DESIGN AND USE OF BUILDING INFORMATION MODELS FOR PREPLANNING COMMERCIAL BUILDING CONSTRUCTION ACTIVITIES

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ABSTRACT: Over the past several years, the building codes that govern commercial building construction have become increasingly prescriptive in nature, specifying detailed information related to the design and installation of the systems, while offering no reasoning behind their prescriptive measures. For example, metal stud framing is commonly used in commercial building construction to create bearing walls and non-bearing partition walls. BIM provides a powerful platform for developing and implementing "pre-planning" tools and methods to facilitate both engineering and administrative controls during construction. This paper discusses the use of BIM to enhance constructability for commercial building construction activities, specifically metal stud framing. Using specific real-world examples this paper demonstrates ways that BIM can be used to foresee potential construction issues and motivates and informs future uses of BIM technologies

Keywords: Building Information Modeling, Commercial Construction, Pre-Planning

1. INTRODUCTION

BIM is commonly defined as the process of creating an intelligent and computable three-dimensional (3D) data set and sharing the data among the various types of professionals within the design and construction team. With BIM technology, an accurate virtual model of a building is constructed with precise geometry and relevant data needed to support the procurement, fabrication, on-site installation activities, as presented in Figure 2 (Eastman et al, 2008).

The use of BIM technology allows for the creation of intelligent contextual semantic digital models in terms of building elements and systems, such as spaces, walls, beams, columns and MEP systems, whereas 3D CAD technology is limited to generating drawings in graphical entities in terms of lines, arcs and circles. In addition, BIM technology allows for a creation of a model that contains information related to the building physical, functional and procurement information. For instance, the BIM model would contain data about the geometry, location, its supplier, operation and maintenance schedule, flow rates, and clearance requirements for an air-handling unit (CRC Construction Innovation, 2007).

Using BIM technology allows designers, engineers, and construction contractors to visualize the entire scope of a building project in three dimensions. Therefore, BIM technology is not only defined by simply creating a 3-D data set for internal analysis. When most professionals refer to a 3-D model today, they are only referring to a digital 3-D data set that contains geographical representations of objects placed in relation to each other. BIM technology is also known as the process of using a 3-D model and associated data set to improve collaboration among project participants. Using this collaborative approach, designers and builders can plan, in precise detail, the location and clearances required for a complete and successful project.

The implementation of BIM systems in modular construction normally involves in the following process:

- Visualization: ability to create a 3D presentation of building modules geometry, location, space, contained systems in relation to each other
- Modeling: ability to generate a 3D rendering tool to present the final product and finishes to owners, designers and constructors
- Code reviews: allows for building officials and fire officials could use the 3D models with related data for code compliance reviews
- Fabrication/ shop drawings: facilitates for the generation of detailed shop drawings could be easily produced once the BIM model is completed
- Communication: facilitates simultaneously creation of construction documents, product imagery, rapid prototypes, exterior envelope, interior finishing, and MEP fixtures of building modules. Through this single information platform, BIM promote collaborations among the design team, consultant, constructors and the clients
- Cost estimating: provides for cost estimating, material quantifications, and pricing to be automatically generated and modified while changes are applied for each building module

- Construction sequences: provides a complete construction schedule for material ordering, fabrication, delivery and onsite installation of each building systems. With the integration of 3D rendering, 4 D (3D model + scheduling information) could be easily generated during the project design and construction phase
- Conflict, interference and collision detection: ability to determine building system interferences which can be visually presented. For instance, an air distribution duct for the HVAC system physically interfering with a concrete beam

Today, there are many 3-D graphical representation software programs available for architects and engineers to model their project in BIM platform as well. Graphisoft's ArchiCADTM allows one to draw in 3-D or import a 2-D drawing and create a 3-D model. This program allows you to toggle back and forth from 2-D to 3-D with the click of a mouse. AutoDeskTM is a 2-D drafting program coupled with RevitTM creating the 3-D model. NavisWorksTM is a software program that interprets all of the other software programs used by various specialty contractors and design engineers. NavisWorksTM is to software what the Rosetta Stone was to interpreting languages. This software has the potential to unlock and or interpret the other 2-D CAD drawings. This program only identifies the clashes and the individual specialty contractors need to revisit their own software programs and revise them in order to resubmit. NavisWorksTM will then reanalyze the new shop drawings and hopefully there are fewer or no clashes. Obviously, when there are multiple specialty contractors involved in a project, the challenge is to create an environment whereby everyone has worked out the details successfully.

In recent years, there has been increasing consideration given to integrating the using BIM into curricula by construction engineering and management faculty.

