Fifth International Conference on Construction in the 21st Century (CITC-V)
"Collaboration and Integration in Engineering, Management and Technology"
May 20-22, 2009, Istanbul, Turkey

Lessons Learned from Generation of BIM for Construction Management: Case Study

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Abstract
Building Information Models (BIMs) are beginning to be utilized for facilitating effective communication of accurate data about projects throughout their lifecycle. Such models are envisioned to be a common medium to store and exchange information amongst various stakeholders involved in a project by enabling the creation and reuse of information. As interest in the usage of BIM grows in the industry, a need emerges to understand what are requirements in terms of time and effort necessary to generate a BIM that is useful for construction management purposes. With the aim of identifying challenges associated with the creation of a BIM, the authors conducted a case study in which a five storey commercial building was modeled at the beginning of its construction period. Core and shell elements were modeled with close interaction with the contractor to understand the level of detail that was needed by that contractor; which resulted in a model containing 6,006 components. During modeling, the amount of time needed for creating and maintaining of the model was also captured so as to be able do an analysis of the requirements for creating and maintaining BIMs. In this paper, the authors present the lessons learned from this building information modeling experience, with a specific emphasis on the issues identified related to the creation of, and level of detail that was needed from, the model.

Keywords
Building information modeling (BIM), Case study, Level of detail (LOD), Time spent for BIM

1. Introduction

Building Information Models (BIMs) are being used by Architecture/Engineering/Construction (AEC) companies for design, construction document creation, and construction coordination (Young et al. 2008). Such models facilitate effective communication of data about a project, since they provide the opportunity to have all building related information coordinated in 3D. BIM is a common medium that allows storing and exchanging information amongst various stakeholders involved in a project by enabling the creation and reuse of information. Stories of successful implementation of BIMs are available in various publications and websites (e.g., Eastman *et al*., 2008; Olofsson *et al*., 2008; buildingSMART 2009; Solibri, 2008 and Vico 2008). Furthermore, there are research studies and articles investigating various BIM uses, such as 3D modeling for construction documents, visualization, collaboration and clash detection/coordination (e.g., Buckley, 2007; Staub-French and Khanzode, 2007) as well as studies describing the benefits of, and testing the capabilities of, BIM (e.g., Khemlani, 2004; Boryslawski, 2006; Smilow, 2007, Akinci *et al*., 2003), and studies assessing the impact of using BIM on project performance (e.g., Haymaker and Fischer, 2001; Staub-French *et al*., 2001, Kam *et al*., 2003).

As the interest in the usage of BIM grows in the industry, companies which are considering to adopt BIM need documented studies to understand requirements in terms of time and effort necessary to generate and maintain a BIM. In such decisions, knowing what it takes to generate a BIM is as important as knowing what returns and advantages can be gained using BIM on a project. To address this need, the authors conducted a case study to assess the time and effort required to generate a BIM to be used purely for construction management purposes. With the aim of identifying challenges associated with creation of BIM, the authors modeled a five storey commercial building at the beginning of the construction period. Core and shell elements were modeled with close interaction with the contractor to understand the level of detail (LOD) that is needed by that contractor. In this paper, the authors present the lessons learned from this building information modeling experience with a specific emphasis on the issues identified related to the creation of, and level of detail that was needed from, the model.

2. Overview of Case Study

A five story high, 189,000 sq.ft. commercial building was modeled utilizing a widely-used BIM software package. During the modeling effort, the team worked in close contact with the contractor to understand the level of detail that is needed for their purposes. The model was generated based on the 2D drawings (in .dwg format) supplied by the architect. The team focused on modeling core and shell elements only, since that was the scope of the contractor. In addition to initial modeling effort, the team also worked on updating the model whenever there was a change. The building being modeled was composed of steel structural elements (beams and columns), curtain walls and brick veneer walls with metals studs on the exterior enclosure and a metal deck roof. A total of 6,006 elements were modeled; the components of the building were created at different levels of detail with the goal of assessing the trade-offs between the effort of creating additional levels of details and the value of information to the contractor. During the modeling process, the time taken to create and maintain the various parts of the model was also documented so as to be able do a detailed analysis of the time and effort required to create and maintain a BIM for construction management purposes.

