CHOOSING LEVELS OF GRANULARITY IN BUILDING INFORMATION MODELING: CONTRACTOR'S PERSPECTIVE

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Abstract. Over the last two years, there has been an increased interest across the Architectural /Engineering/ Construction (A/E/C) professionals in the potential adoption of the Building Information Modeling. Professional Associations such as the American Institute of Architects (AIA), the Associated General Contractors (AGC) and the Design-Build Institute of America (DBIA) are dedicating specific resources to better understand the implications of the use of this concept in their professional activities. However, not much ground has been gained yet in finding practical ways to choose the level of granularity (LOG) or detail that is needed to develop the digital model in a cost effective fashion. Choosing the Level of Granularity (LOG) of the digital model or level of detail development that goes into the model is a key decision that results from careful consideration of many factors. It is a very complex and iterative process that requires a critical assessment of the cost of adding details to the digital model versus the benefits derived from its intended purpose whether the model will be used to enhance the communication process or to support the construction management functions performed by the firm. This paper presents two case studies in which the authors have been directly involved in making the decision on the LOG of the digital model. The first case involves the Togar Suites, Union Station project in New Jersey while the second case refers to the Worcester Trail Courthouse in Worcester Massachusetts. In both cases, the 3D models were developed primarily for visualization of the construction sequence. However, in the case of the Togar Suites the contractor also needed the model for trade coordination and clash detection purposes.

1. Introduction

The potential for building rich digital models is very high as well as the temptation to unnecessarily enhance the model. Therefore, a key decision that needs to be made is to clearly define the ultimate purpose of the model. This decision should dictate the elements that need to be included in the model as well as the timing of model release.

Ideally, the contractor should receive a digital model from the architect that contains all the details typically included in the construction drawings. The reality at this point is that for many reasons this is not the case for the majority of the projects. Therefore, the contractor interested in developing and using the model must start building it off the 2D construction drawings.

In the case of 3D sequencing, it is also necessary to have the construction schedule available to the modeler. The modeler, then needs to match the building objects readily available in the software library with the activities defined in the construction schedule. This is the first challenge for the modeler because the level of detail provided in the 2D drawings and construction schedule does not necessarily keep a one-to-one relationship with one another. Besides, the level of detail contained in these documents does not necessarily match the level of detail built into the current library of the objects. To complicate matters even more, the level of detail that would be displayed in the 3D view that the end user needs may not be well defined or known in advance. So the modeler needs to establish a four-dimensional correspondence among these factors. This process is illustrated in the figure below.

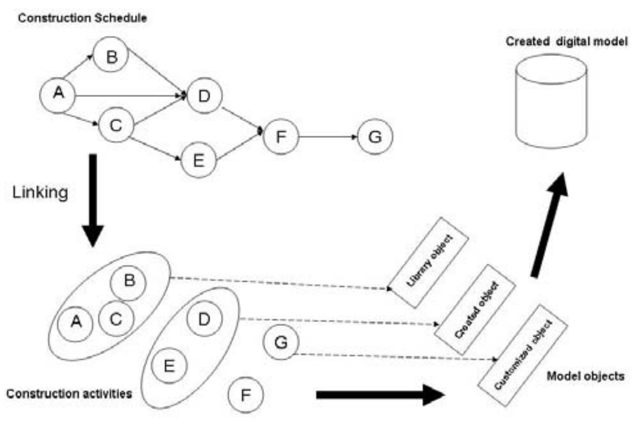

Figure 1 Development process of the digital model

From a contractor’s point of view, the number of activities that need to be linked together to correspond with a specific object represented in the model is mainly dependent on the purpose of modeling it. For example, when modeling the MEP systems for coordination purposes and clash detection, visual scheduling, and/or site logistics planning, the modeler needs to only include the size parameters of the objects to clearly identify the space required to accommodate those systems. . On the other hand when the intent of modeling is to produce shop drawings or perform constructability analysis, obviously further detailing is needed.

After this exercise, the modeler needs to decide on the extent of the additional effort that is needed to generate or search for 3^{rd} party objects that are missing from the current software library. This effort is constrained within the time frame created by the requirements of the project in order to have the model ready ahead of the real construction schedule to have a positive contribution to the construction management process in terms of site logistics and planning.

