



## Analysis 1

### *Construction Research: Implementation of Building Information Modeling at the Construction Phase*

#### **Background**

During the 2006 PACE Seminar, it was obvious there was a high level of uncertainty from industry members regarding Building Information Modeling (BIM) implementation. Industry members struggled to answer the question of how a BIM should be used during the construction phase of the project. Other topics that didn't have clear cut answers were how risk and contractual relationships are affected using a BIM and how a BIM affects project teams. After visiting the TETC project site and observing the very inefficient approach being used for coordination review, it became obvious that BIM coordination would be an excellent topic of investigation.

Building Information Modeling is such a new topic that it has forced construction companies to develop their own implementation approaches with some trial and error. Contractors in the beginning stages of BIM, have a lot of questions with regards to legal, risk, and responsibility issues. Many contractors do not understand that BIM risk can be dealt with in a very simple manner and that BIM doesn't have to mean throwing out all of your old coordination processes. The goal of this research is to gain feedback from construction companies successfully using BIM at the construction stage and be able to write some guidelines for other construction companies.

The end goal of this research is to provide construction companies with a clear implementation plan that presents some options that could be tailored to their company or project. To achieve this goal, interviews will be conducted of multiple BIM experienced General Contractors and Penn State faculty acting as a consultant to a General Contractor. The results of these interviews will be used to compare and contrast implementation strategies.

On the following pages several typical interview questions and the answers are listed.

#### **Research Method**

The Associated General Contractors of America has formed an initiative to write a guide for Building Information Modeling to contractors. This guide defines BIM, gives an overview of tools, the process, and addresses risk. After reading this guide, it was determined that specifics of



BIM use for construction coordination were lacking. Specific information on dealing with subcontractors and the coordination process needed to be elaborated on more.

To develop more detailed guidelines, General Contractors with BIM implementation experience were targeted. Interview questions were drafted for both phone and personal interviews. The use of the interview process versus a survey allowed the interviewee to elaborate more on the processes.

In addition to the interview process, research into necessary contract literature was carried out. Examples of this language are included in this report for the reader's reference.

<b>Interview Sources</b>		
<b>Name</b>	<b>Company</b>	<b>Role</b>
David Epps	Holder Construction Company	BIM Champion
Mike Lefevre	Holder Construction Company	BIM Implementation Leader
Mike Kenig	Holder Construction Company	Vice President
Brian Horn	Gilbane Building Company	BIM Coordinator
Dr. John Messner	Penn State	Faculty
Jake Hawes	Clark Construction Group	BIM Implementation Leader
David Hyde	Holder Construction Company	Sr. Project Manager
Don Miller	Holder Construction Company	Sr. Project Manager



## **Research Interview Questions/Results**

### *Building Information Modeling Implementation at the Construction Phase*

1. From a contractual standpoint, how are you requiring subcontractors to use BIM while still considering legal implications?
  - Specific language is being written into Request for Proposals
  - Specific language is being written into subcontracts
  - 2D drawings still dictate legal responsibility
    - 2D shop drawings and 3D BIM's are required by General Contractor
    - Changes and updates must be carried through both media
  
2. In general, what are the varying levels of modeling capabilities of subcontractors? Is one particular trade more advanced than another?
  - Mechanical, Plumbing, and Structural subcontractors are very advanced with 3D modeling
    - These trades have already been drawing in 3D
    - Many subcontractors are using this process for fabrication
  - Electrical and Fire Protection trades are lagging with modeling efforts
  - Mechanical, Plumbing, and Structural are the most critical for trade coordination so this is not a major issue
  
3. E-mail has difficulties with large file transfers. What options are you using for file transfers between subcontractors?
  - File transfer can be done via E-mail, but subcontractors are using compact disks for file submission
  - For the Public (FTP) sites are also used for file swapping
    - General Contractors can give subcontractors access to FTP sites to retrieve and submit files
  
