# THE USE OF THE BUILDING INFORMATION MODEL IN CONSTRUCTION LOGISTICS AND PROGRESS TRACKING IN THE WORCESTER TRAIL COURTHOUSE

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## ABSTRACT

The construction industry is gradually adopting Information Technology tools into everyday operations at construction sites. The concept of the Building Information Model (BIM), which is an object oriented technology, has a high potential for revolutionizing the way projects are designed and built. Some general contractors and construction management firms are starting to use the BIM capabilities to visually analyze the logistics of the construction process with their subcontractors and to develop well coordinated project schedules.

Over the last five years, the authors have been systematically exploring the emerging BIM concept through research and educational projects. In early May of 2004, the authors got together to plan a research study that would explore the potential benefits of the use of the BIM model in the early stages of the construction of the Worcester Trial Courthouse, a $180 million facility that is currently under construction in Worcester Massachusetts. This paper summarizes the results derived from this experience. The results show that the use of the digital model enhances the communication process among the different construction trades and facilitates coordination. The use of the model also identifies the need for improved interoperability between the scheduling and BIM software. Finally, it shows the need for introducing the building modeler as a new position in construction companies.

## KEY WORDS

IT case studies, building information model, construction logistics, project scheduling and control computing, 3D object oriented models.

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## INTRODUCTION

The construction industry is gradually adopting Information Technology tools into everyday operations at construction sites. The concept of the Building Information Model (BIM), which is an object oriented technology, has a high potential for revolutionizing the way projects are designed and built. This is due to fact that the project can be gradually assembled digitally and visualized in 3D before it is actually built. In addition, the BIM offers a wealth of information that is generated automatically as the model is created. In turn this information can be used for cost estimating, project planning and control, and eventually for management of the operation and maintenance of the building. Some general contractors and construction management firms are starting to use the BIM capabilities to analyze the logistics of the construction process with their subcontractors and to develop well coordinated project schedules. This allows them to detect potential coordination issues before these occur in the field, thus saving cost and time during project execution.

Before a new technology is adopted, there is a period in which the claims about its potential benefits and costs need to be closely examined, tested and verified. This is particularly true in the case of the traditionally skeptical Architectural/Engineering/ Construction (AEC) industry in which the adoption periods of promising technologies may be very long.

Over the last five years, the authors have been systematically exploring the emerging BIM concept through research and educational projects. As a result, the authors have found evidence that the use of this concept has indeed the potential to reduce schedule delays, change orders, and to effectively support cost effective design development. However, in these previous studies the researchers did not have an opportunity to incorporate the BIM model as one of the decision support systems directly available to the site management and to make direct observations on the feasibility of its use and on the impact as decisions were made on a weekly basis.

For this reason, the authors got together with the software vendor in early May of 2004, to plan a research study that would explore the potential benefits of the use of the BIM model in the early stages of the construction of the Worcester Trial Courthouse, a $180 million facility that is currently under construction in Worcester, Massachusetts. This paper summarizes the results derived from this experience.

## OBJECTIVES AND SCOPE

The objective of this research was to explore the BIM capabilities when used in the field to better communicate and integrate construction information across different trades, allowing for efficient work processes and better decisions. More specifically, the study concentrated on the deployment of the model to support planning, scheduling and tracking of the job site operations.

The study was divided into two major phases each one corresponding to an academic semester. The objective of the first phase, conducted during the fall semester of 2004, was to create the digital model of the substructure of the project in order to visually assist the project superintendent to identify spatial conflicts primarily between the pile driving and the earthwork operations in order to improve the work flow for subcontractors, and to create a 3D version of the construction schedule at different stages of development. During this phase, it was expected that the students who were creating the digital model would become very familiar with the project as well as with the phasing capabilities and limitations of the software

The second phase was conducted during the spring semester of 2005. The objective of this phase was to generate 3D versions of the digital model for the steel frame according to the planned construction. It was intended to make these 3D visual models available to the project manager and superintendent at their weekly meeting in order to observe the impact (if any) that this tool would have in facilitating or improving communications. More specifically, the purpose was to observe the following aspects:

- **Software related issues**. Of particular interst to this study was to determine the capabilites and limitations of the software in supporting the development of the digital model. These included ease of use, library of objects, level of detail, and educational material. The software used to create the 3D digital model was version 6.1 of AutoDesk® Revit®
- **Project Information related issues**. It was important to determine the completeness, timeliness, correctness and avilablility of the information that is necessary to build the digital model and also to determine how well the information generated by the digital model complements the information typically used by the project.
- **Model Usability related issue**. Finally, it was important to determine the real value added by the digital model to the project mangement.

