BIM for Virtual Construction: A Collaboration of Three Universities

Tamera McCuen
University of Oklahoma
Norman, Oklahoma

Elbert Speidel
California Polytechnic State University
San Luis Obispo, California

Junshan Liu
Auburn University
Auburn, Alabama

Abstract

Increasingly facility owners require a project team turnover an as-built building information modeling (BIM) for use in operations and maintenance of a building. Depending on the project requirements, the owner may assign the responsibility for the creation and turn-over of the as-built model to the general contractor. As a result there is an increasing need for members of the construction team to be familiar with both the software application for BIM creation and the business processes necessary to support a complete BIM with reliable information about the facility. The creation of an as-built BIM requires the contractor must first create the architectural, structural, and mechanical models based on drawings and information provided by the designers – architects, engineers, and consultants. This requires there be an individual within the contractor's organization with skills and knowledge about various aspects related to each design model. Once the design models are (re)created, the contractor uses them to develop the BIM for construction. A complete construction model typically includes the cost estimate, construction schedule, conflict detection with analysis, and site logistics. The added requirement by the owner of an as-built model for facility management involves adding the data specific for operations and maintenance. The goal of the project presented in this paper is to better understand the complexity of a contractor's role on a project for which the contractor is responsible for the BIM to the owner. To accomplish the goal, three universities collaborated to form interuniversity teams with one student from each university distributed to each team to fill the contractor's role of using BIM for a commercial building project. This paper reports the challenges and the details about the project from two perspectives: 1) instructors – project organization, learning objectives, and strategies, and 2) students – project organization, team process, and strategies.

Keywords: *BIM, Facility Management, Contractor, As-Built, Construction Education*

1. INTRODUCTION

With the increase of building information modeling (BIM) in AEC community, the owners and facility managers' use of that building information for facilities management is becoming more commonplace and more anticipated. Owners can use BIM to optimize project collaboration with the rest of the project team. "BIM is making everyone more collaborative early on," says

Charles Matta, director of federal buildings and modernization at the U.S. General Services Administration (Tuchman, 2008).

BIM has been seized upon by owners, designers, contractors, and suppliers as a manner in which to reduce costs, inefficiencies, claims and conflicts on projects. BIM involves the development of three-dimensional modeling which allows a virtual or digital simulation of a facility to be created, viewed, changed and evaluated. In the evolution from more traditional computer-aided design (CAD), BIM has been deemed to be an intelligent representation since it allows for detailed information about the various building elements to be included within the design (Haynes, 2009).

Why Would Owners Want BIM?

Owners and facility managers can use the BIM model and data for renovations, space planning, maintenance, asset tracking and much more. The BIM model can also be used to graphically illustrate potential security issues, signage, evacuation plans and building analysis (AGC, 2008). Lewis clearly addressed the factors driving owners demand for BIM along a project's lifecycle in his 2010 article:

- In the early design stage the owners benefit from 3D visual communication of the designer's ideas and benefits the owners by creating a common language (visual language) that everyone involved can comment on.
- In the late design/ pre-construction stage visualization helps as well. Everyone can understand a particular condition better by using a virtual model of that condition. Models can also be investigated for coordination issues (clashes) involving all of the building's systems. The owners benefit at this stage in cost and schedule.
- In the construction stage, if contractors have a clear idea of design intent due to a well-built BIM model, the owners would save money (and time) with a reduction of Request for Information (RFIs) and change orders.
- At handoff, the owners benefits when the BIM models contain data such as O&M, specs, and warranties. The model that can serve as a repository for all of that information.
- After a project is turned over to the owner, the BIM model can then serve as a start for a facility management (FM) database. Then model can allow the owner and operator of the building to access FM data in a rich visual environment, which can give them dramatic returns in efficiencies and quality.

With such advantages of BIM, government agencies such as the U.S. General Services Administration (GSA) now require the delivery of spatial program information from building information models for major projects that are receiving design funding since Fiscal Year 2007 and beyond (Snoonian, 2005). U.S. Army Corps of Engineers (USACE) has recognized that BIM supports its strategic organizational goals and provides best opportunities for its projects, and has started promoting BIM in its projects as well. Given the O&M phase accounts for 85% of facility cost while the construction cost accounts for only 15% of the total cost for the facility it is not surprising the increase in BIM required for the design and construction of facilities.

