Implementing Model Quality Control in a Design-Build Senior Project Course

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Abstract

This paper presents a case study of implementing model quality control measures in a Design-Build Senior Project (a.k.a. Senior Design) course at MSOE (Milwaukee School of Engineering). The Senior Design course consists of three-part series in developing a design-build proposal for a real client. Each design-build team includes 7-8 undergraduate students from various AEC-related disciplines including architectural engineering, environmental science, and construction management. BIM has been integrated into the design-build studio since 2006. However, it is often difficult to leverage the full potential of BIM due to inadequate quality of the building models created in the earlier design phase. A "model quality control" assignment was assigned to Construction Management (CM) students to remedy the issues related with model quality and integrity. The CM students acted as BIM managers who are responsible for design review sessions as well as design coordination meetings. They were required to implement four model quality control measures including visual model inspection, clash detection, quality control report, and coordination meeting. The goal of model quality control was to ensure that the model is being used to its full capabilities of producing accurate engineering drawings, construction documentations, schedules and quantities for estimating purposes. Another purpose was to ensure that the structural and MEP models were developed soundly to be used for design coordination and clash detection. The students were asked to prepare model quality control reports that summarize quality control process, design deficiencies, and quality improvement solution. This case study demonstrates the significant value that BIM model quality control can bring to integrated design process. The results of this case study also indicate that model quality control measures help students improve the downstream use of BIM data for the entire design phase.

Keywords

Model Quality Control, BIM, Design-Build, design coordination

1. INTRODUCTION

The Civil and Architectural Engineering and Construction Management (CAECM) Department offers a four year BS degree in architectural engineering with a specialty in building structural,

building mechanical or building electrical design. Students may also earn a BS degree in Construction Management, or they may do a dual major earning a BS in architectural engineering and a BS in construction management in five years.

In fall of year four, students take AE/CM4712 Design-Build Senior Project 1. They are grouped into teams that will stay together for the entire year. Students are grouped in teams that would ideally contain an even distribution of specialties, two structural, two mechanical, two electrical and two construction management students for a team size of eight members. This ideal team size seldom happens due to the varying number of students in each specialty area and overall size of the class. Assignments can be scaled up or down depending on the number of students on a team to insure a realistic workload.

MSOE runs four sections of Senior Design with three teams in each section for a class size of about one hundred to one hundred and ten students. Each section is team taught by an architect, engineers in each of the specialty areas as well as a construction manager. Since an Architectural Engineering (AE) degree requires some architectural design content, all AE students share in the architectural design. These are real projects in very preliminary planning stages for real clients. Clients are charged a nominal stipend to reimburse students for presentation materials and model building supplies.

In fall the architectural program is completed. Activities include site visits, client interviews, code search, building type research, etc. The deliverable at the end of fall is the building program, preliminary budget, and schedule. All of the activities in the fall are led by the architects and Construction Management (CM) faculty.

In the winter quarter most of the architectural design is completed. Students make three presentations. Schematic design to the client in week number three, code review to a Milwaukee plan examiner in week number six and their final architectural design presentation on Saturday of week number nine to their client as well as outside experts in the architectural, engineering and construction management fields. It is usually a jury with six to ten members. This provides important feedback from professionals other than their faculty advisors and it provides the CAECM Department an independent assessment tool that can be used for program accreditation. The final week of the winter quarter is used by students to make final architectural revisions to their designs based on feedback from the jury.

In the spring quarter AE students take AE4731 Design-Build Senior project 3 and AE4733 Working drawings. In AE4731 Senior Project 3 students work closely with their specialty advisors to finish the engineering calculations and design. Architects are not involved in this class at all. In AE4733 Working Drawings students spend part of the time working on architectural working drawings and most of their time working on the engineering working drawings for their specialty. CM students take CM4733 and they work on final estimates schedules and mobilization plans. At the end of the spring quarter they all make individual presentations to guest jurors from their specialty to defend their calculations. As with the winter presentations this provides valuable feedback for both the students and the program.

