

COMPARING TRADITIONAL SCHEMATIC DESIGN DOCUMENTATION TO A SCHEMATIC BUILDING INFORMATION MODEL

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ABSTRACT: The use of Building Information Models has recently moved to a focal point in the Architecture, Engineering, and Construction (AEC) Industry. While there has been much attention on the added value of the modeling process, little focus has been given to the documentation and project requirements in the early stages of the design.

This research focuses on a case study project of the new Dickinson School of Law (DSL) building at Penn State University. The research identifies the areas which provide added value through the use of BIM at the Schematic Design (SD) stage for communication of information and the manner the information is obtained. The focus of the paper, however, is on the issues that arise in how building geometry, building information, and building analysis and simulations are viewed and their potential impact on the Schematic Design phase of a project. To conduct this research, the completed Schematic Design documentation, including drawing system descriptions, and preliminary specifications, was obtained for the DSL building. This Schematic Design information was then converted to a Building Information Model and information related to different building components was incorporated. An analysis was performed, based on the University's design requirements, to assess the information that can be incorporated and utilized. Feedback through interviews was also documented to define the perceived value of a Schematic level BIM for the project. The conclusions identify the likely value that a project owner can derive from instituting schematic design BIM requirements and considerations when defining the scope of BIM requirements for Schematic Design. The results of the model analysis and the interviews are presented in the paper.

KEYWORDS: building information modeling, BIM, schematic design, visualization, case study.

1 INTRODUCTION

Building Information Modeling has become a topic of great interest throughout the Architecture, Engineering, and Construction (AEC) Industry. Building Information Modeling (BIM) is the process of designing, analyzing, integrating, and documenting a building's lifecycle by developing an intelligent virtual prototype of the building using a database of information. The attention on BIM has been highlighted through mandates from government agencies, such as the General Services Administration (GSA) in the US and its counterparts in several European countries (GSA 2006). Now that BIM has captured the attention of the industry, much of the current research has moved in the direction of demonstrating the value of BIM (Bazjanac 2003; Messner, Riley et al. 2006) and the interoperability of software to make the applications more practical (Tanyer and Aouad 2005; Tse, Wong et al. 2005). Another key direction of research is identifying how the changeover to BIM will impact industry practice. The focus of this paper is to identify the differences between BIM and traditional design by comparing documentation of design outputs at the completion of the Schematic Design phase to a representation of the Schematic Design in the form of a BIM. Comparing the differences between a BIM and traditional documents at this

stage is intended to demonstrate three key items: 1) the visualization techniques within each representation; 2) the method for information retrieval in each representation, and 3) the information that may not be incorporated within one of the representations.

2 LITERATURE REVIEW

In the traditional building design process there are several phases of design through which a project progresses. The exact number of phases and their titles are not universally agreed upon; however, the American Institute of Architects (AIA) standard architecture design contracts in the US define three phases: Schematic Design, Design Development, and Construction Documentation (AIA 1997). Though exact language may vary between firms and cultures, for the purposes of this paper the first design phase will be referred to as Schematic Design (SD). One of the challenges to comparing documentation at the SD phase is the ambiguity in the definition at this stage. AIA Contract Document B141, Section 2.2.4 defines Schematic Design documentation with the following language:

“Based on the mutually agreed-upon program, schedule, and construction budget requirements, the Architect shall

prepare, for approval by the Owner, Schematic Design Documents consisting of drawings and other documents illustrating the scale and relationship of Project components.”

The Architect’s Handbook of Professional Practice, published by AIA more clearly explains Schematic Design (SD) as the increment of design to “establish the general scope and conceptual design of the project, and the scale and relationships among the proposed building components.” The explanation goes on to list the deliverables which might include: plans, sections and elevations, perspective sketches, study models, electronic visualizations, and a statistical summary (AIA 2002). The list proposed is a guideline of potential deliverables which needs to be more specifically defined for each project. Defining what constitutes a set of standard SD documents for the purpose of comparison with a BIM at the same stage of development poses a notable challenge. This paper explores the topic through a case study approach.