The modeling effort was the first experience of in-house BIM implementation for the contractor; and their goals from the generation of BIM were to address the issues with pile cap elevations, to coordinate the perimeter slab condition, to check the vertical alignment of studs and shafts, and to better understand the steel structure by the help of the 3D model. Moreover, they were interested in updating the model during construction so as to have an as-built model at the end of the core and shell construction. Contractor was also primarily interested in assessing the effort (in man-hours) required to create and maintain the BIM. The authors' objectives were to observe the benefits of implementing BIM concurrent with the construction process, as well as to identify the time required to generate the model. Problems encountered while modeling the building were also documented. The following section provides the details of these analyses.

3. Lessons Learned from BIM Creation Process

3.1 Breakdown of Time Spent for Generating the BIM

Modelers recorded the time they spent for creating the BIM in six major categories (see Table 1) considering all the tasks performed by the modelers during modeling. The total time spent for creating the 3D model, shown in Figure 1, was approximately 412 hours. It should be noted that the modeling was performed by PhD students, who are not necessarily experts in the operation of the specific BIM tool used. Therefore, the data presented should not be considered as a description of the absolute times for modeling effort to be expected, but rather as a description of the relative amounts of time spent for achieving different levels of detail in the model based on the information requirements of the project manager.

Table 1: Breakdown of the Time Spent for Generating the BIM

	Hours
MODELING	233
REMODELING/UPDATES TO MODEL	41
REVIEWING PLANS	75
MEASURING AND CALCULATIONS	26
LEARNING SOFTWARE	31
MANAGING CONFLICTS	6
TOTAL	412

Table 1 shows that more than 50% of the total time (233 hours) is spent in direct modeling activities. There were no major changes to the plans made during the modeling period and the remodeling and updates to model took 10% of the total time spent (41 hours). Reviewing the plans and making measurements of, and calculations based on, 2D drawings to perform modeling in BIM took 24.5% totally (101 hours). Learning the modeling software required 7.5% (31 hours) of the time. In addition, 1.5% (6 hours) of the time was spent managing conflicts in drawings in order to proceed with modeling. This number shows the time spent only for communicating the conflict to the project manager and discussing how to proceed with modeling. Time taken for all other tasks related to management of drawing conflicts, such as sending RFIs (request for information) or contacting the architect are not included within this time since these activities were performed by the project manager. Moreover, conflicts in the drawings also increased the time spent in reviewing plans.

Table 2 shows the details of the performed activities grouped based on the categories that were presented in Table 1. Components forming the BIM and associated time spent in creation of them, as well as the list of the tasks that required remodeling and calculations can be seen in Table 2. The "modeling time" column is composed of the times for modeling all the elements in the BIM. As depicted in Table 2, most of the modeling time was spent generating the steel beam elements (54 hours), roof elements (44 hours), foundation (34 hours), and curtain walls (31 hours).

Table 3 presents the distribution of modeling times based on the different components in the BIM. Level of detail term was used by the authors in the sense that more elements needed to be modeled to represent a building component or section (e.g., roof, foundation). LOD was increased by adding more elements to a specific component so that previous components were not altered. The steel beams, foundation, roof, and curtain wall components of the BIM required most time for modeling. The reasons for this distribution of effort are explained in the following paragraphs for each component type.

Steel beams took the longest time for modeling because there were differences in beam types of the building preventing the usual efficiency that can be gained from repetitive modeling by replicating the typical elements that were already modeled. When components are unique, a modeler needs to manually create each and every element, which clearly requires more time for modeling. Also, beams at the roof level were inclined and this specific modeling task took more time in the specific BIM software than modeling horizontal beam elements.