2. Case Studies

2.1. TOGAR SUITES, UNION, NJ

The Union station project is a 227-unit apartment complex building. It is a $36M, 4 story, (300,000 SF) wood framed podium style structure over 1 level (100,000 SF) of concrete framed 310 spaces parking garage. Square shaped building with open courtyard/pool in center. Complete site development with extensive site improvements, hardscapes and landscaping. The gross area is 409,000 SF (see figure 2 below)

Figure 2 Togar Suites rendering

Tocci Group of Companies (TBC) is building this project under a Construction Management project delivery system. TBC decided to model this project right at the beginning of construction for the following reasons: a) Clash detection to avoid non-discretionary change orders (NDCOs), b) Sequencing, and c) Visualization. An external model builder consultant was awarded in the summer of 2006 to model all the project disciplines: architectural, structural, as well as mechanical, electrical and plumbing.

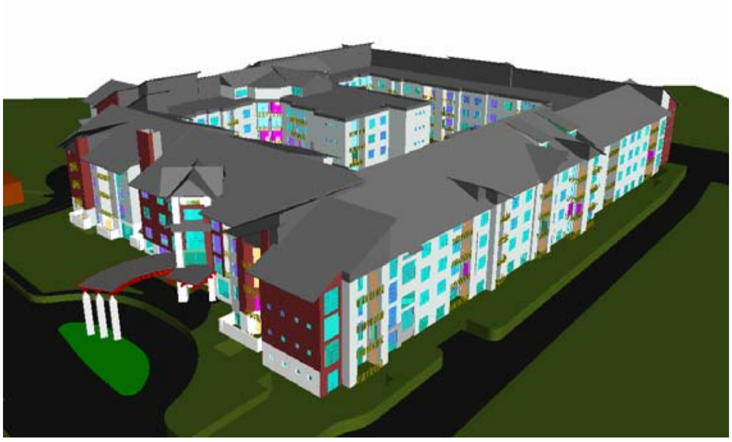

Figure 3 Togar Suites, 3D Model

With regards to the clash detection issue, which was the primary goal of this exercise, TBCs expectations were as follows:

1. The model should include accurate representations of the purchased structural products including structural steel, joists and important, open web wood joist, panels, etc.
2. The model should include a reasonably accurate representation of:
    a. Major mechanical equipment like water heaters, AC equip, fan coils etc.
    b. Major electrical equipment and gear and matched dimensionally with the submitted product.
    c. Submitted Fire protection layouts layered in and coordinated
    d. Major plumbing runs.
    e. A clear delineation of rated membranes and partitions and rated plenums

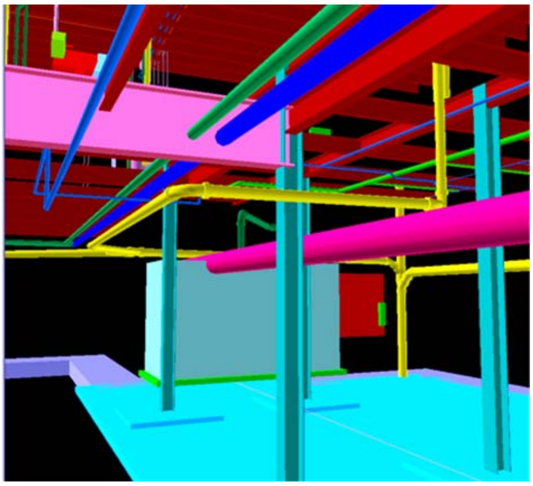

Figure 4 Piping clashing with steel beams at the garage level

As far as sequencing is concerned structural elements were expected to be broken down into the planned pieces for sequencing. The erector needs, requirements in terms of crane sizes, and his expected weekly rates of production should be incorporated in the model. Also deck pours should be sequenced to show expected production rates. The major advantage from a constructor's point of view beyond the clashing is using the model to virtually construct the project.

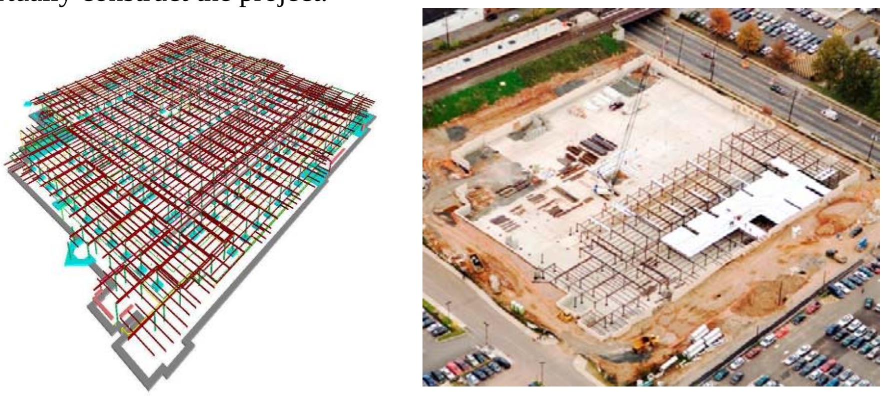

Figure 5 Comparing planned progress to actual progress

In terms of the visualization aspect we expected weekly, or monthly snap shots of the progress depicted by the sequencing.