4. How does using a BIM impact typical weekly on site coordination meetings?



- On site meetings are carried out in a very similar matter but with the use of technology
  - BIM is used for visualization and 2D shops drawings can be utilized at the same time to make notes for both model and 2D shop drawing updates later
  - The use of BIM allows issues to be identified prior to meetings and solutions prepared ahead of time
5. Specifically, how do you utilize a BIM for weekly coordination meetings? Are there any additional tools needed?
- Additional hardware and software is necessary
    - Wall projectors and/or “White Boards” are needed for group meetings
    - Laptops can be linked to projectors/whiteboards to complete model manipulation
    - Universal model viewing software is needed such as Navisworks to accommodate many model file formats
    - Clash detection reports distributed prior to meetings so team members can bring proposed solutions
6. When an architect does not provide an architectural model, is your company using outsourcing or In-House modeling to develop it?
- Both outsourcing and In-House modeling are utilized and this depends on company preference
  - Outsourcing and In-House modeling have advantages and disadvantages
    - Outsourcing eliminates time dedicated to using an associate for modeling effort, however outsourcing tends to have a higher cost
    - Outsourcing puts a general contractor in a model management role, similar to everyday management tasks, versus a technical modeling role
    - In-House modeling eliminates a 3<sup>rd</sup> party and forces company associates to know the project inside and out
    - In-House modeling reduces time. Outsourcing requires transmission of information and wait time until a new model is issued



- For successful Outsourcing, the 3<sup>rd</sup> party must be very involved and frequent site meetings may be necessary
  - Outsourcing can lead to a conflict of interests. Modeling approaches/quality level may differ requiring re-work
7. Does the delivery method dictate whether a BIM can be utilized for a project? Which delivery method is preferred?
- In general, the delivery method doesn't necessarily dictate if a BIM can be used because the shop drawing process still exists
  - The Construction Management at Risk approach tends to be most successful
    - This arrangement eliminates the hard bid approach and introduces a team approach the strengthens a modeling effort
    - The preconstruction stage often is longer and trades can be bought out earlier allowing additional time to coordinate models
8. From an organizational standpoint, how do you deal with coordinating all the modeling efforts from various team members?
- Whether using Outsourcing or In-House modeling the general contractor needs to identify a model manager
    - Referred to as a "BIM Coordinator" or "BIM Champion"
    - Typically a young associate familiar with software applications
    - Responsible for coordinating subcontractors models with architectural models
      - File formats
      - Resolving coordinate issues (X,Y,Z)
      - Tracking updates/changes
9. What are some technical issues that need to be looked out for?
- Some subcontractors have little understanding of what a BIM entails



- Subcontractors need to model using a file format that can be viewed in a program such as Navisworks
- Most models are submitted with major coordinate issues that have to be resolved by BIM Coordinators or Modelers
- Because of the new nature of BIM, IT departments can be of little help to BIM Coordinators/Modelers with software issues

## **Model Development**

General Contractors using BIM are typically relying on subcontractors for model development of technical trades such as mechanical, electrical, and plumbing, however in some cases General Contractors are developing these as well. If not provided by the Architect, the General Contractor's model responsibility mainly lies with architectural aspects of the project. There are two approaches to the architectural modeling effort; In-House Modeling or Outsourcing.

Both approaches have strong points, but it should be noted that for successful outsourcing there needs to be a strong relationship with the consultant. The 3<sup>rd</sup> party consultant must be very involved in the project and frequent site meetings may be necessary. Outsourcing requires strong information transmission between the consultant and the contractor. Every time there are design or coordination changes, these changes must be communicated to the consultant for revisions to the model

In contrast, an In-House modeling effort eliminates the 3<sup>rd</sup> party and the information transmission. In-House modeling efforts allow the project team to model the project to their own predetermined standards and also greatly increase overall knowledge of the building and project. However, Contractors who prefer In-House modeling find it necessary to Outsource from time to time when the project size makes an In-House effort unfeasible.