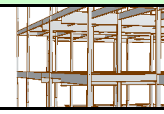
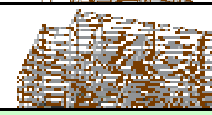
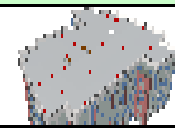
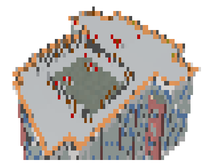
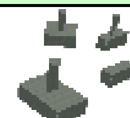
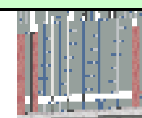
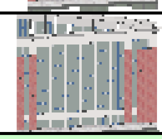
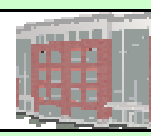
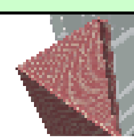
Table 2: Details of Time Allocation

MODELING	Hours	REMODELING/ UPDATES TO MODEL	Hours
layers, xrefs, storeys, etc	6	adding new layers	3
origin shifting (of x-refs)	3	change component type to be used for modeling	1
pile caps and piers	6	change element properties	1
piles	7	update with additional information	4
grade beams	4	update with design change	5
foundation walls	17	remodeling due to discrepancy	4
steel columns	9	remodeling due to Str.-Arch. drawing conflicts	3
steel beams	21	remodel doors	2
roof beams (inclined)	33	remodel foundation walls	5
slabs	4	other	13
roof deck	14		
roof parapets	2	MEASURING AND CALCULATIONS	
roof screen wall (+tubes + wire meshes)	7	calculations for foundation (pile cap, pier depth & elevation)	4
roof HSS tubes (+connections + insulation)	12	measuring and calculations for foundation walls	3
roof cornice	6	measuring and calculations for inclined beam angles and dimensions (2D plane)	2
roof coping	2	calculations for column elevation/height	1
plywood (roof)	1	measuring and calculations for roof beams	5
canopy	7	measuring length of roof tubes	1
brick walls	4	measuring angles of roof decks	1
metal studs + insulation	14	measuring lengths around roof	1
curtain walls	14	other	8
windows	15		
doors	5	REVIEWING PLANS	75
claddings	17	LEARNING SOFTWARE	31
docking area + louvers	3	MANAGING CONFLICTS	6
TOTAL	412 hours		

Brick veneer elements were modeled with the insulation and metal studs as per the design. This was required by the project manager. He stated that he would like to check the vertical alignment of the studs, thus the brick veneer walls could not be modeled as one composite element. Therefore, for the walls, insulation, metal studs and brick veneer were modeled separately. This took more time than putting just a composite brick veneer element into the model. As can be seen from Table 3, modeling brick walls took 4 hours whereas adding insulation and metal studs required 14 hours, causing a four-fold increase in the modeling time of brick veneer walls. Similarly adding cladding elements to the curtain walls increased the modeling time two-fold. Additionally, modeling the windows and doors of the exterior enclosure required 20 hours in addition to the time spent modeling the brick veneer walls and curtain walls.

Lastly, the time spent modeling the roof was a major portion of the BIM creation effort, since many small components of the roof were modeled as per the project manager's request. This decision to model elements, such as roof parapets, screen wall, tubes, wire meshes, hollow structural steel (HSS) tubes, connections, insulation, cornice, and coping, required an extra 16 hours of modeling in addition to 14 hours of modeling the roof deck. The difference in the required level of detail (LOD) caused us to spend more time for modeling. This example showed us that the time tradeoff should be considered for decisions related to LOD of the various parts of the model. Contractors might have other criteria in deciding the LOD, for instance whether they would prefer to see more details for the parts that they will self-perform. A solution to this requirement can be to model typical sections of those parts in detail to

Table 3: Component Based Breakdown and Time for Different Components

STEEL BEAMS	Hours (54)	
steel beams	21	
roof beams (inclined)	33	
ROOF MODELING	**Hours (44)**	
roof deck	14	
roof parapets	2	
roof screen wall + tubes + wire meshes	7	
roof HSS tubes + connections + insulation	12	
roof cornice	6	
roof coping	2	
plywood (roof)	1	
FOUNDATION	**Hours (34)**	
pile caps and piers	6	
piles	7	
grade beams	4	
foundation walls	17	
CURTAIN WALLS	**Hours (31)**	
curtain walls	14	
claddings	17	
WINDOWS and DOORS	**Hours (20)**	
windows	15	
doors	5	
BRICK VENEER WALLS	**Hours (18)**	
brick walls (floor by floor)	4	
metal studs + insulation (floor by floor)	14	

save time on modeling. In any case, users of the BIM should define their aim and the purpose of the model beforehand, since it will dictate the LOD requirements. For example, a model generated for simulating the schedule might have a different LOD than the authors were asked to produce in this case study.