Figure 6 Visualizing the building before it's built – 5 month in advance

Finally the model had to be flown through by the field staff on their regular job meetings to answer their own questions and provide accurate answers to the subcontractors questions.

The model has produced some helpful clash reports especially in the garage level where it pointed out 13 unfeasible pipe penetrations as shown in the figure below (Figure 7).

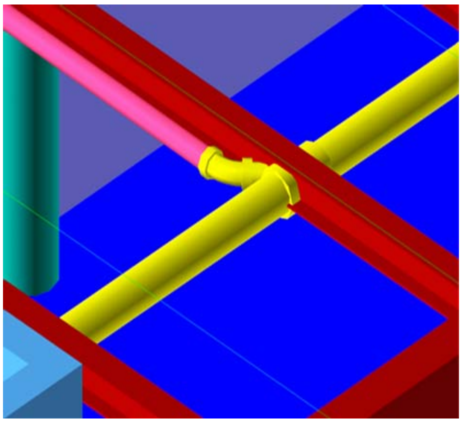

Figure 7. W8 penetrated by an 8" sanitary pipe

The clash reports were sent to the owner and the structural engineer, who replied by changing the concerned beam sizes to accommodate the piping. After looking at the magnitude of the work involved and with the help of the collaborative nature of the project team, it was found that it is more cost effective to re-route the piping to avoid changing the beam sizes and penetrating beams. The cost of rerouting the piping was zero (because the problem was found prior to running the pipe). If the model was not used, the piping would have been run according to the drawings, resulting in a significant amount of re-work. TBC avoided about 25,000.00 dollars in rework due to rerouting the piping before it was installed. In addition, time saved was about three weeks.

On the other hand, when the model was introduced to the field staff, their feedback was that they needed more details to be displayed in order to see the value in the model. Some questions related to the LOG arise here, how far should we go? Where to draw the line? Timely display of correct information by the model is a key factor that adds value for the end user. Other submerging questions are: How long is it going to take to create the model, and, where to fit the modeling exercise in the project schedule? This led TBC to re-think the scope of residential project modeling to include larger scale unit layouts for each typical unit type focused on each typical bath and kitchen; showing piping, fixtures, cabinetry, ceramic layouts, mirrors, backsplashes, outlet locations at kitchen, Grills/registers diffusers in kitchen and bath areas—coordinated with plenums and structure and located in an architecturally acceptable manner, etc. The model has been a step on the right path, it served its purpose of creation in the first place, being able to find clashes ahead of time in order to avoid costly rework and schedule delays. However, if the intent is to have the construction team really rely on the virtual model throughout construction for visualization purposes and for better understanding of how complex areas are specifically put together, a higher level of LOG is required.

Worcester Trial Courthouse:

In mid summer 2004, the authors conducted an exploratory study to evaluate the potential benefits of the BIM to the construction companies. The main intent of this research phase was to explore and investigate the BIM capabilities in the construction field and how it can be used as an emerging IT tool to better communicate and integrate construction information across different trades to allow efficient work processes and better decisions.

The Worcester Trial Courthouse, which is a $180 million new facility to be completed in the summer of 2007 in Worcester, Massachusetts, was used as a case study. The authors considered this project to research how the BIM model can be incorporated to enhance the communication process in the early stages of the construction

The kick-off meeting for this study took place at Worcester Polytechnic Institute in late April 2004. The participants at this meeting included 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 granularity (LOG) that can be obtained from the model. Several issues directly affecting the LOG were discussed such as: software limitations; time for development; level of modeler knowledge; use of the model and the trade-offs between more detailed model and the associated cost.

It was decided that in this case, it was of paramount value is to get a timely production of the 3D phased views of the construction schedule showing the expected progress of the construction activities as planned at constant time intervals. These views were used to facilitate communication of the expected construction progress, to anticipate coordination problems and to facilitate planning of logistics at the site. The study was conducted over a time span of two consecutive academic semesters and covered the site work, foundation and steel construction packages of the building.

The approach that the researchers followed to meet the construction team expectations was to first identify schedule dates for activities of particular interest to the construction team that needed to be modeled. After addressing the needs of the end user then the modelers identified model objects to represent those activities. Some of these objects were readily available in the software libraries but other objects had to created or customized.