## CASE STUDY

The new Worcester Trial Courthouse was used as a case study for the purpose of this study. It is a $180 million facility located in downtown Worcester. It will be the first fully integrated courthouse in the State of Massachusetts. This massive building will be the new home of the Worcester Superior, Housing, District, Juvenile, and Family and Probate Courts. The six-story, 427,500 square foot building will have 26 courtrooms and one grand jury room; offices, public transaction areas, hearing rooms, public lobbies, and a secure holding area. The building also contains parking for the judges (see Figure 1 below). Construction began in July 2004 with an anticipated completion date of July 2007.

The building was designed by Shepley Bullfinch, Richardson and Abbott (SBRA) Architects from Boston Massachusetts. The Division of Capital Asset Management (DCAM) represents the State of Massachusetts who is the owner of this facility. Tishman Construction of New England is the Owner's Agent for the project. The Gilbane Building Company of Boston, Massachusetts, is the construction manager in charge of the construction of the facility. As a result of recent construction reform, this is the first facility in the State being delivered by DCAM under the Construction Management at Risk contracting method. The Gilbane Co. was brought on board in December of 2003 when drawings were about 85% complete. Gilbane worked side by side with SBRA and DCAM in the preconstruction process for 6 or 7 months prior to beginning construction. Figure 1 below shows a rendered design of the future courthouse.

Figure 1: The Worcester Trial Courthouse

## METHODOLOGY

The kick-off meeting for this study took place at Worcester Polytechnic Institute in late April 2004. The participants at this meeting included two representatives from the software vendor, two representatives from the construction management firm and the research team consisting of two graduate students and a faculty advisor. The software vendor introduced the BIM concept and the group discussed at length the potential benefits and limitations of its application in this study. Of particular interest to the discussion was the determination of the level of detail that can be produced by the software in generating graphic 3D, 2D and text information to facilitate communication and coordination during construction, and to insure compatibility with the design documents. The discussion also addressed the level of training and effort necessary to create and maintain the digital model.

As a result of this discussion, the group established what could be a realistic expectation derived from this study. It was decided that in this case the value of the model would come from the timely production of 3D views of the project showing the expected construction progress according to the schedule at predetermined time intervals. These views would not only facilitate communication of the expected construction progress but also could be used to anticipate coordination problems and facilitate planning of logistics at the site. By the end of the meeting it was agreed to conduct the study in two phases over a time span of two consecutive academic semesters. This period of time would allow the research team to create phased versions of the 3D digital model to track the progress for site work, foundation and steel frame work-packages. Objects representing construction components such as piles, foundation walls, columns and beams were either obtained from the software library or created by the research team. Additional objects representing construction equipment such as cranes, pile drivers, and trucks were also incorporated into the 3D digital model for construction planning purposes. The link of these objects with the construction schedule was created by assigning a date of execution to the properties of each object. This allowed for the progressive display of phased views of the projected construction progress as dictated by the schedule.

## PHASE 1

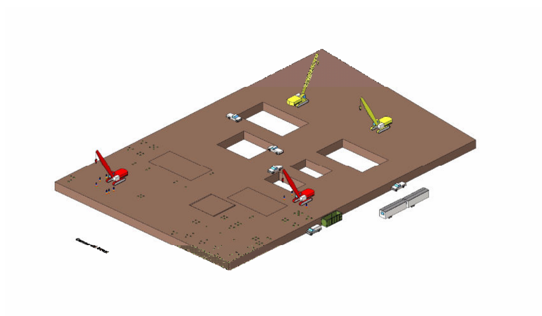
This phase took place between July 23 and December 29, 2005. During this phase the 3D digital model of the building showing site work and foundation work-packages was created using selected information from 2D project drawings provided by the architect in paper and in electronic (DWG) format. The construction schedule was provided by the construction management firm who periodically produced an updated 2-week look-ahead version of it as construction progressed. The research team visited the site weekly and worked closely with the site personnel of the construction management firm during the development of the 3D digital model. This decision-making group included the field superintendent, the project manager, two graduate students and two undergraduate students under the supervision of the project executive and the faculty advisor.