Although the time spent for learning the software is captured separately (see Table 2), the need for getting familiar with different features/modules of the tool is apparent in the modeling activities that are not repetitive. Activities requiring creation of custom elements (e.g., metal stud sections, curtain walls and windows) and deeper knowledge of the tool (e.g., inclined beam modeling) took more time. Major time increases also came from the need for one-by-one modeling of non-repetitive components (such as beams, curtain walls and embedded doors and windows), which requires more time than building the model by replicating typical elements.

3.2 Problems

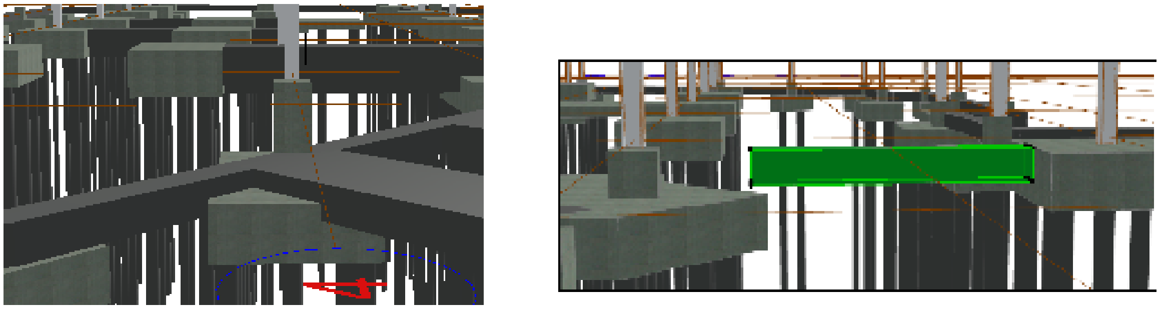
The authors also encountered some technical problems while modeling in the selected BIM tool. The design drawings (in .dwg format) provided by the architect were used as the template of our 3D model. Differences in the origins of structural and architectural drawings was a major problem that needed to be solved by contacting the software tool's representatives, as it was not possible to change the origins in the source files and there was no information of the current origin of the plans.

Another problem was the need to model walls in order to embed curtain walls within them. The specific BIM tool utilized required having wall components already in place, to be able to model components such as windows, doors and curtain walls. However, curtain walls were designed to serve as exterior walls by themselves, so there should not be a need to model extra walls to embed them. Yet the authors needed to model curtain walls by first modeling the walls that will contain those curtain walls. These walls are extra components in the BIM that took time to create and had to be added to the model unnecessarily. Furthermore, these walls are likely to appear in any other analysis (e.g., clash detection) that will be performed by using the BIM, unless they were discarded manually.

Moreover, some components that needed to be modeled were not available in the library of the BIM tool. Therefore, these were created from other components that were available. For instance, insulation was not a type that was available so it was created from wall type components. Wall tool was used since it was possible to model vertical insulation components using walls. This might create problems since the type of the insulation element is captured as a wall in the BIM tool and will be exported as a wall element to other applications (such as estimation, clash detection or analysis tools). This limitation of the selected BIM tool makes the model vulnerable to creation of incorrect information about the building.

3.3 Benefits

The creation and use of the BIM had several benefits to the contractor. Creation of the 3D model concurrently with the start of the construction helped them to detect some problems with the design earlier in the construction process and thus be addressed more cost-effectively. For instance some grade beams were running into pile caps (Figure 1.a.) and one grade beam had an elevation difference problem that was causing it not to connect with a pile cap at one end (Figure 1.b.). This was easily visible in 3D but wasn't identified before generation of the BIM; the problem would have been noticed at the site later in the process. The project manager stated that early identification of this problem was a great help to them. An RFI was issued and the architect did the required changes to the plan before the construction of the grade beams. Had this problem been identified during construction, it would have caused the construction to stop while waiting a design change from architect as a solution to the problem.