The project chosen was being performed for Penn State University’s Office of Physical Plant (OPP). OPP has a well defined set of submittal requirements for each stage of the design process. The primary submittal requirements include specific requirements and scales for plan, section, and elevation drawings for the project, as well as identification of major systems and materials, a description of how each system will work, and a statistical summary of the design areas. From the viewpoint of an OPP project manager, the submissions rarely have problems because of OPP’s well defined requirements (OPP 2007). The definition enables them to move directly into reviewing the content of the submission, such as the aesthetics of the building or potential constructability issues (OPP 2006). The value of this information is a clearly defined set of expectations to compare through these consistent and typical documents in an OPP project at this stage.

3 CASE STUDY INTRODUCTION

The project analyzed for this study is the new Dickinson School of Law (DSL) Building being constructed at the University Park campus in Pennsylvania, US. The DSL building contains four floors with an 10,500 square meters (113,000 square feet) building footprint. The building will include a green roof in support of its Leadership in Engineering and Environmental Design (LEED) certification goal along with three terraced 75-seat classrooms, a 50-seat courtroom, a 250-seat auditorium, a café, and gathering space on the first floor. The second floor will host 19 offices, three seminar rooms, a faculty lounge, law review offices and a conference room. One of the unique interior architectural features is a glass enclosed library with its own group study rooms and offices. The library continues into the third floor where the main book shelf area is hosted. The third floor also boasts additional faculty offices, study rooms, and conference spaces. The lower floor will have a tiered classroom, library storage, along with the buildings mechanical support and janitorial space (Dickinson School of Law 2007).

4 RESEARCH METHODOLOGY

A detailed review of the SD documents along with a comparison to a SD level BIM was performed to identify the differences in information in each representation and the new considerations in developing design scope when using BIM. To identify the differences, a basis of comparison was needed. The BIM representation was developed to make a comparison to the traditional documentation. It also served to identify the perspectives of industry members to better evaluate the range of issues related to the use of BIM for SD.

4.1 Comparison criteria

The first research step was to define the standard Schematic Design documentation. The standard submission requirements for OPP served as a basis for this research. In addition to specific drawing requirements, OPP has additional documented goals for the review of the SD documents. The additional goals from OPP include:

1. Constructability review
2. Spatial program verification
3. Sustainability review
4. Presentations to user groups

These goals aided in the identification of the aspects of the model which should be defined in the BIM. To work towards these goals and to gain the best value of the process, the conversion to BIM focused mainly on the Architectural and Mechanical systems. The conversion was the next step following the development of the comparison criteria.

4.2 BIM development

The next step was to develop the Building Information Model through a conversion process. A “2D Conversion” is using the traditional design documents or CAD files and using the necessary information to incorporate the third dimension (AGC 2006). The time and effort needed to perform a conversion changes depending on the level of detail incorporated and the experience of the modeler. When the design CAD files are available, as with the DSL project, they can be inserted into the BIM authoring software and the BIM is drawn over the original 2D plans. The use of the CAD files simplified the geometrical modeling of the project.

One potential value of a BIM over a traditional 2D documentation of the design is the ability to easily perform additional analysis tasks such as energy, daylighting, construction scheduling, and quantity takeoffs (Messner, Riley et al. 2006). To investigate this value, the model was used to perform an energy analysis via the Green Building Studio (GBS 2007). Energy modeling was chosen because of the LEED goals of the project and the importance of the mechanical systems and energy performance as components in LEED certification.

4.3 Identification of differences

The third step was to identify the differences between the more traditional SD documents and the BIM. This was achieved using three methods. The first was through an

analysis of the development of the model. The CAD files for the 2D design documents were imported into an architectural BIM authoring software, for this project Autodesk Revit Building and Systems. Using the 2D drawings, the 3D geometrical aspects of the model were developed. From the preliminary technical specifications developed by the design professionals, additional information such as finish materials was incorporated into the model. The conversion of the design into a 3D model aided in the identification of geometrical challenges which do not readily present themselves in traditional 2D documents. The development of the model and the incorporation of project information into the model very quickly indicated some simple differences in the way information can be found or viewed.