The members of the research team were familiar with the use of the software but had never been exposed in detail to the production of periodic "phased" versions of the model. Therefore, there was a continuous learning curve taking place as the 3D digital model was generated. This learning was facilitated by the on-line help available in the software and by the direct technical support and tutoring provided by the software vendor who was available for consultation through web casts and electronic mail. A technical face-to-face meeting took place in one occasion at the vendor's office in Waltham Massachusetts, to discuss some specific issues with the software design team.

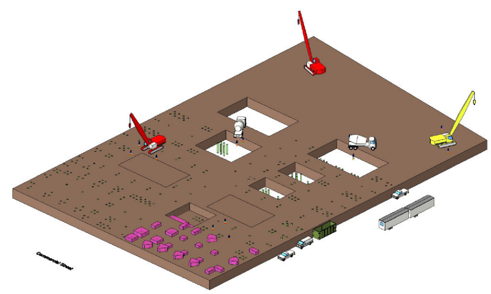
This phase required the creation of seven major types of objects or building elements as follows: elevator pit excavation, piles, pile caps, perimeter walls, band-beams, sub grade and slab on grade. The objects for eleven different types of piles and eleven different types of pile caps were created by the research team while the rest of these objects were taken from the software's library of objects. The decision as to how many construction activities should be "packaged" into one particular object was made jointly between personnel of the construction management firm and the research team based on the desired level of detail for project control, the capabilities of the software and the time involved to generate the desired level of detail. Initially, the *Structural Foundation Family Template* was used to build the piles and its corresponding pile caps ***as one object***. As the gradual development of the 3D digital model started to take shape it was found that the pile-pile cap object had to be recreated into two separate objects to better reflect the construction process since there is typically a lag between the time that a set of piles are driven into the ground and the time in which the pile caps are poured in place. On the other hand, one object was created to represent the sub grade which was made of a rather complex system of subcomponents that included underground ventilation piping, gravel bed, a geo-textile layer, sand bed and reinforcing steel.

Color was also used to distinguish specific objects assigned to different work-packages as planned for in the construction schedule. This simple visual requirement posed a major challenge for the research team since the version of the software used at the time of the development of the 3D digital model did not have the functionality to accomplish this in a simple fashion. Therefore, a more involved procedure was developed by the research team in consultation with the vendor's technical personnel to accomplish it. Newer versions of the software have now developed a simplified procedure for this visual operation.

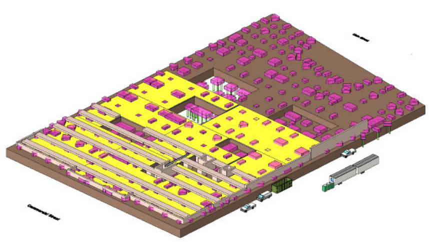
Seventeen versions of the 3D digital model showing a phased development of the construction process were generated during the first phase of this study. These phases were created at roughly at two-week intervals. Figures 2a to 2d below show four of these scheduled phases at different dates and stages of development. These 3D versions of the schedule were posted at the contractor's site office to aid discussions during sub-contractors meetings.



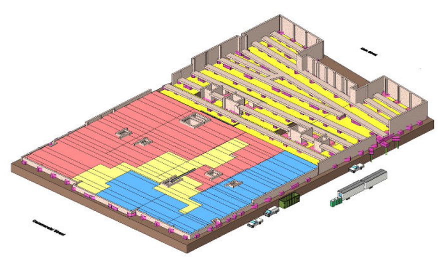
a) August, 2004



b) September, 2004



c) October, 2004



d) December, 2004

Figure 2: Gradual Progress of Site-Work and Foundations

Figure 3 below illustrates the use of color in the objects representing the sub grade, slab on grade, the band-beams and perimeter walls for the foundation of the building.