When subcontractors develop models for the coordination/shop drawing submission process, General Contractors need the ability to incorporate these models with the Architectural model. A composite model or multiple composite models must then be created for coordination purposes. A composite model entails combining Architectural models with trade contractor



models. Several models may be created combining all trades or particular trades depending on the coordination goal.

This process requires an associate with a working knowledge of BIM file formats, software applications, and the models themselves. Associates such as these often work directly on site in the construction office and are referred to as BIM Coordinators. These associates manage the model submission process, the construction of composite models, and are involved in the trade coordination/shop drawing review process.

## **Contractual Language**

Simple provisions can be made to already existing subcontracts and Request for Proposals. For the time being the question of accountability for Building Information Model files is still unclear, however a BIM can still be a powerful coordination tool.

In the future, 2D Shop Drawings may no longer be required, but for the time being Subcontracts and Requests for Proposals (RFP) can be tailored to still allocate responsibility using a BIM for construction coordination. Including this information into a RFP will guarantee that bidding subcontractors are qualified and have the ability to produce Building Information Models. These documents are written to call for subcontractors to submit 2D drawings AND a Building Information Model. The language makes it clear which media are primary, requirements for submissions, requirements of models, and how coordination meetings will occur.

For comparison, two examples of language are below. The language from the Request for Proposal and Subcontract shows two different approaches.

## **Sample Language**

### **From a Request for Proposal**

*Example to an Electrical Subcontractor*

“It is agreed and understood that the Subcontractor shall prepare a complete set of 2D construction coordination drawings and 3D model utilizing a Building Information Modeling Software package per Specification 16010 1.12 for the coordination of all electrical work with the Architectural, Structural, and Mechanical Drawings to minimize conflicts during the design and construction process. Electrical Subcontractor shall provide the 3D model & 2D drawings to the Mechanical



Subcontractor, who will create one composite drawing with the mechanical, fire protection and electrical systems coordinated with the architectural and structural systems.

Subcontractor acknowledges that the HVAC ductwork drawings are the base for the Contractor's Coordination Drawings and the HVAC contractor will be in the leadership position Subcontractor acknowledges that 2D construction coordination drawings will dictate all legal responsibility .”

### **General Requirements from a Subcontract**

1. In general, the goal of the BIM scope of work is to create a technically accurate and detailed 3D computer model of the architectural, structural, mechanical, plumbing, and electrical systems.
2. The level of detail defined in the Specific Scope Requirements is the minimum level of detail required in the model. Greater detail than the minimum should be incorporated into the model where important details are necessary for communicating information about a system.
3. The Trade Contractor shall provide shop drawings in both 2D and 3D model format. 2D drawings will be primary for legal responsibility.
4. The 3D model shall be located and oriented to the predetermined world coordinates for the project to allow easy integration into the BIM for the project.
5. The 3D model shall be constructed in a manner such that all elements of the model can be converted into a 2D dimensioned drawing for use in the field.
6. In addition to the native file format, the Trade Contractor shall provide translation of the 3D model into a .DWG, CIS/2, or other agreed upon file format that can be viewed using Navisworks JetStream v5.
7. The following changes shall be incorporated into the drawings and model:
  - RFIs, ASIs, and Owner changes
  - Changes in the sequence of work
  - Field modifications
  - Shop drawing review comments
  - Changes requested by the Construction Manager
8. All revised 3D model or 2D drawing submittals shall have a written narrative to define changes from previous submittals. Typical





drafting techniques such as 'clouds' or 'bubbles' are acceptable means of tracking changes on the 2D drawings. Layer control shall be used to define changes in the 3D model. All revisions shall be shown in both 2D and 3D formats.

9. The working 3D model will be shared with the Trade Contractors and design team at least once every two weeks. This will be performed by posting the model to the project FTP site. The Trade Contractor will post the native file format and an agreed upon file format as defined above.