The second method used to identify differences was a detailed comparison based on OPP's submission criteria using an evaluation matrix, shown in Figure 1. The first column is dedicated to the traditional design documents and was used to identify the form of the information. The second column is dedicated to the BIM which was developed. The second set of columns focuses on the information in the BIM and aids in identifying the differences in the information and the manner in which it was obtained. The comparison of the two columns also served to identify information which was not represented in one of the two forms of media.

Information	Traditional Documentation		Building Information Model	
	Form taken	How it was obtained	Form taken	How it was obtained
Design Concepts				
Floor Plans	2D	Printed Sheets	2D & 3D	Visualized in BIM
Elevations	2D	Printed Sheets	2D & 3D	Visualized in BIM
Sections	2D	Printed Sheets	2D & 3D	Visualized in BIM
Rendering	2D	Printed Sheets	2D	Visualized in BIM
System Info				
Architectural (Room Information)	Drawings & Text	Finish Schedule in Drawings & Specifications Found in Drawings & Preliminary Specifications	3D Images, Text	Seen in model, Properties Window, or Generated Finish Schedule
Mechanical (Duct & Equipment)	Drawings & Text	Preliminary Specifications Found in Drawings & Preliminary Specifications	3D Images, Text	Seen in model or Properties Window
Major Materials/Finishes	Drawings & Text	Found in Drawings & Preliminary Specifications	Visualized in model or plan	Properties Window or generated Finish Schedule
System Coordination	Not clearly evident		Conflicts in Model	Conflict report, seen in model
Other				
Description of Work	Text	Preliminary Specification	Not included	
Summary Room Areas	Not included	Hand takeoffs & manual calculations	Schedule in model	Generated
LEED Information	Text	Achievable Points Listed in Specification	Not included	
Constructability	Drawings & Text	Determine from review of documents	Model, Plans	Determine from review of model

Figure 1.

The third method for identifying the primary differences was to perform interviews with three project participants or related professionals to identify their perception of the differences between the two representations. The interview subjects were asked questions related to the quality of the visual representations of the design, the potential added value of any additional information, and the potential process changes that may need to occur to use a BIM approach to SD. They were also asked what impact moving to BIM could have on their role in a project, and to their interaction with other project team members.

5 RESULTS

The identified differences between the 2D and BIM methods for schematic design can be categorized into three categories: visualization of geometric information, data availability for further analysis, and the existence of information. Some examples clearly illustrate a difference in the way information was obtained and presented between the two media. Additional results identify the methods that contain information which is contained in

one form but not the other. Figure 2 shows the areas of the identified differences visually from the requirements matrix.

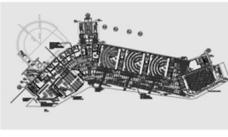
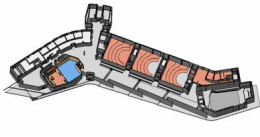
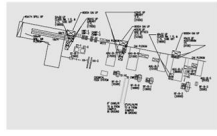
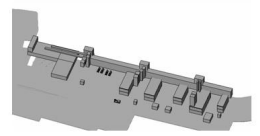





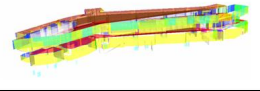
View	Traditional Documents	Building Information Model
Plan		
HVAC System		
Elevation		
Section		
Quantities	N/A	
Energy	N/A	

Figure 2.

5.1 Differences in visualization of geometrical information

One of the primary expected differences when developing the BIM was in the geometrical information; the BIM allows for multiple, and dynamic, 2D and 3D views of the building, while the traditional documents have purely predefined 2D views as shown in Figure 2. The impact of this difference would depend on individuals' abilities to interpret and visualize from 2D or 3D images, but it was a difference focused upon by the interviewees. Other information found to be visualized in a new way in the BIM included textured finish materials, color coded mechanical zones, and customized views, such as the 3D perspective of the mechanical system in Figure 2.