2. OPPORTUNITY FOR INTEGRATION AND EXPERMENTATION

Historically, there has been a wide variation in the level of technology used in the MEP coordination process. At the low-tech end of the spectrum, specialty contractors drafted plan-views on translucent media and prepare section-views when necessary. At the other extreme, progressive contractors have used 3D CAD to improve the process. With the recent development of BIM, the process has gravitated toward the use of BIM software (Korman 2001).

There are many locations in buildings that repeatedly cause coordination problems. These include building corridors, points of entry and exit, openings in shear walls, and vertical utility chases. Reserving space for access is more easily accomplished using BIM models. However, often times resolving interferences most frequently entails determining which building system has priority. In these cases priority is typically determined by evaluating the functionality of each system. In the event of interferences or clashes, the newly proposed route must be evaluated to determine if the new route changes the systems' functionality. If it is determined that the new route affects the functionality of the system performance, it is given priority over another system (Tatum 2000).

The need for MEP coordination grows out of the lack of detailed design provided for fabrication and installation of building systems, and exists regard-less of the project delivery process used. The current conditions in the design and construction industry drive current practice for MEP coordination. The use of BIM technology has created an opportunity to improve the current process by changing the way design engineers and construction contractors interact with each other during the coordination process. BIM offers parties involved in MEP coordination to take the opportunity to align goals and define requirements during the construction of the model. In addition, when historically MEP design consultants have not considered constructability issues and made assumptions about constructability or ignore the issue totally, the use of BIM allows a mechanism for dialogue between specialty contractors who install the system and design engineers who design the system (Korman 2001).

3. APPROACH, LEARNING OBJECTIVES, AND DELIVERY METHODS

The integrated course described above was designed to introduce students to the construction methods for various work items common to commercial building construction. Therefore the course was developed and delivered with the following goals:

- Understanding the types of materials used in commercial buildings
- Understanding how to read commercial building project plans and specifications
- Knowing the different types of equipment and materials used in commercial building projects
- Comprehend the design intent and constructability issues in commercial building projects
- Synthesizing the knowledge gained through class readings and exercises by participating in a construction site visit

The class was divided into several key methods of delivering course content: lectures, lab exercises, construction site visits, plan reading and material take-offs, and the use of interactive learning stations. Introductory lectures were given on each subject matter. Following the introductory lecture and a reading assigned, an in-class lab exercise was given for students to work on. Lab assignments varied by subject matter but primarily included system sizing and layout, construction document reading, preparation of cost proposals, and estimating and scheduling exercises. The plan reading and material take-off exercises required the students to work within their three-person teams and review a set of commercial building drawings and specifications for an instructor-selected building located on campus. In addition, several construction projects were visited during the course, including residential, commercial, and institutional sites, varying between 30% and 90% construction completion. Following each site tour, students were required to submit a field trip report focusing on the commercial building systems at the site. Finally, throughout the class, a common interactive learning station with related laboratory exercises was developed for use in the course, which allowed students to perform "hands-on" framing exercises using light-gauge steel. The following paragraphs illustrate the design of these interactive learning stations and their use, including the learning objectives and outcomes assessments.

4. LIGHT GAUGE STEEL EXPERIENTAL LEARNING EXERCISE

Over the past several years, the building codes that govern commercial building construction have become increasingly prescriptive in nature, specifying detailed information related to the design and installation of the systems, while offering no reasoning behind their prescriptive measures. For example, metal stud framing is commonly used in commercial building construction to create bearing walls and non-bearing partition walls. Students now read about metal stud framing methods and practices in textbooks, and using published productivity rates, they perform in-class exercises estimating quantities and scheduling their installation, but they lack the experience working with the material and understanding the challenges trade workers face in the field during installation.

5. PLANNING AND DESIGN

The interactive learning station originally proposed was envisioned to be a laboratory tool that would enhance students' understanding of light gauge steel construction systems beyond the textbook explanations by allowing students to observe how light gauge steel systems perform in addition to allowing them to gain "hands-on" experience of framing. By using the interactive learning station, students would be able to test each of the many practices commonly used for the installation. Laboratory exercises for the interactive learning stations were designed to enhance student learning with the following learning outcomes and objectives:

- Name and identify the components used in the installation of the light gauge steel
- Describe and perform the installation commonly used on light gauge steel
- Explain the theory behind the prescriptive building codes
- Develop construction sequencing and installation schedules for the light gauge steel
- Perform inspections and create reports for light gauge steel

6. IMPLEMENTATION

It was conceived that students would be given architectural layouts of proposed framing layouts. Students would be required to produce diagrammatic installation drawings and then have the opportunity to fabricate, test, and analyze the performance of their system.

In a typical construction management program course, classes usually range from 20 to 26 students and it was envisioned that students would work best in groups of two (2) or three (3). Therefore, eight (8) to ten (10) stations would need to be fabricated for students use. Preliminary dimensions for the framing exercise were estimated to be 4' wide by 12'-8" long. The structure was proposed to be constructed from light gauge steel framing members; similar to what students will find in the a commercial building.