2. BIM COURSES AT MSOE

MSOE offers two courses in Building Information Modeling (BIM), AE1312 and AE3311. Both courses are offered as one hour lecture and two hour lab per week, for one credit. Phasing in BIM at MSOE began in fall of 2007 when AE1312 Introduction to Building information Modeling 1 replaced AE1311 Introduction to CAD. This course is taken in the fall quarter of a student's freshman year. Both BIM courses are required for Architectural Engineering and Construction Management degrees. AE1312 is five weeks of basic AutoCAD and five weeks of Revit Architecture. AutoCAD is still part of the curriculum because the CAECM Industrial Advisor Committee believes some knowledge of AutoCAD is still an asset to graduates entering the industry. Students have an opportunity reinforce these modeling skills in AE100, AE1301 and AE2212. AE3311 Introduction to Building Information Modeling 2 is offered in spring of junior year in preparation for the start of Senior Design the following fall. In addition, CM students will gain working knowledge on model-based estimate, model-based schedule, 4D scheduling, and clash detection in CM specialty courses. Even though Revit has been used in Senior Design since 2006, it was not required until the freshman class of 2007 became seniors in the fall quarter of 2010.

3. BIM IMPLEMENTATION IN SENIOR DESIGN

Until fall of 2010 BIM software was available but its use was optional. Senior Design Teams that utilized BIM could be classified as pioneers or early adopters. It is hard not to like the quality of graphics that are produced by BIM software. Another side benefit to using BIM is the ease of producing renderings and walk-thru movies for presentations; however this is not the main benefit of using BIM. One of the benefits of implementing BIM into Senior Design is that it improves collaboration among disciplines. Construction Management students can access the building model to take off information for cost estimates and scheduling. Structural and HVAC students can check the model for conflicts by using clash detection software. This increase in the amount of data has caused some challenges, though. Student laptops have to be powerful enough to run these programs, and the network needs to have enough capacity and speed to serve up this data quickly. Since 1995 senior design teams have been assigned secure shared network space for their team folders with AutoCAD files taking up most of this space. As the CAECM Department has transitioned to using BIM for Senior Design the network requirements have expanded from 100 megabytes in the late 1990's to nearly 10 gigabytes per team in the 2010/2011 academic year.

4. PROBLEMS

While BIM offers new methods for integrated design and construction, it introduces new challenges in regard to collaboration and teamwork. Eastman et al. (2010) also identified two major challenges of BIM implementation in design and construction: significant changes in work processes and extensive information sharing among project teams. Bedrick (2008) also pointed out that there is a need for guidelines for adequate sharing of BIM data and procedural details of BIIM data uses. Few studies have focused on documenting and understanding design coordination processes (Khanzode et al. 2008).

In the Design-Build Senior Project at MSOE, students tend to use BIM for early design activities only due to poor perception of BIM functionalities. It is often difficult to leverage the full potential of BIM due to inadequate quality of the BIM models created in the earlier design

phase. The models from different design disciplines are not usually coordinated even though the design team format is interdisciplinary. Furthermore, the models generated by students typically do not have sufficient level of details on Mechanical, Electrical, and Plumbing (MEP) systems, structural systems, or other components for extracting necessary building information. If a model is not correctly built, it is hard to extract accurate building information from the model. This problem often occurs when a project team carelessly uses a shared building model during design phases without proper procedural details on a BIM quality control.

5. MODEL QUALITY CONTROL

What is Model Quality Control?

BIM quality control measures facilitate comprehensive analysis of building models in order to check quality, integrity, and level of details. BIM Execution Planning Guide (CIC Research Group 2010) recommended the following quality control checks

- Visual Check: Ensure there are no unintended model components and the design intent has been followed by using navigation software
- Interference Check: Detect problems in the model where two building components are clashing by a Conflict Detection software
- Standards Check: Ensure that the model is to the standards agreed upon by the team.
- Element Validation: Ensure that the dataset has no undefined or incorrectly defined elements

There are other tools for model quality control and BIM development plan. AIA BIM protocol Exhibit (E202-2008) provides a very useful matrix defining two fundamental concepts of BIM quality control: Level of Development (LOD) and the Model Element Author (MEA). These two concepts are then combined in a matrix for each phase of the project, corresponding to model element assemblies in the Model Element Table. ConsensusDOCS 301 Building Information Modeling (BIM) Addendum is another tool for model quality control. It assigns the specific responsibility for the various project team members in developing model elements to specific levels of development for project phases. It also establishes how the model is developed and who is responsible for different parts of the building models. BIM Execution Plan is included in the 301 document for defining additional project specific requirements.