5.2 Differences in obtaining data from the design

Obtaining data from the two design representations was also found to be notably different. For the traditional 2D document representation, one would need to become familiar with the coding system for the drawings or specifications, and then find the correct drawing or page in the specification to gain the desired information. With the BIM, the user can open a properties window for a given element to find the aspect they wished to know. This requires familiarity with the computer application or an experienced user. An example from the requirements matrix is the information pertaining to the mechanical equipment. From the traditional documents the user

would need to find the different piece of equipment on the drawings, identify the meaning of the letter designation from the definitions and symbols drawing, and then find the equipment information in the preliminary specification. This information is located on three different pages in the SD documentation. Using the BIM, the user can see certain properties, such as component pieces, from the plan view. The user could also open the properties of the equipment from the floor plan and the detailed air flow information or other critical data is readily available. The user also has the option to develop an equipment schedule by automatically generating one within the BIM software. In addition, other schedules of information can be generated from the model. An area or volume takeoff, as shown in Figure 3, can be generated to save time in the estimating process and to provide accurate area information to the owner.

Room Schedule						
Level	Name	Use	Zone	Area	Perimeter	Volume
Ground	Vestibule	Vestibules	Zone 5	41 SF	25' - 10"	662.66 CF
Ground	Vestibule	Vestibules	Zone 6	67 SF	33' - 2 17/32"	1122.54 CF
Ground	Vestibule	Vestibules	Zone 6	67 SF	33' - 2 25/32"	1134.67 CF
Ground	Janitor's Cl	Support Space	Zone 6	46 SF	27' - 4"	736.09 CF
Ground	Men	Restrooms	Zone 6	253 SF	77' - 2 7/32"	4041.73 CF
Ground	Women	Restrooms	Zone 6	249 SF	73' - 6 7/8"	3990.97 CF
Ground	Elevator	Vertical Transport	Zone 6	46 SF	27' - 3 31/32"	735.81 CF
Ground	Classroom	Classrooms	Zone 7	1831 SF	172' - 4 11/3"	29287.15 CF
Ground	Electrical	MechElec	Zone 7	151 SF	49' - 10 23/3"	2422.11 CF
Ground	Storage	Storage	Zone 7	172 SF	56' - 3 27/32"	2747.66 CF
Ground	Electrical	MechElec	Zone 7	58 SF	33' - 4 7/32"	934.09 CF
Ground	Electrical	MechElec	Zone 8	65 SF	32' - 4"	1045.33 CF
Ground	Audio-Vis	Support Space	Zone 8	30 SF	21' - 10 5/16"	477.84 CF
Ground	Vestibule	Vestibules	Zone 8	57 SF	30' - 9 1/8"	919.83 CF
Ground	Shaft	Shafts	Zone 8	163 SF	57' - 8 11/32"	2613.37 CF
Ground	Classroom	Classrooms	Zone 8	1828 SF	173' - 4 3/32"	29253.27 CF
Ground	Audio-Vis	Support Space	Zone 10	30 SF	21' - 10 5/16"	477.84 CF
Ground	Vestibule	Vestibules	Zone 10	58 SF	30' - 11 1/8"	930.71 CF
Ground	Shaft	Shafts	Zone 10	165 SF	58' - 2 11/32"	2640.51 CF
Ground	Electrical	MechElec	Zone 10	65 SF	32' - 4"	1045.33 CF
Ground	Classroom	Classrooms	Zone 10	1828 SF	173' - 9 29/3"	29240.40 CF
Ground	Shaft	Shafts	Zone 11	89 SF	33' - 6 1/32"	360.65 CF
Ground	Shaft	Shafts	Zone 11	55 SF	29' - 8"	300.11 CF
Ground	Audio-Vis	Support Space	Zone 11	29 SF	21' - 6 11/32"	159.30 CF
Ground	Vestibule	Vestibules	Zone 11	65 SF	33' - 2 23/32"	359.35 CF
Ground	Men	Restrooms	Zone 11	134 SF	58' - 2 5/16"	713.92 CF
Ground	Vestibule	Vestibules	Zone 11	56 SF	30' - 0 9/32"	300.13 CF
Ground	Women	Restrooms	Zone 11	186 SF	58' - 7 3/4"	992.99 CF
Ground	Elevator	Vertical Transport	Zone 11	46 SF	27' - 4 1/32"	245.38 CF
Ground	Law Clinic	Unique Use	Zone 12	460 SF	100' - 4 25/3"	2453.99 CF
Ground	Law Clinic	Office	Zone 12	153 SF	49' - 6"	813.41 CF
Ground	Electrical	MechElec	Zone 12	65 SF	32' - 3 3/32"	345.17 CF
Ground	Stair 3	Vertical Transport	Zone 12	157 SF	55' - 3 1/16"	862.50 CF

