EVOLUTION + BIM: The Utilization of Building Information Modelling at an Early Design Stage

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Abstract. The paper introduces an experimental design studio that explores the optimal use of current digital technologies in order to allow the adoption of Building Information Modelling at an early stage of the design process. Based upon outcomes from the aforementioned studio, the paper discusses issues regarding the adoption of BIM.

Keywords. Building Information Modelling; Design Studio; Design Strategy

1. Building Information Modelling

Building Information Modelling (BIM) is a process of establishing manageable and sharable representations of physical and functional data that define buildings throughout their life cycles. BIM allows an architect to perform a continuous update and sharing of critical design information among various disciplinary areas in the building industry. BIM provides real-time, consistent relationships between digital design data and innovative parametric modelling technology. It saves significant amounts of time and money and increases project productivity. Building Information Modelling shows a possibility of saving a large portion of the $ 15.8 billion wasted each year in the US building industry.

However, the usage of BIM in the design process of architectural firms and design studio settings is not fully implemented due to: 1) the linear model of the existing design process (Kolarevic, B., 2003; Onuma, K.G., 2006); 2) the already built-in computer applications that support the existing process in most architectural firms and studio settings (Bernstein, P.G. and Pittman, J.H., 2004); and 3) the various limitations of current BIM applications (Cheng, R., 2006). Especially, these limitations of the current applications become main hindrances to employing BIM at an early stage of design development, the stage where the architect can increase the impact of functional capabilities with low cost of design changes, and can have a high degree of design freedom that supports creativity in design. The limitations are 1) inflexibility of generating a high degree of morphological complexity, 2) difficulty of learning the applications, and 3) their low level of interoperability with other existing applications.

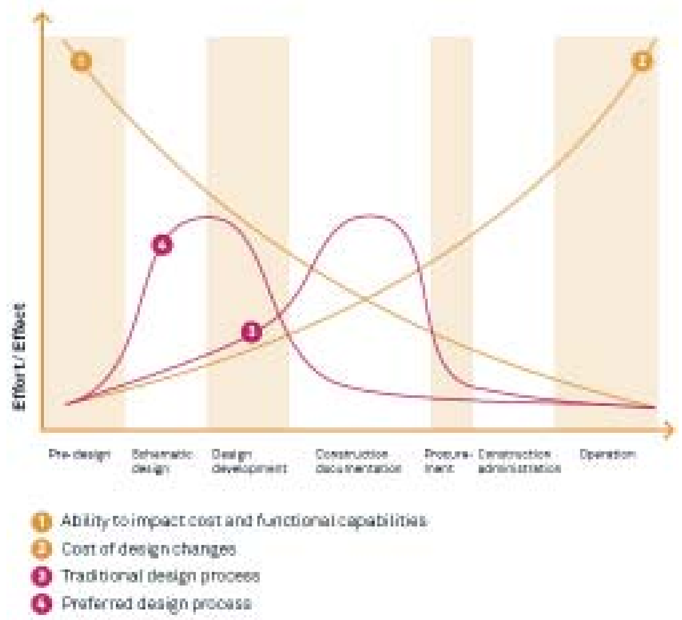

Figure 1. Collaboration, integrated information, and the life cycle in building design, construction and operation (Fallon, K.K. and Hagen, S.R., 2006)

Within a pilot studio setting, this paper investigates the optimal use of current technologies for the adoption of BIM at an early design stage.

2. A Pilot Studio

2.1. STUDIO DESCRIPTION

The School of Architecture at the University of Hawai'i at M noa offered a pilot design studio based upon Building Information Modelling (BIM) in spring, 2007. Five students and six professionals participated in the studio. For 16 weeks, students developed a design proposal for a new residential high-rise condominium complex of approximately 230,000 square feet. The first four weeks consisted of intensive training sessions of BIM applications (*Autodesk Revit* or *ArchiCAD*) for the students. These training sessions included a one-week introduction of four professional areas including construction management, structure, professional practice, and design technology. The time schedule for this studio comprised six weeks for concept design including three weeks of training sessions, seven weeks for schematic design including one week of spring recess, and three weeks for document preparation

A basic unit of the studio consisted of a student, four professional mentors (construction management, structure, professional practice, and design technology), a client and a project manager. During the studio, students employed three design methods including manual modelling (MM), geometric modelling (GM), and building information modelling (BIM) in order to develop their design. Freehand sketches and physical modelling were included in manual modelling. Applications for geometric modelling included *SketchUp, AutoCAD, FormZ* and *3D MAX*, while those for building information modelling (BIM) included *Autodesk Revit* or *ArchiCAD*.