Procedures

The course instructors understood that there is an immediate need of implementing model quality control measures in order to use BIM as integrated design platform for the entire design process. A "BIM Quality Control" assignment was assigned to Construction Management students to remedy the issues related with model quality and to ensure that the project is modeled with an appropriate level of detail and accuracy. CM students acted as BIM managers who are responsible for design review sessions as well as coordinating all phases of the design and incorporating construction knowledge into the design process.

The CM students were required to implement four model quality control measures including visual model inspection, clash detection (or model checking), model quality control report, and design coordination meeting. The goal of model quality control process was to ensure that the model is being used to its full capabilities of producing accurate drawings, construction documentations, schedules and quantities for estimating purposes. Another purpose was to ensure that the structural and MEP models were developed soundly to be used for design

coordination and clash detection. Here is a process diagram for Model Quality Control (Figure 1).

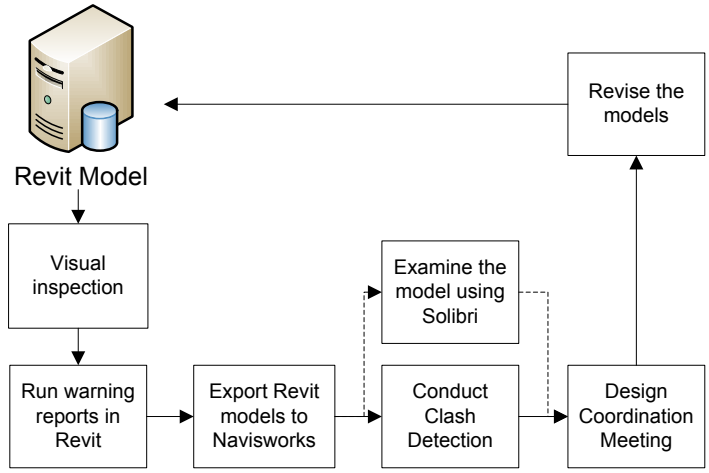
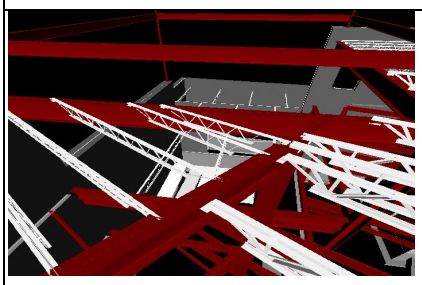
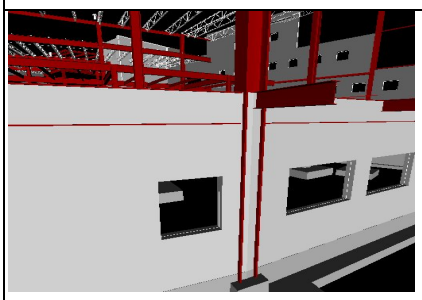


Figure 1 Process diagram for Model Quality Control

CM students were also responsible for preparing model quality control reports that summarize quality control process and design deficiencies, and develop corrective action plans. An example is shown in Figure 2. The report includes viewpoint, location information, problem, and instructions for resolving the issue and assigning responsibility. Team members were able to discuss design issues in a well-organized manner and communicate the findings with all participants including owners, mentors, and faculty members.

Screenshot	**Description**	**Location**	**Solution**
	This area looks as if there are more trusses then needed because of the radial format of the structural system. There may be one or more trusses that could be taken out throughout the building.	Northeast part of the building next to the atrium at roof level.	Structural students need to remove unnecessary trusses by the end of week 6.
	This area has the concrete wall overlapping with the columns and beams.	All along the concrete walls on all levels of the building.	Need to talk with structural mentors to discuss wall type changes.