So that framing sections could be reused each course offering, it was envisioned that they would be fabricated so that they would not have to be modified and that they could accommodate multiple uses. Following that reasoning, once a student group fabricated and tested an installation, they would need to be able to disassemble their fabrication so that another installation could be fabricated and installed to demonstrate another type of system. Basic information provided to the students regarding light gauge steel was provided to the students.

Prior to physically beginning work, the student groups are asked to complete a preplanning assignment, which can take form of a list of what input resources and information are needed, - schedule timing for the inputs (e.g., principles of just-in-time delivery), sketches and drawings such as concrete lift drawings and layout drawings. Basic information regarding who, what, where, when, how and why of a construction operation. This requires the student groups to study work packaging, which is concerned with breaking work down into packages that constitute work for about one week for a crew. Typically, they utilize coding schemes and a physical breakdown that corresponds to project information systems' such as schedules, cost control systems, and even drawing numbering systems. In the course, the students are introduced to the concept of breaking work tasks down at various levels in the organization by project level, area level, disciplines (e.g., pipefitters, millwrights, electricians), categories (e.g., for pipe we have steam, water, air, gas systems), line numbers (e.g., for steam we may have line 1,2,3,4), isometrics (e.g., for line 6 we may have four isometric drawings).

They begin by collecting information about the work activity selected above, and develop a (set of) of preplans for it. Guidelines for the preplan(s) ask the students to describe the optimum method that a crew(s) should use to perform the activity. The students are asked to design the method considering the site constraints (e.g. allocated space, availability of tools, site conditions, etc.), but not be limited by them. As a suggestion, the groups are encouraged to meet for a "brainstorming" session to develop input for the method prior to proceeding to the design and preplan(s).

The preplan(s) should be no longer than three (3) pages in length in length and should include essential information about materials, labor (including optimal group size optimal crew size), tools, place, equipment, information, energy, quality procedures and standards, safety, and environmental factors, and schedule requirements. While the preplans should be concise, the requirement is that they be very specific and include the following: types and quantities of materials, workers, tools, where to set up and work, size, type and role of equipment, references to pertinent specifications and drawings, quality standards and procedures, pertinent OSHA safety regulations, specific environmental issues and contingencies, descriptive sketches; etc.

7. OUTCOMES ASSESSMENT

As a result of implementing and using the proposed Interactive Learning Station, the students were able to perform the following new and enhanced learning outcomes and objectives:

- Name and identify the components used in the installation
- Describe and perform installations
- Explain the theory behind the prescriptive building codes
- Perform installations of systems according to building codes
- Develop construction sequencing and installation schedules
- Create a "Bill of Materials" for fabrications
- Estimate fabrication and installation schedules
- Advise others on the installation techniques and practices commonly used
- Test installations
- Perform inspections and create inspection reports

Examples of assessments that were used in the laboratory where students have participated in the experiential learning exercise have included the following:

- During an examination period, students were shown an installation, constructed with the experiential learning exercise, and asked to write an inspection report and identify installation errors and/or potential problems.
- Students were asked to give an oral presentation in which they were required to give a presentation to the class on a particular system that they built using the experiential learning exercise.
- For a quiz, students were shown a particular assembly constructed with the experiential learning exercise, and then were required to use the experiential learning exercise to produce diagrammatic installation drawings.

8. CONCLUSIONS

Mixed-use development is complicated, costly and risky.
The continued emergence of mixed-use projects as a powerful community development tool will ultimately require all parties involved to continue learning about and refining their approach to these projects. Successful implementation of a mixed-use project requires a carefully assembled development team that possesses strong management, development and design experience. It is most useful to involve the local government as a partner in the process, as they play an active role in developing local urbanization plans, providing necessary infrastructure, and even altering the public's perception of market conditions in the area. Financing mixed-use projects is more complicated. This is exacerbated by the fact that traditional means of financing (bank loans) could come at a higher cost due to the perception of higher risks. As such, the development team needs to structure the project creatively to provide investment opportunities for a range of investors. The responsibility is on the team to demonstrate that the project is creating value in the community beyond its short term market performance and will prove its worth in the market place over time.

Some common pitfalls and drawbacks that create barriers to the realization of mixed-use development have also been identified. However, the events in the two case studies suggest that these barriers can be overcome – with good determination, proper planning and design, co-operation, flexibility, imagination and good timing. It is important to realize that mixed-use is more of a development culture, rather than simply being another technical planning aspect. Ultimately, it is the mixed-use outcome (a richly textured environment comprising a mixture of life activities) rather than the mixed-use output (a discrete development incorporating a mix of uses) that underpins the success of a mixed-use development project.

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