2.2. DESIGN COMMUNICATION

This studio had three formats of design communication. The first was a weekly-based "one to one" communication between a student and a mentor/ client. The second was a monthly-based communication between a student and the four mentors, a "one to multiple" communication. The third was an irregular communication called by either a student or a mentor/ client. The format of the third type of meeting was a combination of the first and second. It is important to note that the design communication introduced in the studio was not a traditional pin-up with hard copies. With the traditional method, a student could not satisfy the needs of four different mentors. The design communication here was a sharing of the building information of each student's design development with the rest of the basic unit members, using parametric models of the student's project and other meta-data attached to the models in digital format.

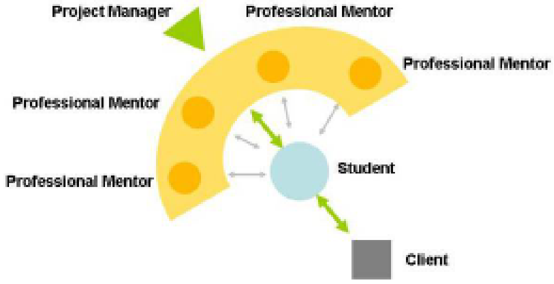

Figure 2. Design Communication

This design communication was essential for the success of a design project because each student developed the project based upon the communication with the rest of the basic unit members. It was quite challenging for each student to establish the best interface(s) for this design communication with four different specialists, the client, and the project manager. It led the student to explore and enhance his/her own design strategy with selecting various digital technologies for the migration of BIM into the process of his/her design development. Each student's evolutionary adaptation of the digital technologies that maximize the use of BIM in the design process was the core of this pilot design studio. The size of Building Information Modelling of each student's design project increased as the design communication grew. In this process, the student learned various interoperability options of the digital technologies and developed a strategy for employing BIM as an integrated environment for the design communication.

3. Studio Outcomes

During this studio, the students made a conceptual design, schematic design, and partial design development of a given project. Upon completion of the project, the student made a final presentation of each project and submitted a design process description of the project. The student's design work and presentation were evaluated according to how well the client's needs were satisfied, with consideration of four different areas: construction management, structure, professional practice, and design technology. Each student's design process description became an instrumental yardstick to measure the degree of utilizing BIM in a design project with various design applications. It showed the efficiency and effectiveness of the student's usage of design applications for making fluent transition of their design idea to Building Information Modelling. The design process description was composed of 1) the strategy for selecting various design methods, 2) the time record of using the design methods, and 3) any problems encountered, and reflections on their design strategies.

3.1. DESIGN STRATEGIES

Students explored various design applications for manual modelling (MM)—freehand sketches and physical modelling, geometric modelling (GM), and building information modelling (BIM). They explored each application as a design method, not as a mere tool. This means that they investigated an optimized combination and sequence of using the applications for increasing both productivity and creativity in their design process. Each student developed different strategies according to 1) the efficiency and effectiveness of design communication, 2) his or her skills in utilizing the design applications, and 3) their level of understanding of the concept of building information modelling.

3.1.1. BIM as a design tool

The early adoption of BIM in the design process provides essential design resources for establishing the design communication between mentors and students. All the necessary design components are propagated from the outcomes based upon the design communication. Most students using this strategy already have some strength in various geometric modelling applications. This allows them to explore an integrated environment for exchanging different types of building information in their design process.

From the beginning of the design development, *Autodesk Revit* was employed for defining a three-dimensional design boundary according to given site conditions such as circulation, shape, floor area ratio (FAR) and maximum building height regulation. Within the boundary, various design concepts were tested with freehand sketches. At the same time, the students started geometric modelling with *SketchUp*. With its high degree of flexibility and ease in geometric modeling, *SketchUp* was employed for developing various spatial containers, which are ready to be filled with architectural components already built in to *Autodesk Revit*. With *SketchUp*, students transformed the given three-dimensional boundary model according to their concepts and divided the model into a group of small objects that satisfy functional, structural, and environmental requirements.

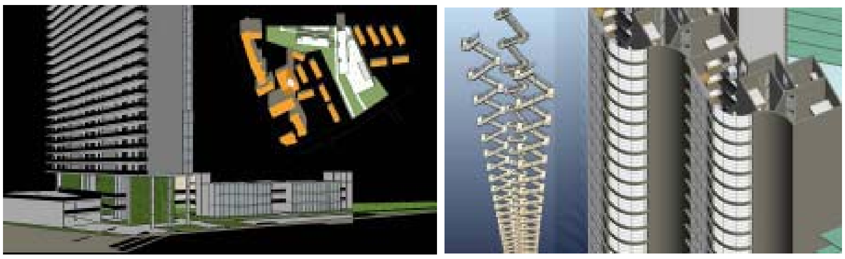

Figure 3. Student designs

Various forms developed in *SketchUp* were redefined for accepting meta-data stored in the database of *Autodesk Revit*. In this strategy, the usage of *SketchUp* is not limited to serving as a geometric modeller for establishing the numeric data of a form, but it becomes a pre-building information modeller for providing a spatial container that accommodates detailed information of building construction. Creating spatial containers is instrumental in enhancing a transition from concept through geometric modeling to information modeling. The employment of *SketchUp* partially resolves the issues of the limited morphological complexity within current BIM applications and their limitations on design creativity.