10. The 3D modeling conventions will be established at a pre-detailing meeting to be attended by:

- Concrete Contractor and detailer
- Steel Fabricator and detailer
- Mechanical/Electrical/Plumbing Contractors and detailers

11. The Trade Contractor will submit its 3D modeling software and proposed file format(s) for approval prior to proceeding with detailing.

12. The Trade Contractors are advised that the model shall be shared among all trades and shall be the basis of coordination and fabrication. Costs incurred for post-coordination changes caused by unauthorized deviations from the model shall be borne by the Trade Contractor that initially deviated from the model. This determination is at the sole discretion of the Construction Manager.

13. The base architectural BIM will be created using AutoDesk's Revit Building.

14. The 3D modeling effort is intended to augment and assist in the MEP coordination process outlined in the Bid Documents. Before first submission shop drawings the elements shall be first pass coordinated in the 3D model. The model is intended to find conflicts before shop drawings are reviewed and approved.

## **On Site Coordination Meetings**

BIM brings a completely new approach to coordination meetings. Typically, coordination meetings use a team approach to identifying problem areas on the drawings. Problems are identified during the meetings, a proposed solution is agreed upon, and the subcontractor will



incorporate these revisions for the following meeting. This style tends to be very time consuming.

In contrast, a BIM coordination meeting allows for problems to be addressed prior to these meetings and the proposed solutions to be discussed during the meeting itself. General Contractors using BIM for coordination will require subcontractors to submit models well in advance to a coordination meeting being held. In between meetings, the General Contractor's 'BIM Coordinator' will run clash detection reports on their own or in junction with subcontractors. These reports are then distributed to all team members. This increases collaboration between Subcontractors, Designers, & the Construction Team.

This approach allows a subcontractor or designer to propose a solution or multiple solutions to an issue at the next meeting. The meeting time can be used to discuss options and finalize a solution instead of spending time just identifying problem areas. Although many clash detection issues can be caught in between meetings, model review is still performed during meetings. Model review is performed to confirm incorporated design/coordination changes and to pin point any new issues. Examples of clash detection reports that would be distributed to the construction team and flow charts of the coordination process can be seen below.

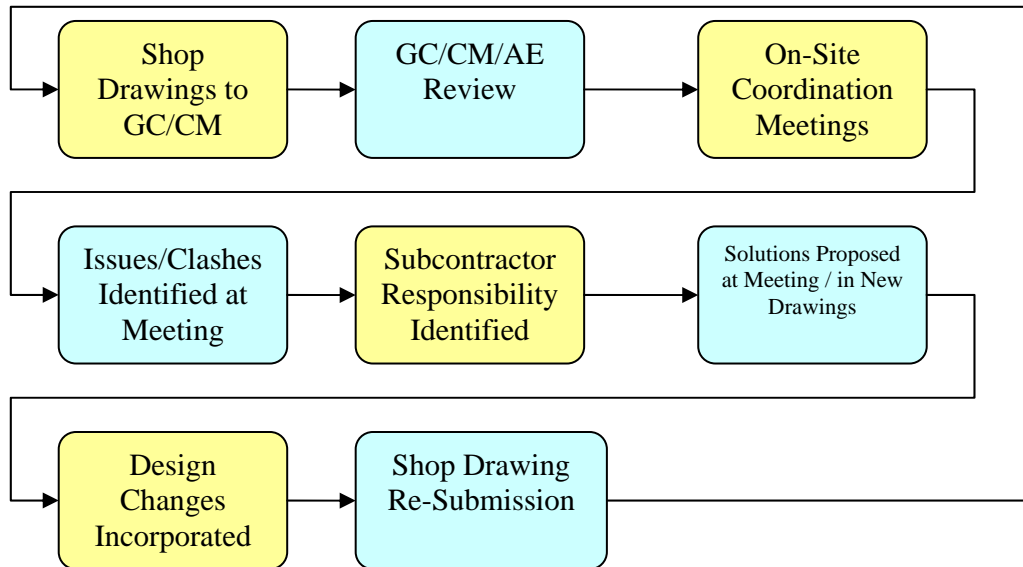
An interesting, underlying theme found here were different perspectives of BIM implementation and the elimination of "finger pointing". The perspective of BIM implementation between GC's/CM's and Subcontractors was very different. Subcontractors tend to be very willing and excited about the idea of using BIM for coordination. Many subcontractors are already using BIM for their own in-house benefits. GC's & CM's can tend to have a very timid, unsure attitude towards implementing BIM and seem like they could be hindering the implementation. The other item of interest, "finger pointing", deals with Subcontractors coming to traditional coordination meetings and individuals not wanting to take responsibility for a coordination issue or trying to steer blame to another party. The use of BIM for coordination forces the Subcontractor to draft solutions to issues prior to meetings and this eliminates "finger pointing".