Figure 3.

5.3 Information not contained in traditional documents

The traditional 2D design representation for this case study contained all of the required information for the SD submission to the owner. However, there was information which could be seen in, or generated from, the BIM which could not be identified from the 2D design representation. The BIM can offer views of the building mechanical zones, such as those in Figure 4, or the "thermal view" of the building (Bazjanac 2005). An energy analysis performed which was relatively easily performed on the BIM could not be performed from the design documents without extensive manual data entry. Exporting the model geometry and thermal properties, and evaluating it using energy analysis software generates information about systems costs for the building, temperature information at different locations, and a visual model of energy flow which enables clearer communication about the issues and design aspects of the mechanical systems, which can be seen in Figure 5. Similar analyses are possible for structural systems, lighting and daylighting systems, among many others. The traditional design repre-

sentation contains the expected achievable LEED points, which suggest the potential energy savings, but the BIM actually allows an analysis of the energy usage to give more information and other visual feedback to validate potential energy savings.

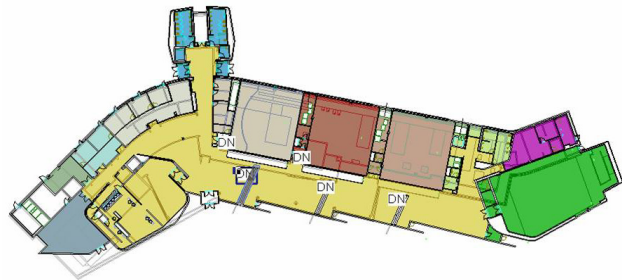


Figure 4.

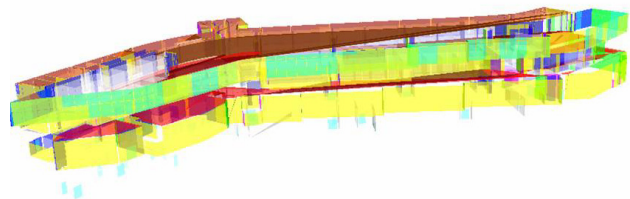


Figure 5.

5.4 Information not contained in the BIM

Another result from this research was the identification of information expected in the SD submission which was not easily incorporated into the BIM. A notable example for this project was the system descriptions. With early design submissions there is a narrative requirement to explain the overall system function and intent. It provides a basis for the evaluation of the system before it is fully developed. The BIM authoring applications had no practical location to incorporate this information. The software has the capability to add or link text to individual elements, but no predefined location could be easily identified for systems level or overall descriptions. There may be other BIM authoring applications that better support this type of documentation.

6 DISCUSSION

Most of the results determined during the comparison validate previous research results concerning the added value of using BIM on a project. The results indicate the potential for clearer communication, whether it is through better understanding of the systems, visualization of complex building geometry, or simplifying how building spaces are zoned such as color coding the rooms by mechanical zones. There is also the added value of the computational aspects of the model, such as generating square foot data to save manual takeoffs and calculations (Ibrahim and Krawczyk 2003). The true value of this comparison, however, was focused on the impact to the Schematic Design phase.