BIM for Construction

BIM is becoming a "growing factor" in how contractors do business in the U.S. A primary reason of the creation of BIM is that conflicts within the design and construction documents that

have created an environment where change orders have become commonplace (Stauffer, 2008). BIM makes it possible to solve these conflicts and reduce the amounts of change orders and RFIs dramatically. BIM models produce detailed electronic and hard-copy construction drawings that show a significant amount of detail. For contractors, there are advantages and disadvantages to using BIM and it is important that they recognize the effect this technology may have on their work (Carlin, 2010).

Advantages of BIM for construction:

- *Visualization*. BIM models are relatively easy to understand and show depth and elevation in a clear, visual way.
- *Collaboration*. BIM allows for unprecedented collaboration. BIM models give all contractors an opportunity to sit down together and work through issues before construction begins, especially in the case of "clashes" that can lead to the "stacking of trades" - areas where two different contractors plan to install material in the same space, sometimes at the same time.
- *Cost Saving*. By the reduction of design and construction errors in the early stage and reduction in time required to complete construction, BIM can save cost for the contractors.

Disadvantages of BIM for construction:

- *Extra Costs*. The use of BIM requires significant training, and software program and hardware update.
- *More Work Upfront*. BIM requires more effort at the outset of a project. When BIM is used, the contractor must first sit down with the designer and other prime contractors and create the collaborative model before beginning construction.
- *Disruptive*. Although one of the advantages of using a BIM model is that changes can be made quickly, BIM can disrupt the general procurement and construction process when ordering items that require a long lead time, especially if changes occur during the process.

Why Would Constructors Create Their Own As-Built BIM?

In a perfect world, the owner, design team, and contractor work closely throughout the whole BIM process. Architects and engineers develop the building information models; contractor reviews the models and provide feedback to the design team on constructability or building system interferences; the design team uses the feedback from contractor to make adjustments to their model that would create significant cost-saving benefits during construction; and then the design team passes the revised models to contractor as a construction management tool for cost, time, safety and quality control. Such process has the capability of improving coordination and, subsequently, documentation. This will reduce construction-related questions, leading to a reduction in change orders and the length of construction.

However, due to several reasons like liability concerns, quality concerns, unauthorized reuse of intellectual property, appropriateness of BIM projects, an architect normally does not want to share BIM projects with contractors (Brown, 2010). On the other hand, because of the lack of confidence in the design models, uncertainness of ownership or copyright, extra time spent reviewing models, availability of software and resources, and other issues, in the current stage of BIM practice, many contractors are unwilling to acquire BIM models from designers. They just develop their own as-built models for construction management and turn it over to

owner at the end for as-built document or facility management (Azhar, 2010). In some other circumstances, the owner may assign the responsibility for the creation and turn-over of the as-built BIM model to the general contractor.

As a result there is an increasing need for members of the construction team to be familiar with both the software application for BIM creation and the business processes necessary to support a complete BIM. This also requires there be individuals within the contractor's organization with skills and knowledge about various aspects related to BIM. Once the design models are (re)created, the contractor uses them to develop the BIM for construction activities, such as cost estimate, construction schedule, conflict detection with analysis, and site logistics. The added requirement by the owner of an as-built model for facility management involves adding the data specific for operations and maintenance. The goal of the project presented in this paper is to better understand the complexity of a contractor's role on a project for which the contractor is responsible for the BIM to the owner. To accomplish the goal, three universities, Auburn University, California Polytechnic State University (San Luis Obispo), and the University of Oklahoma, collaborated to form interuniversity teams to fill the contractor's role of using BIM for a commercial building project.

2. INTERUNIVERSITY PROJECT DESCRIPTION

The goal of the interuniversity project was to demonstrate the challenges and benefits faced by virtual construction teams tasked with the creation of an as-built BIM for turnover to the director of facilities with complete confidence. Students were assigned to one of three teams with one student from each university on each team. Industry sponsors provided three different real-world projects to model, estimate, schedule, and turn over as-built information for operations and maintenance (O&M). As-built drawings and specifications for facilities are the ultimate deliverable for this activity. It was expected that each team member would bring different skill sets to the project and consequently enhance the fabric of the information exchange. Throughout the process team members will be exposed to different software to achieve the best results. There are many software solutions to choose from and we can expect strong cross-disciplinary skills to surface. This exercise will elevate strong leadership talents which will promote team performance.