To perform these on-site coordination meetings some small additions must be made when using BIM. The most commonly used coordination strategy is the use of computer projectors and laptops for model review. Models can be projected onto screens or trailer walls, and then

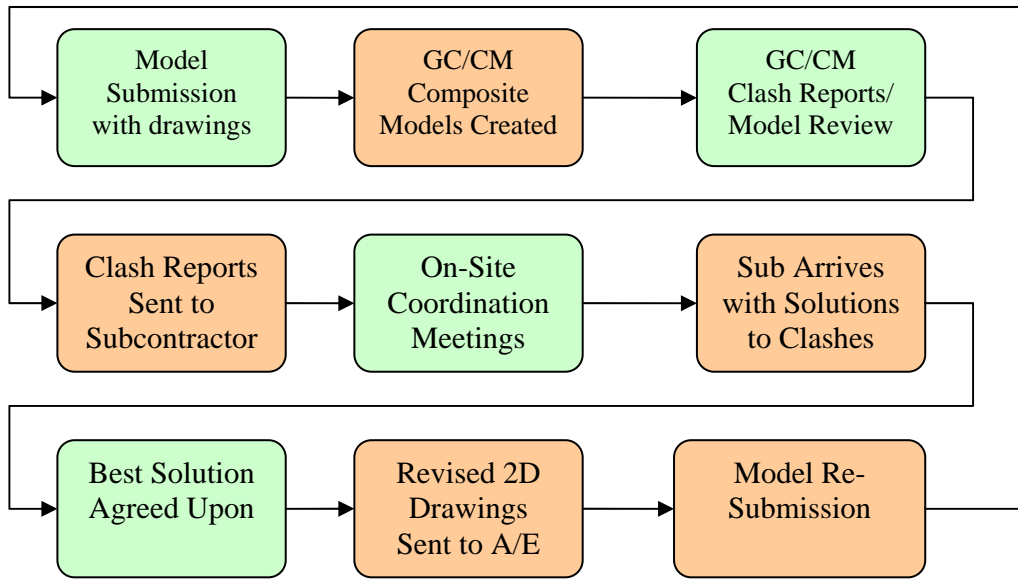


manipulated for visualization purposes. Projectors such as these can be purchased for as little as \$500.

Another common strategy is the use of 2D paper drawings in conjunction with the 3D models. This approach allows team members to make notes for model updates on the fly and helps relate 3D visualization to the 2D drawings. 2D drawings are necessary due to the inability of software applications to implement specification data, notes, and dimensions when viewed in 3D. Subcontractors will be required to make coordination and design changes addressed in these meetings to 3D models and 2D drawings to be submitted per the General Contractor's schedule.