6.1 Geometrical information and systems coordination

The impact of using BIM during Schematic Design was identified for several areas. The move to using BIM during SD for the major systems design makes systems coordination more of a necessity than in traditional documentation. The owner's project manager pointed out the strict guidelines which they have for submissions allows for their review to focus more on the building through spatial, aesthetic, and constructability issues (OPP 2007). The review documents provide feedback on how to develop the design further in the next phase. Moving to a BIM in this stage would make physical conflicts of the systems more obvious (AGC 2006). An independent mechanical designer, upon reviewing the model and documents, commented that BIM would "bring designers to a consistent level." He continued to explain that in traditional documents different designers may devote energy to developing different areas of the project. Using BIM would allow the designers to see what areas the other team members were developing and encourage them to make sure they had enough information and design components in a given area that they could minimize conflicts and rework of the design in the future. The coordination of the systems was a major change found for the use of BIM in the schematic phase.

6.2 Level of detail

The other challenge when developing a BIM at this stage is planning what level of information and detail to display. One of the key points in any Penn State building project is its presentation to the Board of Trustees. Typically, renderings of the building are employed to more clearly demonstrate the final appearance of the buildings presented. Many times, OPP has been questioned about physical features of the building when it was complete that were not demonstrated in the renderings presented to the Board. On a recent building, some of the mechanical equipment was visible on the roof when the project was complete. The Board raised the point to OPP that the equipment was not shown in the rendering presented to them at the end of Schematic Design (OPP 2007). A more accurate BIM containing representations of all components would have clearly illustrated this equipment in a 3D view.

Another example identified by the mechanical designer during his interview was how electrical wiring would be displayed. On traditional electrical drawings, a drawing indicates electrical devices on a circuit and then shows a "home run" which is typically an arrow pointed in the direction of the relevant electrical panel with text to clearly define the panel and circuit. Moving to designing in BIM creates the issue of whether or not to show every electrical conduit, or just certain conduit runs. If only certain conduits are shown, then what are the criteria for showing them or having a simpler indication of their location in the design? The applications which are appropriate need to be determined for each application (Fischer and Kunz 2003). Information which is not displayed or displayed inaccurately may be as important as the information which is shown in the model.

6.3 Converted to BIM, not designed in BIM

One of the challenges for this comparison is that the BIM for this case study was developed through a conversion process after the SD documents were complete. It provides a comparison of exactly what is shown in the drawings to how it would be represented in a BIM, but does not allow for the changes in how the design would be developed differently if it was created using BIM applications. In some instances it allows for the opportunity to identify where information was not contained in the SD documents that was needed to create the BIM, such as depth or elevation of ductwork. A key example of this was when the construction manager (CM) pointed out an error in the model. In the lower level of the building there is a large air plenum. The SD documents do not provide the depth of the plenum on the drawings, so the depth was approximated from an attached riser when developing the model. The true plenum, from the CM's knowledge using the more updated drawings, is roughly three times as deep as it was shown in the model. Despite the identified differences in information displayed, the conversion does not provide for how the design process changes when design professionals use BIM authoring applications.

6.4 Forms of visualization

Another challenge in the comparison was the actual form of visualization which was used. The traditional documents were viewed by the interview subjects in the large scale paper format. To view the BIM, interview subjects were brought into the Immersive Construction Lab and they viewed the model on a 3-screen projection system (Otto, Messner et al. 2005). The ability to identify some of the differences could be attributed to the format of the display, and not entirely to the different form the information actually took on. If the subjects had viewed the model on a single screen desktop, they may not have identified some of the geometric elements as quickly or clearly as they had on the large displays. The issue of how to properly view a computer model is another issue which cannot easily be resolved in this comparison.

The comparison provided feedback concerning the differences in the information that could be presented and how it was obtained. The challenge for this comparison was that it was sometimes difficult to compare the two different design representations at this stage, one developed traditionally and one developed using BIM. It would not be practical to develop a comparison of two projects designed using the alternate representations, the two projects would have two unique designs. The development of the BIM after the design makes it challenging to compare the differences in the process, but allows for differences in the possible end results.

