Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 117 (2015) 52 – 59

Procedia Engineering

www.elsevier.com/locate/procedia

International Scientific Conference Urban Civil Engineering and Municipal Facilities, SPbUCEMF-2015

Challenges of BIM for Construction Site Operations

Hans-Joachim Bargstädt*

Professor for Construction Engineering and Management at Bauhaus-Universität Weimar, 99421 Weimar, Germany

Abstract

Building Information Modeling is a powerful tool for the design and for a consistent set of data in a virtual storage. For the application in the phases of realization and on site it needs further development. The paper describes main challenges and main features, which will help the development of software to better service the needs of construction site managers

Peer-review under responsibility of the organizing committee of SPbUCEMF-2015

Keywords: BIM, Building Information Modeling, site management, construction site.

1. Introduction

BIM (Building Information Modeling) is a powerful tool, which has taken almost two decades to be developed to the current status. In the last few years the application of BIM tools has been pushed by a large number of architects, engineers and consultants (AEC industry) such that now also construction companies start to accept these innovative ways of improving work performance [1].

Nevertheless, the scope of BIM tools in the first place has been governed by design features and by the ability to show the client the final project by the use of animations and nice renderings [2]. This is different from what information construction companies need for their building processes.

Students and young site engineers must be trained in the use of BIM tools for construction processes. This is a different application than generating a model. It is more concerned with adding specific information to the model.

* Corresponding author. Tel.: +49 (0) 36 43/58 23 23; fax: +49 (0) 36 43/58 23 75
E-mail address: hans-joachim.bargstaedt@uni-weimar.de

Peer-review under responsibility of the organizing committee of SPbUCEMF-2015
doi:10.1016/j.proeng.2015.08.123

But also data mining gains importance because a main reason for applying Building Information Models is the ability to keep large amounts of data in a consistent digital environment.

2. Improvement of work processes by Building Information Modeling

2.1. Definition of BIM

Building Information Modeling is a modeling technology and associated set of processes to produce, communicate, and analyze building models. Building models are characterized by

- Building components that carry computable graphic and data attributes, as well as parametric rules …
- Components that include data that describe how they behave, …
- Consistent and non-redundant data such that changes … are represented in all views …
- Coordinated data such that all views of a model are represented in a coordinated way.

This basic definition, given by Eastman et alii [3], does not enumerate, in the first row, the many stakeholders in a project, which can commonly be found to be involved. However, these stakeholders are identified as different partners on a building project, and the roles and duties of these partners are well addressed in the same literature.

Within the last two decades two powerful applications have been found in realization of BIM. One is the generation of marketable visualizations, derived from digital models, in which different alternatives of finishing, of coloring and other selected topics have been displayed. The other strong application has been developed from industrial companies, who rather work on the automation of production processes, mainly in the prefabrication area, and who directly control their machines from the set of geometric data.

2.2. Software development issues

The development of more powerful hardware as well as the growing dissemination of easy-to-install end appliances, both have made possible that the AEC industry more and more applies sophisticated software with large amount of data storage. Designing a new building and the following processes of tendering, cost estimate, contracting, the long phases of realization of a building and finally the handover generate a vast amount of information which has to be controlled by the involved architects and engineers.

Many engineering companies have mastered this challenge by developing and setting their own in-house standards. For example architects provide standard design books for repeating construction details. The demand for standards for a lot of detailing issues like construction details, standard pricings and legally checked descriptions of tasks have opened the market for specialized construction software, which still is very successful for small and medium enterprises in the AEC industry. Even the traditional way of doing construction for public clients is still working on this ground in Germany.

Some current features, which are not yet sufficiently solved, are the different uses of the same data storage. Concepts to merge different partial models on the basis of an integrator program [4] or on the basis of a multi model storage container [5] are appropriate answers to the different phases and actors in planning. For the phases of realization, starting from tendering, contracting, work planning approval, until as-built realization, more complex systems of access to data are needed. These must consider the different roles and, more important than others, also activate the role of the construction companies as authors of additional information to the Building Information Model.