Coincidently all teams will be working on hospital projects that are either complete or near completion. These are very real examples of good architecture, engineering and construction. Because there are three separate projects the teams are not competing with each other. In addition individual team members will be encouraged to gain knowledge by conversing with classmates on other teams. Because these are real projects we will be able to compare the team results with what actually happened in the field and the final facilities report.

To complete their project and make a final presentation the students will be exposed to many software packages to achieve a level of detail (LOD) of 300. Students will be expected to load as many programs as possible on their personal laptops. Most of these programs are free to full time students The following is a list of software companies that provide a range of technical sophisticated programs to help the students succeed: ArchiCad, Artlantis, Constructor, MSProject, NavisWorks, Onuma System, P6 Primivera, Microsoft Project, Prolog, Revit Architecture, MEP and Structures, Solibri, Tekla and Tekla BIMsight, Trimble, Vico Office, WinEstimator and others. There are many mechanical, sustainable and ECO friendly programs as well that students may elect to utilize. BIM technology has expanded greatly in just a few years.

Some are more user-friendly, some are more precise, some are faster using less computing power, and some are multifunctional. The goals are to not only produce an accurate graphical model but also tie the estimate and schedule to the model so that any changes to the model will result in a change of the estimate and schedule.

3. CHALLENGES

This section of the paper discusses the challenges faced by the instructors during the project's planning phase. Details about the instructors' approach to develop a unique learning experience are also included in this section. The challenges discussed here include both the actual challenges experienced, and some possible challenges students might experience during the project's execution phase. The instructors' main focus during the planning phase was on the project's organization, learning objectives, and execution strategies. The instructors' agreed early on in this phase that their goal was to create a project for students to participate in that provided an authentic learning experience supported by instruction. As discussed in the previous section, the problem was a real-world project that would be anchored in the realistic problem situation. This approach is typical to the constructivist philosophy for instruction and is uniquely identified as contextualism. Guiding contextualism are two key assumptions: 1) learning should occur in realistic settings and 2) testing should be integrated into the task. (Smith & Ragan, 2005).

The planning phase began in April of 2011, approximately four months prior to students' involvement with the project. Instructors began brainstorming about the possibilities during this phase. Dialogue at this point was informal and conversational in its approach, absent of rigid agendas or prescribed objectives for meetings. This phase of the project proved quite fruitful as several decisions were made that ultimately established the guidelines for the project.

Project Organization

One of the first challenges faced by the instructors was to determine the appropriate number of students and student teams for the project. In addition to the number of students and teams, the student profile was considered and decided that all students should be from the construction discipline since the project's goal was to demonstrate the challenges faced by constructors tasked with delivering an as-built model to the owner when the design model is not shared. Another challenge faced early in the planning phase was coordinating the project's timeline. This seemingly easy task was complicated by the fact that two of the universities were on a semester schedule and one was on the quarter schedule. Based on this gap in university schedules, the instructors agreed the team assignment duration would be six weeks and it would start mid-September and complete early November. With decisions made about the student team composition and project timeline, the instructors faced the challenge of identifying the building type and an appropriate size of facility for the assignment. All instructors agreed on using commercial buildings. However there were three primary factors that influenced the decision on the size of facility. First of all the instructors were tasked identifying a size of facility that would provide a challenge for the students, yet be reasonable in its scope so not to overwhelm the students. The next challenge faced by the instructors in identifying the right size of facility was the fact that all the teams were new and virtual, thus adding a layer to the complexity of effective communication between team members. Finally the size of facility must align with the six week timeline for the project assignment.

With the student team composition, assignment timeline, and size of facility determined, the next step was to plan the deliverables for the assignment. In keeping with the project's goal the instructors decided the deliverables would include the architectural model, structural model, MEP model (simplified and optional), cost estimate for certain work packages, construction schedule, and site layout. The final challenge in the planning phase was to recruit industry sponsors. The instructors decided that each one would recruit an industry sponsor for each student team. The industry sponsors were asked to provide documents and support for a facility that was recently completed by their company. The fact that the universities were geographically dispersed added richness to the opportunity in this area.