These objects represented construction components such as piles, foundation walls, columns and beams. Additional objects representing construction equipment such as cranes, pile drivers, and trucks were also incorporated into the 3D digital model for construction planning purposes. Finally, the digital model was built.

The link between the 3D model and the construction schedule was achieved by first creating new phases within the model representing the finish dates of the chosen activities, then manually assigning those dates to the corresponding object's database using the phase created attribute in the element property of each object. This allowed for the progressive display of the projected construction progress as dictated by the schedule (see figures 8 to 10 below).

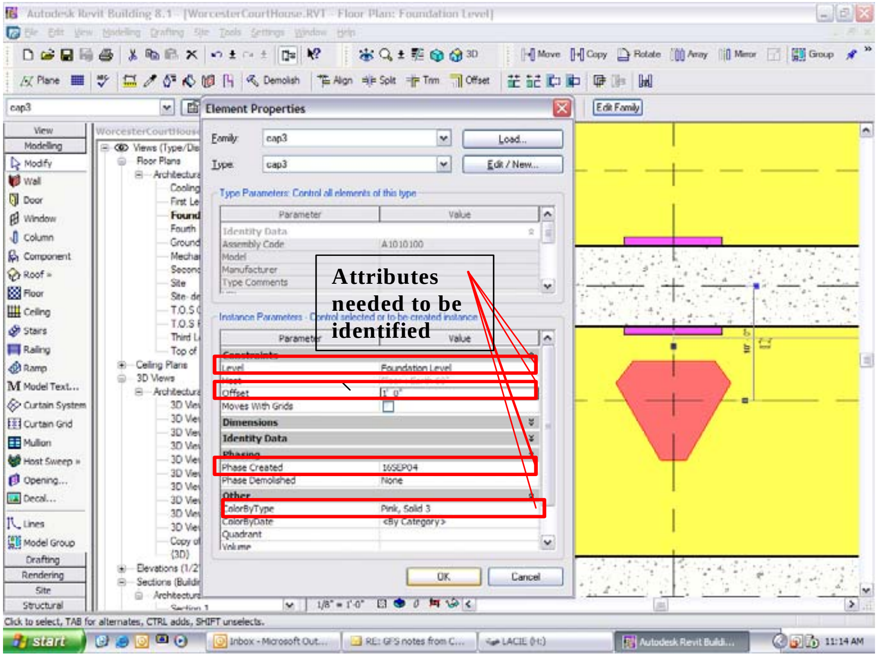

Figure 8. Attributes needed to be identified for a created object

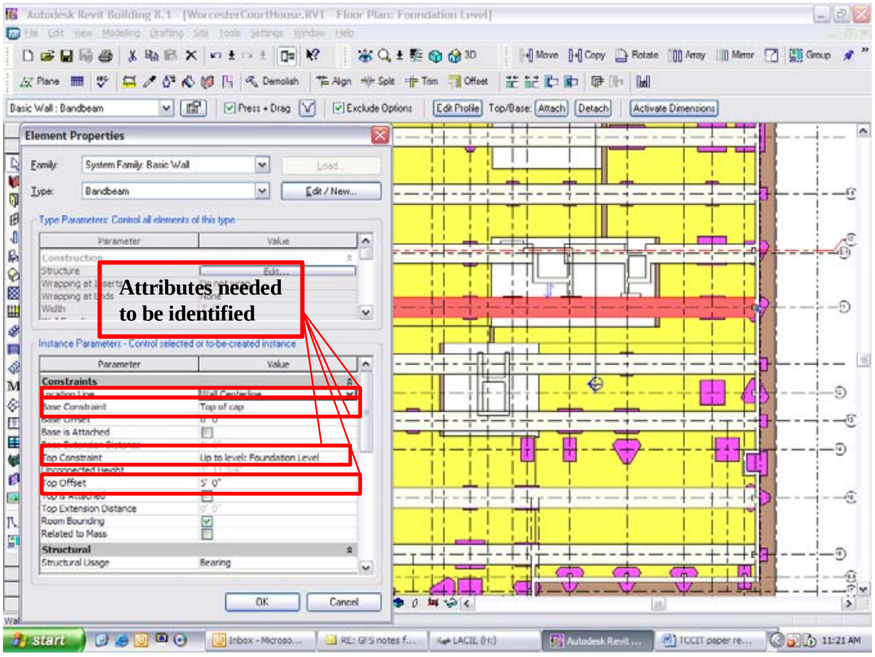

Figure 9. Attributes needed to be identified for a built-in object

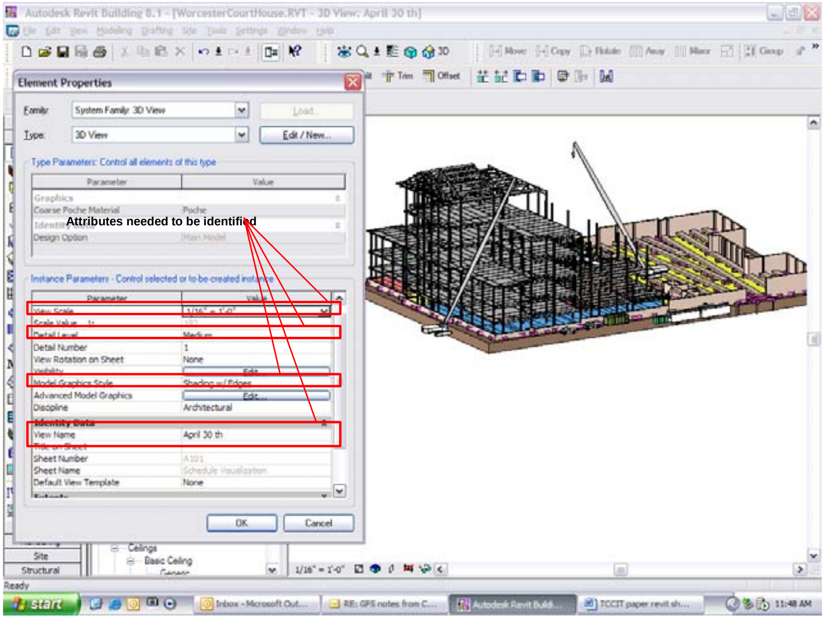

Figure 10. Attributes needed to be identified for a specific view

The software used to generate the model was AutoDesk® Revit 6.1®. This was a very helpful tool in the creation of a 3D digital model of the construction schedule. The level of detail that the software was capable of producing for the visual renderings of the schedule was adequate enough in comparison with the limited time and resources allocated to the study. However, for the initial phases of the project, some additional work and operational procedures were needed to achieve the desired objectives such as the use of different colors to identify some construction activities from the schedule that were of interest to the construction team. It also required the customization of available objects such as the cranes to resemble the pile-driving machine.

The modeler's professional knowledge and skill set is crucial in the modeling process. It requires the modeler to be experienced to use the software and to have an adequate knowledge of the construction workflow and processes in order to develop the virtual model as accurately and cost effectively as possible.

As far as the output information from the model, the construction team will need to be sophisticated and trained enough in the use of the technology to be able to professionally deal with the model and the extracted data. This also would help them in developing more realistic expectations about the benefits that can be derived from the model.

3. Conclusions