These challenges are innovative in certain aspects, since they are not common in other industries. No other industry has to manage so many changes by so many different partners during the phases of tendering, of provision, and of realization as the construction industry does. Just to emphasize: according to construction standards, as for example the German VOB/B [6] states in § 1 (3): “The client reserves the right to order alterations to the design”.

2.3. Operability

Not only the client – and his consulting architects and engineers on behalf or, with the authority of the client – often change the design, but also construction companies frequently propose alternative ideas for better quality and for improved performance, with which they also try to improve their cost/price ratio at the same time [7].

These demands show the need for differentiated rights to read the data in the model, to write changes into the model and to evaluate and approve certain changes [8]. Especially the process of bringing in alternatives, which have to be discussed and which finally might be approved or be rejected, need powerful algorithms to document and control these alterations on the Building Information Model.

Complex relations are generated in regard to the data in the virtual BIM model, when the construction enters the “hot phases”, where any decision, no matter whether positive or negative, costs extra money, if not made at the right time.

Currently the successful examples of construction projects run with BIM have been saved on central servers, which are accessible for all partners on different levels, However, in the case of later disputes, this central storage is still fragile.

It is only one year ago, that a big German client ran into trouble about a large construction project with a well-known contractor. He called in some external legal and construction management advice. When asking for the documentation on the project, the advisors found out, that the client had no access to any information on the server. And of all contractors in question only the approval engineer seemed to be so far reliable that the client could ask him a favor. So the first thing to do in order to start the evaluation of the dispute was to ask the approval engineer to kindly backup the server from his access point and pass this copy to his client.

This example shows that there will be serious questions to be asked, as soon as really several partners work together on the same Building Information Model during realization. Currently, and still in the status of new developments, the attitude of partnership is prevailing.

3. Current status in site operations

3.1. Execution planning

Nowadays the complete specifications as well as the legally binding contract description are still paper-based. Even if prepared electronically, a set of printed documents will be produced, which can then be signed by the contracting parties. Elaborate outlines can be found in [9], [10].

Since quite a number of these specifications have been produced at different locations, with different calculation tools, sometimes on the basis of different analyzing models, and often at very different times within the total planning phases, there is a high potential for contradictions [11].

On the other hand the printing limits the amount of information which can be transferred on each detail of the work. In the past, more elaborate written detailing has been avoided, since further information can be taken from the national standards and from other regulative sources.

Finally the construction companies bring in their experience, their skills and their special knowledge. To a great part this is implicit knowledge, not written down, or at least not yet documented in such a way that it could be transferred to the client or anchored within the common Building Information Model.

Many construction companies see this incompleteness of information as one major business goal for their business. While doing work preparation it gives them the freedom of disposition and flexibility to act in order to look for the most efficient way to do the work for the contracted price [12]. However, it also keeps many clients from looking too much into the details for the work. Their argument in this case is: ”We agreed with the contractor on the scope of work and on the price. Now it is the contractor’s business to do the work according to the requirements. We are not and we will not be responsible for the way the contractor fulfills his obligations.” Obviously this behavior of non-interference can be observed within a lot of contractor-subcontractor-subcontractor-relations, where each contractor is only interested on his level of work share.

3.2. Flexibility in contracts

One of the main sources of improvement in competing companies is the different approach within their domain of knowledge. Companies use their strength to apply their specific knowledge, their special equipment and their improved organization to further development the state of the art. This necessitates a certain amount of freedom to organize work within the specifications. In case that all details, all work procedures and all material needs had been specified, then there would only remain a competition on the wages of the workers, or, as we see in other industries, only a differentiation of the wages between contract workers from different regions.

3.3. Reality faster than planning

The performance of contracts in practice shows, that there are many situations where conflicts must be solved on the spot. Even if many of these could have been solved by more thorough work preparation, there will always be new insights, “last minute changes” or freshly developed issues on the prototype “building”, which force the site management to look for ad-hoc solutions. Nowadays we observe on many construction sites that reality is faster than planning, surpasses planning stages and defines new facts. These have to be taken up into the Building Information Model such that the next decisions can already be steered by these changed parameters [13].

