seria Inżynieria Lądowa, Kraków, 2015, pp. 28-58

[4] F. Liu, A. K. Jallow, C. J. Anumba, D. Wu (2014) A Framework for Integrating Change Management with Building Information Modeling, Computing in Civil and Building Engineering, ASCE, 2014, pp. 439-446

[5] V. Moayeri, O. Moselhi, Z. Zhu (2015) Design Change Management Using a BIM-based Visualization Model, 5th International/11th Construction Specialty Conference, Vancouver, Canada, pp. 191-1-191-9

[6] M. Nour, K. Beucke (2010) Object versioning as a basis for design change management within a BIM context, Proceedings of the 13th International Conference on Computing in Civil and Building Engineering (ICCCBE-XIII), Nottingham, United Kingdom, 2010, pp. 147-152

[7] B. Pilehchian Langroodi, S.Staub-French (2012) Change Management with Building Information Models: A Case Study, Construction Research Congress, ASCE, 2012, pp. 1182-1191

[8] E. Shourangiz, M.I. Mohamad, M.S. Hassanabadi, S. S. Banihashemi, M. Bakhtiari, M. Torabi (2011) Flexibility of BIM towards Design Change, 2nd International Conference on Construction and Project Management, IPEDR vol. 15, IACSIT Press, Singapore, 2011, pp. 79-83

[9] A. Tomana (2015) BIM. Innowacyjna technologia w budownictwie, Kraków, 2015