From the analysis of the above two case studies, we confirm that the LOG of BIM primarily depends upon the specific needs of each project. The project executive has to first define the purpose of modeling the project, the available timing, resources, and funding, and the benefits anticipated from this exercise. That would definitely help choose the adequate LOG. Input should be collected from representatives of all disciplines that could benefit from the use of the model because each discipline within the building team places different value on details. For example, details that architects consider unnecessary might be essential for the structural engineers and contractors. Therefore, the key to solve this dilemma is to get the entire building team on the same page before the modeling process starts to set and coordinate their requirements and expectations. This will provide the modeling team with information necessary to determine the scope of work as well as the LOG required given the available resources.

In the Togar Suites case, the model satisfied the purpose it was created for by being able to find clashes between structural and mechanical systems before the time of fabrication in order to avoid costly rework and schedule delays. However, the exercise pointed out that in order to get the field staff full attention and confidence in the model, a higher level of LOG has to be incorporated in the model.

In the Worcester trial courthouse project, the purpose of the model was to provide strong and effective visual representation of the construction schedule and to simulate the concurrent site activities. Therefore the corresponding LOG was chosen to satisfy that purpose without going far beyond and spending a lot of time and money on modeling a construction activity that would be of a little additional value. In this model, there were about twenty five pre-defined attributes that could be associated to each view representing a given state of the construction progress on the site. Each of these views might differ from one family to another and could be customized differently. Only 25-30% of the pre-defined attributes were used in each view.

In conclusion, each project needs an early plan to assess the value derived from the use of the model versus the output LOG. More research in this regard needs to be conducted in order to better define and generalize the LOG suitable for each project type. The AEC practitioners should collaborate and share their experiences to enhance and standardize the essence of the modeling process.

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