Fig. 1 shows the processing of decisions in general, where detailing of decisions passes different phases. Whereas, on the upper part, the standard planning procedure allows for revisions, shows buffer times and runs along a controlled sequence, the lower part symbolizes the phasing in case of alternate planning. Alterations are induced later, forcing all involved planners to react quickly and without extra time, and mostly they still have an effect on some delay in realization time as shown in Fig. 1.

How crucial changes are in reality, can easily be demonstrated, if for example unfinished work must be secured and conserved during the interruption of work. In construction there is almost never a simple “arrested status” of unfinished work.

Special attention has to be paid on last minute changes. Traditionally clients tend to believe, that changes are still possible, as long as the concrete is not poured. But the complex chain of supply, the specialized crafts even in structural work make it difficult to see from the status of a building, what type of changes can still be put in effect, and what type of changes will definitely suspend work for the next weeks.

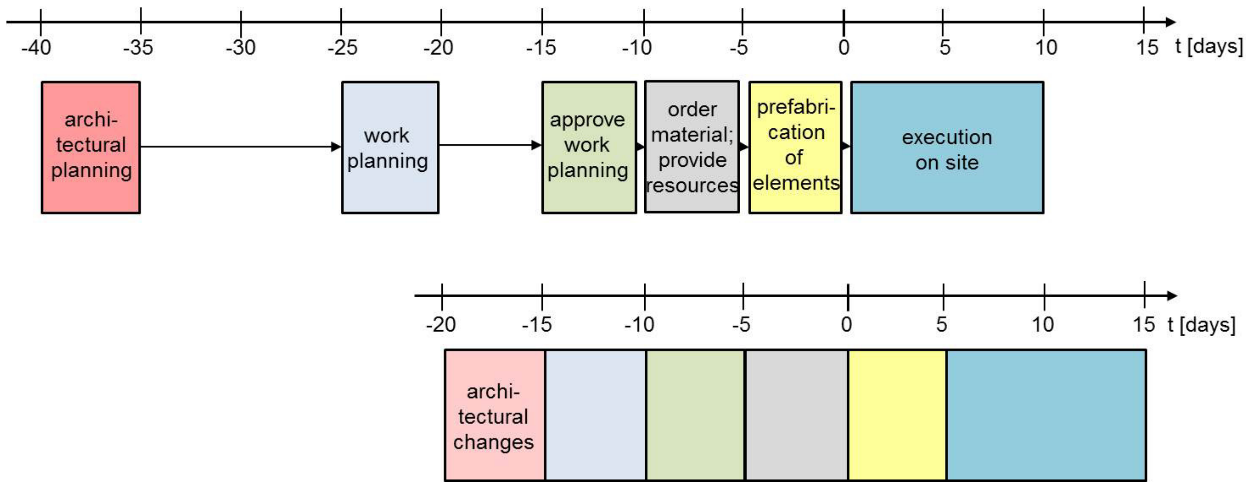

Fig. 1. Time line for standard planning procedures (above) and for late changes (below)

4. Merging BIM abilities with site requirements

4.1. Overview

As elaborated in the previous paragraphs, there are a number of issues that must be respected when realizing a building on the basis of BIM data models [14].

Site operations need reliable, fast and precise information. Besides geometric data there is large demand on further specifications to the geometry, for example the parameters of material, the performance factors etc. From the point of view of the construction site this additional information, attached to the 3D-model, is the most important enlargement to a 4D-model.

From this 4D Building Information Model and using all the additional data, the construction manager can develop the schedule for the site realization [15], [16], [17]. This is the next step, called 5D. As soon as a schedule is developed, the whole data model can be used for estimation and for other work planning activities as resource planning, equipment installation etc. Finally and with this information also brought into the model, the whole set of the Building Information Model can be used as source for controlling activities. Controlling means that the directives for work, the as-planned processes, can be derived from the model; that the actual status can be checked against the model status; and that also additional measures for steering can be tested on the model before putting them into effect on site [18].