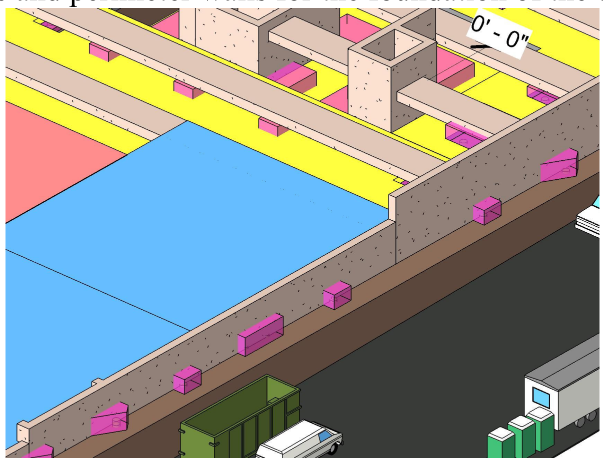



Figure 3: Object representing band beams, sub-grade, slab on grade and walls

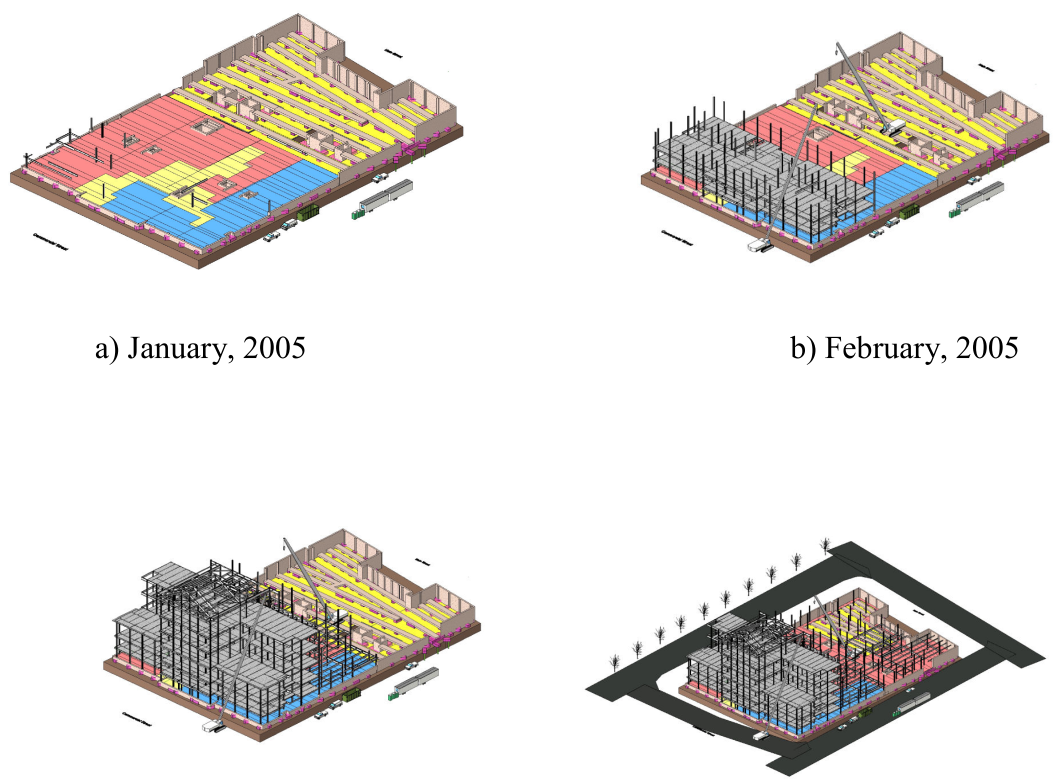
During this time the research team conducted a detailed time study of the effort that it takes to create and maintain the model to determine cost and benefits of this technology in the construction site.

**PHASE 2**

This phase took place between January 4 and May 5, 2005. During this phase the 3D digital model of the building showing primarily the structural steel frame was built upon the one created in phase 1 using selected information from 2D project structural drawings provided by the architect in paper and by the erection sequencing plan created by the steel frame subcontractor. It is important to note that the steel subcontractor used a 3D digital model for the fabrication and erection of the steel frame using STELTEC software. However, this 3D model had no interoperability with the one used by the research. Therefore, there was duplication of effort in this regard. The construction management firm continued to provide updated 2-week look-ahead versions of the schedule as construction progressed. The research team visited the site weekly and worked closely with the site personnel of the construction management firm particularly in identifying mobilization and location of cranes.

During this phase all needed types of objects or building elements which included columns, beams, and girders and cross bracing were available from the software's objects library. The use of color was not necessary used in this case to distinguish specific objects from different work-packages.