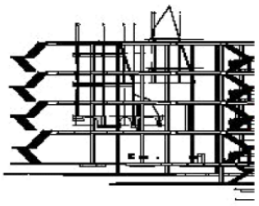
Screenshot	Description	Location of Issues	Importance (1-5 highest)
	The three upper stairscase in this stairwell doesn't have the desired amount of risers as determined by Revit	The northwest Staircase: id #372605, 373119, 378491	3

Figure 2 Model Quality Control Report Sample

Firstly, visual model inspection was done by using Revit models to review major architectural components such as interior and exterior walls, stairs, and openings. Some of the frequent findings include duplicated components, un-joined walls, clashing walls, incorrect thicknesses of walls, or incorrect types of windows and doors. The students eventually realized that visual model inspection has a limitation on finding some errors that could not be found readily with a naked eye. Therefore, the students started using the Warnings function in Revit to highlight all issues that it found within the model. Using this warning report, they were able to locate certain instances that were troublesome easily and see if they were of great importance.

All design issues are not equally important. Some of the errors are just what Revit found and not actual errors but it was helpful to know of them. The students generated Warning reports from Revit and review these warnings and weeding out which ones are actual problems and which ones are not. Based on this Warning report, they created an Excel spreadsheet of the problems and ranked them with their importance. Any error that had an importance factor of 4 or 5 was taken care of immediately because these would have a significant effect for downstream BIM data uses. If the error was ranked at a level 3 of importance, it was discussed with the overall group to determine the impact on the project. The errors that ranked at level 1 or 2 were determined to be Revit issues than that of an actual error. These were noted for future reference but at this time have no affected on the model.

Secondly, the students also examine the structural and MEP components of the model. This process begins with exporting structural and MEP components from Revit to Navisworks in order to use sophisticated navigation functions for model inspection. All building components were inspected to see any design discrepancies. Several were discovered including structural members protruding through concrete, enlarged window openings, random mullion placement, etc. Once they found some errors on an object, they applied Color Override for quick identification of the objects (Figure 3)

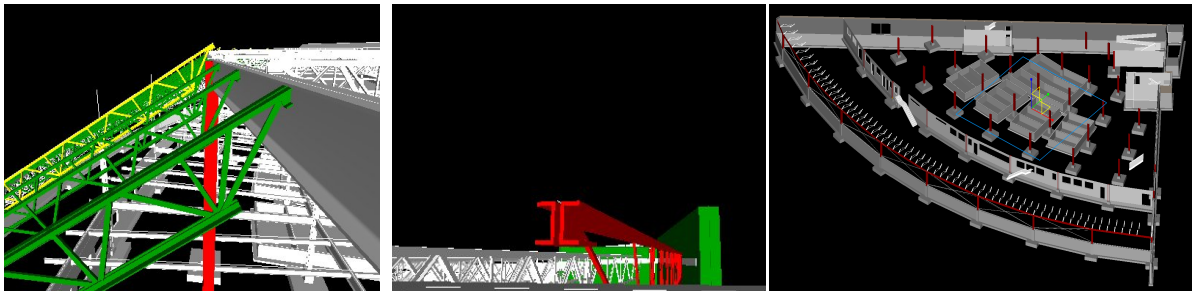


Figure 3 Viewpoints from Navisworks

Thirdly, students were required to perform Clash Detection using Autodesk Navisworks. Clash Detection has been a very popular way for identifying design discrepancies in 3D models where multiple building components are overlapped at the same location. It provides many advantages to general contractors by helping them detect any potential conflicts. In turn general contractors can save time and money for handling construction delays or change orders. The students additionally spend some time to prioritize some clashes and share the findings with team member (Figure 4).