Site operations call for additional modeling, for example for site installation and for temporary work. This implies that also the site manager must be able to actively access the modeling environment of the Building Information Model. Otherwise he would risk to plan outside of the model and thus initiate unforeseen conflicts, for example between temporary scaffold areas and final mounting activities. Major temporary work must also be shown in the general Building Information Model [19].

4.2. Framework plan

The 5D site model which can be derived from BIM is a strong tool, which helps to organize and structure the work. Experiences on recent construction sites in Germany, which have applied Building Information Modeling tools, show, that there is a strong discipline created by having an overall framework plan at hand, which is consistent with all activities of the consulting and realizing partners. The framework plan derived from a 5D Building Information Model shows all necessary information and also the time schedule with attached figures for resources, costs and other dependencies [20].

Such a virtual 5D process is not only a valid guideline for site management. It also proves to be a powerful psychological support in the discussion about keeping the plans in force and giving them a stronger binding effect. Especially because scheduling is still an art for experienced engineers, the authorization by checks through simulation or by attached detailed information is an important feature of good scheduling

4.3. Handling of changes

Site management's Achilles' heel, nowadays, is change management. Changes might arise from client and from the contractor. But changes also frequently occur, if material doesn't arrive on time, if personal resources are not available or if other circumstances force the supervisor to leave the intended path.

Building Information Modeling allows to watch time lapse processes and to concentrate on the crucial moments of a whole chain of processes [21]. This is facilitated by simulation studies which can be derived from the information in the Building Information Model environment.

Special focus should be steered to the so called "last minute changes". Often disputes arise from the different opinions about the effect of changes. As soon as the work planning for the building has been put together by planning engineers and contractor's site manager, there will be a definite as-planned status of the organized work, which easily can be checked against the status "with changes" or later with the status "as-built".

But, when handling changes in general, there are different types of changes. Some of them will be announced and authorized by the client or his authorized personnel. Others are just deviations from the planned status and as such will be protocolled by the contractor or by the client. Here it must be organized, who will be responsible for bringing the changes into the Building Information Model.

4.4. As-built documentation

In theory the as-build documentation seems to be very easy. The contractor just has to state after completion, that he has worked according to the plans and specifications. But in practice it is far more complicate.

The as-built documentation has to specify that the work has been completed within the given tolerances, that is has been corrected where previously exceeding these tolerances. In other cases, for example a bridge gradient, the exact deviations must be calculated such that the succeeding work can be aligned accordingly. As-built has also to document the further detailing, which has been made by the contractor, for example the chosen producer of an element or other parameters like the material, color or texture. Among other this information is important for future maintenance operations.

5. Challenges for Research and Education

5.1. Learning Environment

There are a number of software companies worldwide which offer extensive BIM software. The big players like Autodesk, RIB, Tekla and others have complex software systems in stock, which answer to different demands from architects, structural engineers, HVAC engineers, green building evaluation and others. There is also growing scenery of small software houses which develop specialized programs for the end user.

As an institute for higher education we train the students to “play the game”. The students are encouraged from early semesters on to apply different software and to find out about features, as if they would discover a computer game on their home computer. Playing the game proves to be a very good intrinsic motivator to learn the basics of construction engineering software. It also activates some “hidden skills”, before we add the theory of construction management processes into it.

Finally the students learn about problems which can be solved with their acquired skills. Thus actually the sequence of learning is turned around: first the skills and tools and then the theoretical background for the problems in construction engineering and management.

5.2. Flexibility for future demands

Essentially, the education is not focused on one or a few special software suppliers. But in order to maintain the community’s help service it is effective to concentrate on a small number of software programs. Among those we always try to keep open source software in parallel, so that students learn to adapt to different interfaces, different levels of service comfort and also to different attitudes for the given set of problems.

The open source concept is also giving the opportunity to program individual interfaces and to create additions to existing software. This is a main feature in order to improve the performance of future computer programs in the field of construction engineering and management. Main directions of innovations will be the integration of laser scanning and photogrammetry in the as-built documentation and the concepts of augmented reality.