Thirteen versions of the 3D digital model showing a phased development of the construction process were generated during the second phase of this study. These phases were created at roughly two-week intervals, plotted and brought to the site on time for the subcontractor meetings. Figures 4a to 4d below show four of these scheduled phases at different dates and stages of development.



a) January, 2005 b) February, 2005

c) March, 2005 d) May, 2005

Figure 3: Gradual Progress of Steel Frame

## RESULTS

This study was conducted on an experimental basis; therefore the 3D digital model and the printouts made out of it were never part of the contractual documents of the project. The following results with respect to the objectives of the study were obtained:

### SOFTWARE RELATED ISSUES

The software was a very helpful tool in creating a 3D digital model of the construction schedule for the site work, foundation and steel frame work-packages form July 2004 to early May 2005. The level of detail that the software was capable of producing for the visual renderings of the schedule was found to be adequate given the limited time and resources allocated to this study. The use of color to identify specific parts of interest of the project was also adequate and helpful. However, for the initial phases of the project, some additional work and operational procedures were needed to achieve the desired objectives. More recent versions of the software seem to make it for functional in this regard.

### PROJECT INFORMATION RELATED ISSUES

One of the main objectives of this study was to observe the value added by the information generated by the 3D digital model to the communication and coordination during the weekly subcontractor meetings at the site. This required timely submittal of this information by the research team. During the first part of this study this objective was hardly met due to the several factors. One of them was the software learning curve fact and the level of familiarization of the research team with the project. A second factor was related to the continuous updates in the schedule that take place in any project and the limited ability of the research team to learn about these changes as they take place to be able to make rapid adjustments of the 3D digital model. This is specially more demanding in the context of the construction management project delivery system in which design is not 100% completed before construction starts. During the second part of the study, and for the most part, the research team was able to timely deliver the printed poster and hang it on the wall before the subcontractor's meeting took place. The project manager suggested that a better interoperability between the 3D modeling software and the project management software could have had simplified and expedited the transfer of schedule information. It seems that this link is now available from the software vendor through Applications Programming Interface (API) but is not an operational feature yet.

### MODEL USABILITY RELATED ISSUES

The reaction of the site management to the first version of the 3D digital model presented by the research team was very encouraging and created great expectations in terms of the potential value added to the project. When the project superintendent saw the 3D version of the construction schedule he had a very spontaneous reaction and seemed rather surprised when he realized that the progress observed in the field to that date was going to make it very hard to match the scheduled progress of construction as shown by the 3d digital model. The superintendent shouted "Is this (3D view) based on our schedule?" The added value of 3D visualization was reiterated by this reaction. 3D leaves few room for misinterpretation by all parties involved and it helps to realign their expectations as compared to what a bar chart schedule can do in this regard. A similar reaction was observed from one of the subcontractors who felt a bit threatened because his trade has started work later that intended because of bad winter conditions. When he saw the 3D digital model posted on the wall showing work form his trade well ahead than what was actually been done in the site he yelled at one of the meetings:" That's not my fault, I am not the one responsible for the delay. The site was not ready on time". The site management agreed with his statement and reassured of that fact.

The research team was not able to observe any more reactions of these type or more active use of the 3D model for construction planning purpose or for trade coordination beyond the ones referred above. However, an unintended positive consequence of this information being available on the site was manifested by a request by some of the judges for extra copies of the model.

## CONCLUSIONS

The BIM is a new and promising approach which is gradually gaining acceptance by owners, architects, engineers, and builders

The objective of this research was to explore the BIM capabilities when used in the field to better communicate and integrate construction information across different trades, allowing for efficient work processes and better decisions. More specifically, the study concentrated on the deployment of the model to support planning, scheduling and tracking of the job site operations. During this time the research team conducted a detailed time study of the effort that it takes to create and maintain the model to determine cost and benefits of this technology in the construction site. The results show evidence that the use of the digital model enhances the communication process among the different construction trades and may facilitate coordination. The use of the model also identifies the need for improved interoperability between the scheduling and BIM software. Finally, it shows the need for introducing the building modeler as a new position in construction companies. This in fact is already taking place in a very small number of construction management firms. This study suggests that a full-time or at the least part-time individual should be responsible for the creation and update of the digital model. This will be a minor investment compared with the potential benefits derived from the use of BIM in improving coordination and communication during construction among all members of the project team including the owner. It is also recommended that further studies explore other BIM potential benefits to construction managers such as cost estimating, interference detection and 3D coordination of MEP work.

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