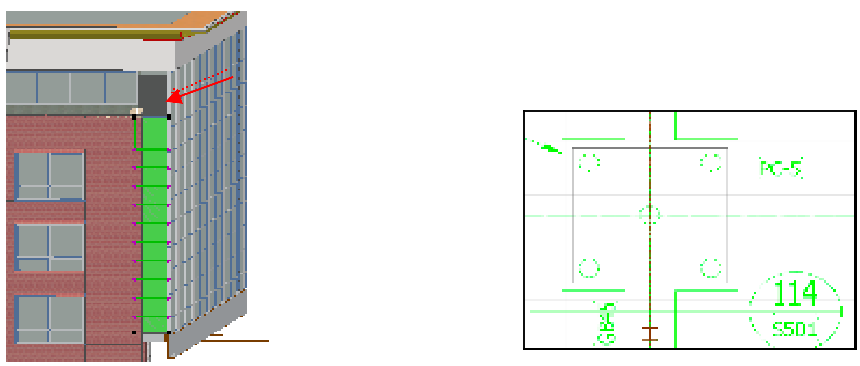


(a) Grade beams running into pile cap (b) Grade beam that is not connecting to lower pile cap

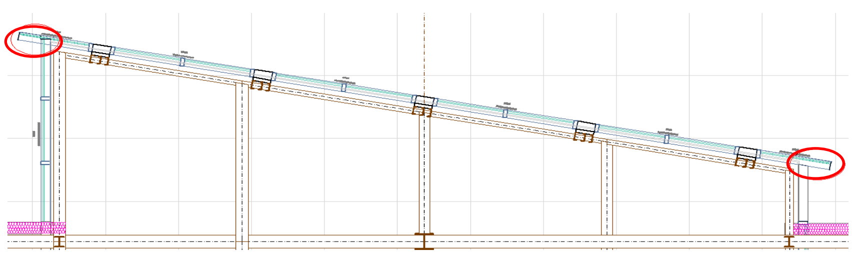
Figure 1: Grade Beam Problems in the Design Identified in BIM

The authors identified some mistakes in the dimensions of the steel beams as well. When modeled with the planned dimensions, some beams were not connecting. This problem was also solved by an RFI sent to the architect. The steel beams were already ordered, and the problem in the dimensions of the beams was solved before their delivery to the site, at no cost to the contractor since the problem was discovered before the wrong beams were fabricated.

There were also some other errors in the plans, such as: 1) having curtain wall typical dimensions shorter or longer than the exterior façade in which it is supposed to fit; 2) differences in the dimensions denoted in the typical drawings and floor plans of pile caps, piers, curtain walls and the elevations of grade beams; 3) windows with dimensions that did not fit into the façade width; and 4) pile cap details that did not exist in the typical drawings (some shown in Figure 2). All such problems were identified during the modeling process. Therefore, generation of the BIM model enabled early identification of problems that otherwise would have been identified later in the construction process; which would result in costly remedies.



(a) Curtain wall shorter than the façade length (b) Pile cap dimension conflict



(c) Curtain wall width longer then the façade width

Figure 2: Curtain Wall and Pile Cap Problems in the Design Identified in BIM

4. Conclusion

The authors conducted a case study of modeling a five story commercial building at the beginning of the core and shell construction. The time spent for various activities was captured during the generation of the BIM. The authors identified differences in the time required for modeling the components that were at different levels of detail dictated by the project manager. The presented records support the requirement for defining the usage and aim of the BIM before its creation, since more detail required significantly more (2-4 fold) time for modeling. Issues in the design that were identified during the modeling process demonstrated several significant benefits for utilizing a BIM model for construction management. Identifying problems early in the construction phase is one of the many benefits that would motivate the AEC companies to deploy BIM technology.

5. Acknowledgements

The building information modeling effort of the presented project was performed by the help of PhD students Semiha Kiziltas and Guzide Atasoy. The authors gratefully acknowledge their help and contribution in this case study.

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