5.3. Standards and Interoperability

Keeping interfaces open and defining standards for the exchange of data are important issues on the agenda of interacting developers. Big software companies try to offer a complete set of harmonized products for their clients. Nevertheless, the market is so dynamic, that competition between different products as well as interchange between the different systems will be demanded by many users. Initiatives as the Building Smart Alliance for Interoperability

[22] are vivid initiatives on the right track – to set standards for interoperability as well as to foster improved interfaces in highly competitive large software packages.

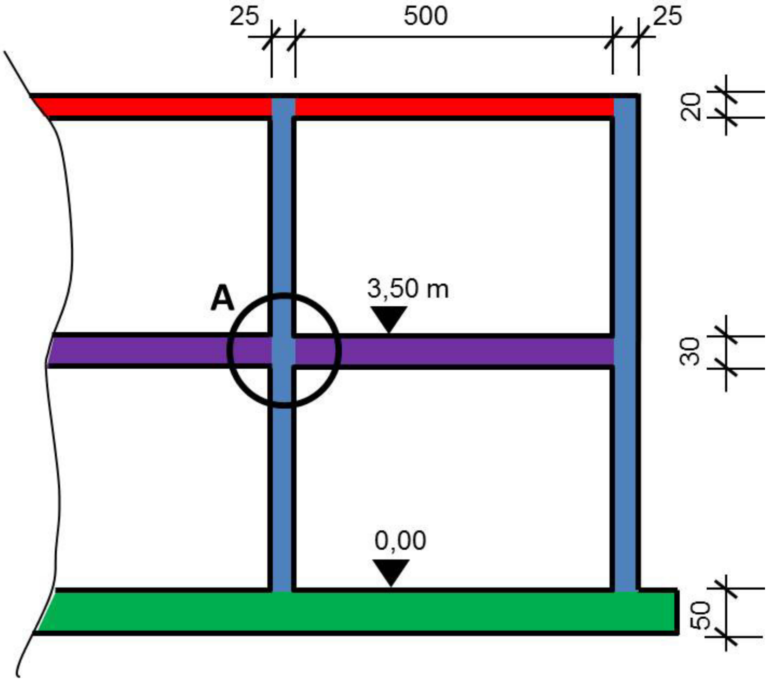

Fig. 2. Cross section of a building structure with overlapping partial sections of walls and slabs, here exemplarily marked at reference point A

5.4. Transparency of Documented Knowledge

Our current research initiative focuses on the transparency of documented knowledge. Here we observe special demand by clients and contractors, who still want to know more about the applied algorithms, about the conventions and regulations, which run in the back of automated processes in software programs [23].

Nowadays the flexibility of site management is such that experienced engineers often question the underlying regulations, so that they can make out the weak points for their individual purpose. Figure 2 shows a simple example of a cross section. When defining the section of a floor slab or a wall, there should be a definition, whether the part of the crossing section between wall and slab (circled with A) belongs to the wall or to the slab or to both elements, depending on the views on reinforcement, on formwork or on concrete volume.

5.5. Special Topic: Clash Detection

A powerful feature of BIM is the possibility to run clash detection programs. To detect clashes seems to be easy at first glance. But it implies a large number of considerations, whether crossing of two power lines is a mistake or a connection. Crossing of pipes with walls can be hazardous or harmless. Two parallel pipes might be allowed one next to the other, or they need a distance for isolation, or they need even a larger distance for inspection. Each of these views needs special considerations, which also must be described properly, so that the user can chose the right checking algorithm.

Transparent checking procedures not only make work faster and easier. They should also allow the engineer to better concentrate on the remaining problems and checks, where his experience and special knowledge is still needed and highly respected.

6. Summary

Building Information Modeling yields high potential. Currently this is gaining momentum in the architect and engineering phases. However, for site operations, there are additional and specific demands. The paper shows the specific tasks, which can be supported by Building Information Modeling in the realization phase. Main features are collaborative detailing on a consistent data model, the flexibility for work planning, as-built documentation and powerful procedures to process changes. Nevertheless, the more Building Information Modeling automates support services the more the applied algorithms must be made transparent for the responsible site engineer.