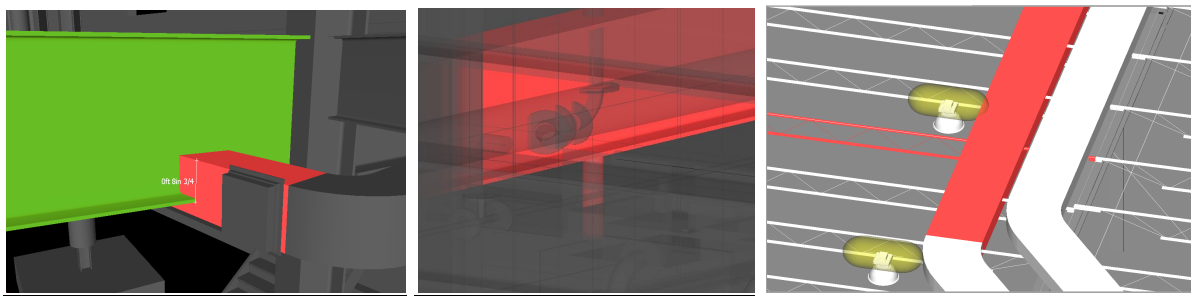


Figure 4 Clash Viewpoint Examples

Finally, CM students were required to prepare a Model Quality Control report per each team to discuss and share the findings in the report. These meetings allowed them to determine what issue was important and needed to be corrected to improve the quality of the models.

6. BENEFITS AND LESSONS LEARNED

This section introduces the benefits and lessons learned of implementing Model Quality Control measures in the Senior Design. The significant benefit was the sharing of building information during the entire design phases with all design disciplines including structural engineering, mechanical, electrical, plumbing and fire protection, and construction management. CM students easily use extracted information for quantity takeoff and clash detection. CM students spent significantly less time on construction estimate. AE students spent substantially less time during the construction documentation phase of the project due to substantially decreased amount of revisions.

7. RECOMMENDATIONS

The overall strategy for model quality control should be determined and accomplished at each major design phase as an important milestone. This allowed students to conduct comprehensive model analysis from various aspects. Studio instructors need to document a guideline for model quality standards and should discuss at the beginning of the design phase. The guidelines may include the following contents: level of detail, model elements, format, and responsibility, and model location. Standards such as AIA E202-2008 or ConsensusDOCS301 may be appropriate for the team to consider. One of the major challenges was the lack of prior knowledge in BIM authoring tools and model navigation tools by some of the students. Although many of the students are good at model authoring, they need additional BIM lectures on advanced topics such

as interoperability, managing central files, managing clashes in Navisworks, or navigation tools in Navisworks.

8. CONCLUSION

This case study demonstrates the significant value that BIM model quality control can bring to integrated design process. The paper illustrates the challenges that project teams need to address when using BIM for integrated design process. These challenges include determining how to develop a guideline for model quality, how to train students to leverage the full potential of BIM, and how to perform design coordination among multiple disciplines.

The results of this case study also indicate that model quality control measures help students improve the downstream use of BIM data for the entire design phase. Incorporating the concept of model quality control was a challenging endeavor. This transformation obviously requires time and effort. However, the results were very positive. The students gained valuable experience about integrated design and construction. Model quality and integrity are critical to the success of integrated design and construction. In order to ensure the highest quality it is necessary for project teams to find design deficiencies and correct them as early as possible. Team members should agree to some basic standards at the beginning of the project so that the sharing of BIM is efficient and benefits the whole team.

6. REFERENCES

Bedrick, J. (2008) Organizing the Development of a Building Information Model, AECbytes, http://www.aecbytes.com/feature/2008/MPSforBIM.html (accessed February 2010)

Eastman, C., Teicholtz, P., Sacks, R. & Liston, K. (2008) *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*, Hoboken, NJ, Wiley & Sons.

CIC Research Group. (2010) BIM Project Execution Planning Guide, CIC Research Group, Department of Architectural Engineering, The Pennsylvania State University. http://bim.psu.edu/Project/resources/default.aspx (accessed June 2010)

Khanzode, A, Fischer, M, Reed, D. (2008) Benefits and lessons learned of implementing building virtual design and construction (VDC) technologies for coordination of mechanical, electrical, and plumbing (MEP) systems on a large healthcare project. *ITcon* Vol. 13, Special Issue Case studies of BIM use, pg. 324-342. http://www.itcon.org/2008/22 (accessed July 2011)