7 CONCLUSIONS

This paper has identified three primary differences in design representations between traditional 2D documents and BIM for representation the Schematic Design information. The differences identified in this case study lead to an important question, what should or should not be

incorporated into a BIM at this stage of design. The answer is not a simple one. Each project will require different information to be incorporated depending on the individual goals of the project and the different interests of the owners. The mechanical interviewee pointed out that using the software would enable more thought and energy into the maintenance aspects of the building. The example he used was changing the fan in an Air Handling Unit (AHU); using the BIM would allow the visualization of the process of moving the necessary component through the building to identify if there was a clear path, and whether the component piece of the AHU was readily accessible to make the change. The software also enables the incorporation of a variety of other information and visualization which is not readily available in traditional 2D drawings, such as structural or lighting analyses. The challenge for each project will be to identify what aspects should be modeled, what level of detail needs to be shown, and how much information or intelligence the components should have.

7.1 Changes to design

One definite change when using BIM is that the designers would need to incorporate more information into the design sooner than with traditional design. The use of BIM facilitates the need for certain assumptions to be made, such as the wall type to be used. In the traditional documents submitted, the wall types are only indicated for certain walls, such as the curtain wall. The rest of the walls indicate a thickness in the drawings and finish material in the specifications. To use that same wall in the energy analysis of the BIM, it needs to have thermal properties assigned. The thermal properties may be default assumptions the software has built in, but the feedback from the analysis is more beneficial if the designer inputs values. The designer can choose whether to use an actual wall assembly with a known thermal resistance, or use a generic wall and assign the expected thermal value. The need for assumptions provides guidelines for the other system designers to work from, but can have negative consequences if they are not properly revised as the design develops (Ibrahim and Krawczyk 2004). If the final wall type assigned has less thermal resistance than in the early design model, the mechanical system may be undersized and the space adjacent to the wall will have greater temperature variations.

Also, using BIM the designers would be encouraged to spend more time coordinating the designs than with traditional design documents because conflicts could be more quickly and clearly identified. From OPP's perspective, if the designers could identify these conflicts, then they should be able to resolve them before presenting those aspects of the design. The incorporation of information and additional geometry poses a challenge to owners in what to ask of designers when transitioning into BIM.

7.2 Timeline of design

Despite the increased information and geometry, there may still be potential time savings from BIM use within the Schematic Design phase. The most valuable aspect cited in the interviews for this stage of the project was the

computational aspects. From the CM perspective it would be a time savings in generating area and quantity takeoffs for the estimate. The mechanical designer would be able to more quickly develop the loads and system requirements. The owner could very quickly validate their program requirements, display the information more clearly to the end users, or perform more thorough maintenance and upkeep analysis. The conflicts raised through the design coordination would require more time to work out the solutions, but the conflicts would be simple to identify using clash detection software. The time savings of the parametric modeling of building components also helps balance added information requirements (McDuffie 2006). The balance of time savings using the computational aspects of the model versus the added time of incorporated information was beyond the practical scope of this comparison but would be a valuable area of future research. The time to develop a design using a BIM could increase or decrease depending on what is required and what is incorporated into the model.

All of these items contribute to a potential front end loading of the design process. Incorporating all of the information and design necessary to reach the same point as with traditional SD documents requires the design team to put more energy into the 3D aspects, the coordination with the other design elements, and decisions about the level of detail and information to incorporate. However, the resulting BIM should save coordination and development at later stages of the project. The key will be to work out for each project what is the appropriate level of detail and information to incorporate at this early stage.

8 FUTURE RESEARCH

Using the same project, further research will be performed on the value of BIM and related visualization technology throughout the Design Development, Construction Documents, and Shop Drawing phases. Research related to the phases of development for BIM will also be performed to more clearly delineate the phases using BIM and compare these to the current documentation oriented design process. Another area will be to develop guidelines based on project goals and requirements to help simplify the decision process on the level of detail and information to incorporate into a BIM.

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