References

[1] Borrmann, A., König, M., Koch, C., Beetz, J. Building Information Modeling (2015 Springer)
[2] Huhnt, W. et al. Data management for animation of construction processes (2010) Advanced Engineering Informatics 24 (4), pp 404-416
[3] Eastman, C., Teicholz, P., Sacks, R., Liston, K. BIM Handbook – A guide to building information modeling: 2nd edition (2011), Wiley.
[4] Günthner, W. A., Borrmann, A. Digitale Baustelle – innovativer Planen, effizienter Ausführen (2011 Springer.
[5] Scherer, R., Schapke, S.-E. Informationssysteme im Bauwesen 1 (2014) Springer-Vieweg.
[6] VOB/B – Construction Contract Procedures (2012) Beuth.
[7] Bargstädt, H.-J. Modern Construction Quality – a technological approach to improve quality and target accuracy for workers. (2014) International Scientific Conference at Moscow State University of Civil Engineering, 12-13 November 2014, Moscow
[8] AIA Document G202-2013 – Project Building Information Modeling Protocol Form. (2013) http://www.aia.org/contractdocs/AIAB098226
[9] Bauch, U., Bargstädt, H.-J. Praxis-Handbuch Bauleiter (2015) Rudolf Müller.
[10] Kochendörfer, B., Liebchen, J., Viering, M. Bau-Projekt-Management. (2008) Wiesbaden, Vieweg + Teubner in GWV Fachverlage GmbH.
[11] Hollermann, S., Bargstädt, H.-J. 4D site installation planning in virtual reality for multi-user (2014) ICCCBE – International Conference on Computing in Civil and Building Engineering 23-25 June, Orlando.
[12] Behaneck, M. More efficient production and assembly (2012) BFT International 01-2012, pp 46 - 55
[13] Bargstädt, H.-J.: Leistungsverträge und durchgängige Arbeitsorganisation – wie passt das zusammen? (2010) Kumlehn, F. Die wirtschaftliche Seite des Bauens. Technical University Braunschweig, pp 25 - 40
[14] Scherer, R., Schapke, S. E., Tauscher, H. MEFISTO: Management – Führung – Information – Simulation im Bauwesen: Tagungsband 2 (2011) Mefisto Kongress, 13. Oktober, Dresden.
[15] Tauscher, E. Vom Bauwerkinformationsmodell zur Terminplanung (2011) Dissertation, Bauhaus-Universität Weimar.
[16] Tulke, J. Kollaborative Terminplanung auf Basis von Bauwerkinformationsmodellen (2010) Dissertation Bauhaus-Universität Weimar.
[17] Richter, S., Huhnt, W., Wotschke, P. Applying a new approach to generating construction schedules to real projects. (2009) Computing in Engineering. EG-ICE Conference 2009, pp 234-241
[18] Horenburg, T., Wimmer, J., Günthner, W.A., Borrmann, A., Dori, G. Towards collection, processing and use of actual data for the process simulation during construction (2012) EG-ICE 2012 International Workshop: Intelligent Computing in Engineering. 4 - 6 July, Herrsching.
[19] Melzner, J, Bargstädt, H.-J. Construction Safety Management based on a 3D Building Model – A review (2013) CSCE 2013 General Conference 29 May - 1 June, Montreal. pp GEN-325-1 to 9
[20] Kugler, MM. et al. Linking product and process data in the modeling environment CISMO (2011) 11th International Conference on Construction Applications of Virtual Reality, pp 171-181
[21] Bargstädt, H.-J., Nasir, A. R. Can BIM support better working conditions for low-skilled labor? (2014) CONVR – 14th International Conference on Construction Applications of Virtual Reality, 16-18 November, Sharjah.
[22] Buildingsmart. www.buildingsmart.de.
[23] Bargstädt, H.-J.: Transferring BIM information into respected work orders (2013) CSCE Annual Conference Montreal, CON-214 pp 1-9.