As mentioned previously the duration for the planning phase spanned four months, which seems lengthy however the extended timeline allowed the instructors to think creatively about the project and explore the possibilities. Many of the ideas discussed during the organization phase were integrated into the project, however many were not due to the expected limitations associated with the assignment. The limitations identified were 1) lack of experience with a distributed team project, 2) uncertainty about the students' abilities to execute the project in a virtual team environment, and 3) questions about the assignment scope's relationship to the projected learning curve for the students. Consequently in the discussions about the limitations, a specific set of learning objectives emerged and were considered the foundation from which the students would build and develop individual team approaches to meet each objective.

Learning Objectives

Identifying learning objectives for the assignment challenged the instructors to think beyond their previous experiences of developing learning goals for students in the classroom. The objectives for this assignment must be specific for the construction students that would be working in a virtual classroom. The four learning objectives in this assignment were:

1. Develop an as-built model from a set of traditional construction documents that is in accordance with the project requirements.
2. Given the virtual work environment dictated by distributed team members, implement interaction processes based on the six aspects of teamwork quality (TWQ) for effective performance.
3. Recognize the traditional business processes common in the construction industry that need revisions for work in the BIM environment and describe the recommended revisions.
4. Given the access to industry sponsors for the project, develop a system for feedback from the sponsor through which real world experiences using BIM for construction is conveyed and assimilated by team members working on the current project.

Execution Strategies

The students participating in this project were senior level undergraduates and second year graduate students who had the technical construction knowledge expected at this level from both the classroom and industry work experiences. Based on the student profiles for this project, the instructors agreed that each team would ultimately be responsible to determine their own approach to meet the project's learning objectives. The instructors did however address each objective and provide the students with a list of items to complete successfully in order to meet

each objective. The instructors anticipated that students might struggle with the execution phase of the project. As a result, the instructors identified key areas in which the students should concentrates efforts in developing execution strategies. Student teams were provided with the following list of strategies that should be employed to complete specific tasks required by the team assignment.

a. Assign responsibilities for task completion based on technical expertise and software skills.
b. Follow the six aspects TWQ for effective team performance (Hackman & Wageman, 2005):
    1. Communication is frequent unencumbered two way communication.
    2. Coordination of project work that is distributed across team members based on individual member's area of expertise.
    3. Balance of contributions such that all team members bring in task-relevant experiences and apply them in a way that seeks to avoid mistakes
    4. Mutual support exists within the team so team members cooperate with each instead of compete with each other
    5. Level of effort to complete the tasks is continuous
    6. Cohesion demonstrated in the team's commitment to the task as a unit
c. Identify ways to improve traditional business processes based on historical best practices.
d. Establish a relationship with industry sponsors and learn from their expertise.

In addition to the topics above, the instructors discussed their role in the project during the execution phase and it was determined that the instructors role would evolve from educator to coach. The evolution from educator to coach is consistent with the constructivism philosophy on education and contextualism (Smith & Ragan, 2005).

As discussed earlier in this section, TWQ is a way to effective performance and is an area of focus for this project in both the learning objectives and execution strategies. Consequently TWQ guided the decision of the instructors to act as coaches during the project execution stage. The instructors' decision is grounded in prior studies on project team coaching that identified the relationship between a coach's actions and the coach's actions that can foster team effectiveness (Hackman & Wageman, 2005). The instructors agreed to incorporate the following two recommendations for actions in their role as team coach.

1. Coaching behaviors should focus on salient task performance rather than on interpersonal relationships
2. Coaching interventions should be made at times when the team is ready for them and able to deal with them

4. Conclusion

At the time of paper submission students at Auburn University and the University of Oklahoma were returning to classes after summer break and anxiously anticipating the project start when California Polytechnic University students return for the fall semester. Students began preparation for the project through various activities – traditional business process research, project construction documents' review, and learning more about each industry sponsor. In the end student teams will meet face to face for the first time at the Ecobuild 2011 conference in Washington DC thanks to the industry sponsors. Students will present their projects as a team to

the instructors, educators, and industry professionals. Due to the time constraints teams will have to quickly develop a presentation strategy.

The instructors hope this project and team assignment will influence other universities to incorporate similar exercises into their curriculum. The instructors' mission was to provide a learning experience for students and a demonstration project for industry as a means to highlight areas that need improvement if BIM is to be widely adopted within the AEC industry.

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