**Traditional Coordination Process**



### **Coordination Using Building Information Modeling**

#### **Example Clash Detection Reports**

Clash detection reports can be filtered to include only pertinent information to the trade contractor receiving the report. An example of this would be sending an HVAC/Plumbing contractor a report detailing ductwork and overhead piping interferences with structural steel. NavisWorks prepares clash detection reports, in HTML format, that detail the two items (or more) that have interferences issues, with the distance of interference, and a small thumbnail rendering of the trouble area. This allows for interferences to be identified and corrected quickly without presenting any more information than what is needed. An example of a NavisWorks clash detection report of Structural Framing vs. Plumbing can be seen in Figure 1 below.



## Clashes

### Report Batch

A screenshot of a software interface showing a clash detection report. The title is "Beams &amp; Columns Vs HVAC Clash". Below the title, there are several fields: Tolerance (0.000m), Linked to TimeLiner (a radio button), Total (22), New (22), Active (0), Approved (0), Resolved (0), Type (Hard), and Status (OK). The main area contains two items. Item 1 has a small 3D visualization of a clash, followed by its details: Name (Clash1), Distance (0.193m), Description (Hard), Status (New), Clash Point (39267.161m, 21392.138m, 25.874m), and Date Created (2007/4/1 21:46:02). Item 2 has a similar 3D visualization and details: Name (Clash2), Distance (-0.167m), Description (Hard), Status (New), and Clash Point (39252.531m, 21392.137m, 25.848m). The interface includes a vertical scrollbar on the right side.

Figure 1- Example Clash Detection Report

## Request for Information (RFI) Impact

One of the biggest benefits of a BIM and using a BIM for coordination is reducing the number of RFI's. RFI's are often populated due to missing dimensions, unclear documents, or coordination problems. BIM can often reduce the number of RFI's for a typical project to fewer than 100. The use of this tool helps to communicate the design and construction plan to subcontractors more clearly than 2D drawings and therefore reducing questions. When RFI's do occur a BIM is a useful tool for visualization. The General Contractor or Designer can include a JPEG image of the area in question for clarity purposes in the answer.

## Model Updates and Shop Drawing Submissions

Although the BIM is used as the basis for coordination between MEP, Structural, and Architectural trades, revisions and submissions of 2D drawings still need to be performed. BIM software packages are tailored to combine model and 2D revisions into a single process. Typically, the 2D submission will follow the digital model submission to a FTP site.



Similar to the existing shop drawing process, some type of written submission noting design and coordination revisions is typically required. Revisions to 2D drawings can be easily communicated using normally accepted conventions such as clouding or text, but communicating changes through a BIM could be harder. Modelers are using two approaches for communication. Layering applications in BIM software is common but experienced contractors are also submitting text documents in digital formats. Written documents allow information such as specification data and exact dimensional changes to be clearly communicated quickly with little model manipulation.

### **Application to the Teachers Education & Technology Center (TETC) at Salisbury University**

TETC is not a highly complex project with respect to MEP coordination; however, BIM could have benefited the project. Although not required, the structural steel contractor modeled the project for their own purposes. An addition of an MEP model would have been a big addition. To date the project has over 200 answered RFI's from subcontractors. BIM could have reduced this number greatly.

Many of these RFI's dealt with overhead coordination of MEP trades with Structural Steel. The high level of Audio Visual equipment in the building added coordination problems with floor penetrations, structural framing, and interior wall partitions. RFI's and Change Orders had to be written for relocating interior partitions and un-planned penetrations to structural framing. Building Information Modeling could have eliminated these costly Change Orders and RFI's.

### **Conclusion**

Building Information Modeling is a powerful tool that more construction companies need to utilize. The implementation of BIM at the construction phase of a project does not have to involve more risk or cost to a company. Construction companies need to become more informed about the process of BIM Implementation and form company specific master plans for implementation. A greater understanding of BIM as a construction tool, and less perception of BIM as a completely new construction approach will strengthen BIM Implementation. As more General Contractors and Subcontractors implement BIM, the push for and pressure will become greater for Design Professionals to design buildings using intelligent, 3D models.