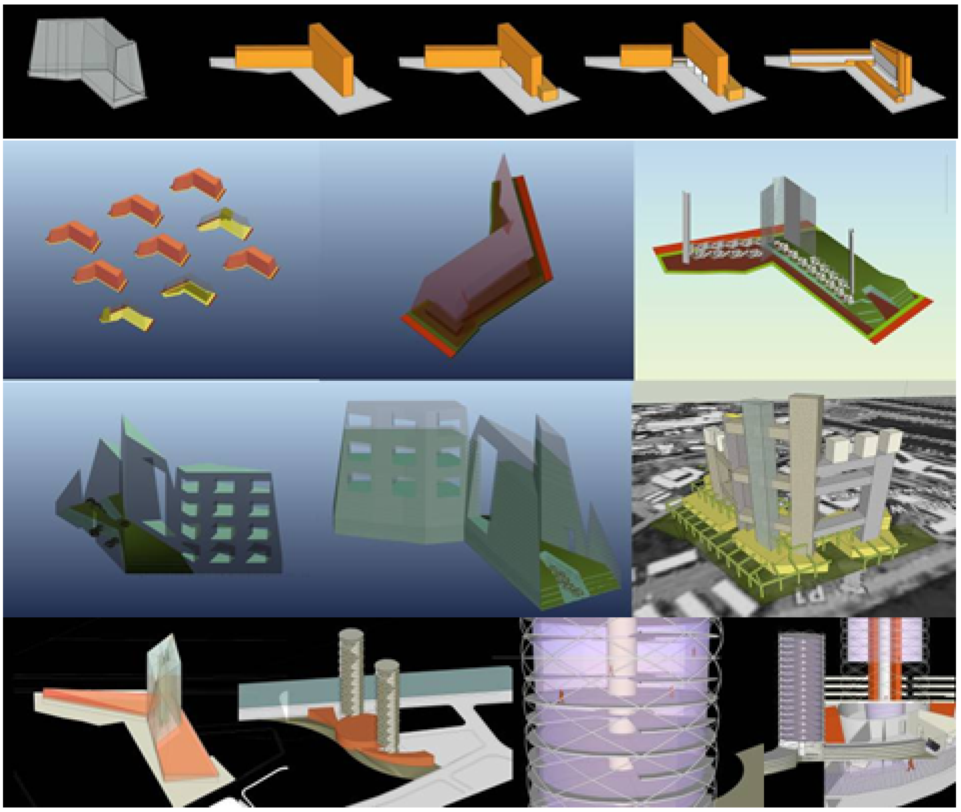

Figure 4. Design processes from geometric modelling to building information modelling

Therefore, until "massing" tools built in to the BIM applications are developed enough to allow a high degree of morphological complexity, the strategy of combining GM and BIM with spatial container- or placeholder-making needs to be considered as a method for increasing both productivity and creativity in the architectural design process. Students using this strategy spent 134 ~ 150 hours for this project, about 16 ~ 32 hours less than students employing the other strategy. The students used BIM for more than 70 % of the total amount of time. Of this, 30 ~ 39 % of BIM usage occurred in the conceptual design, 34 ~ 43% of BIM usage in the schematic design, and, 25 ~ 34% of BIM usage in the documentation process.

3.1.2. BIM as a construction tool

Most architectural firms employ this design strategy for adopting BIM with design applications already built in their firms. With freehand sketches, a design concept is developed under given site conditions. Two-dimensional drawings and three-dimensional mass models are developed in *AutoCAD*. The developed three-dimensional mass models are reconstructed within *Autodesk Revit* for assigning detailed architectural information. The final design is developed through continuous design exchanges between *AutoCAD* and *Autodesk Revit*.

The easiness of manipulating existing applications provides the strength and efficiency to this strategy up until the transition from geometric modelling to building information modelling. However, with this strategy, after the geometric models are constructed for representing a design concept with *AutoCAD*, another modelling process needs to be performed in *Autodesk Revit*. This means that BIM within *Autodesk Revit* is required as an additional process, because conversion of the imported mass models to the components in *Autodesk Revit* is not fully accomplished yet due to the lack of a meta-data defining process. In order to make a smooth conversion between these applications, the geometric models within *AutoCAD* should be layered and partitioned properly in order to accept architectural information in the advanced database system of *Autodesk Revit*. This strategy requires an extra 11 ~ 24 % of the total amount of time used for the other design strategy. Basically, a secondary model is constructed in BIM based upon the one in *AutoCAD*. The clumsiness of current BIM applications in geometric modelling is still a major limitation of BIM in the creative process, especially in making various descriptive geometric models.

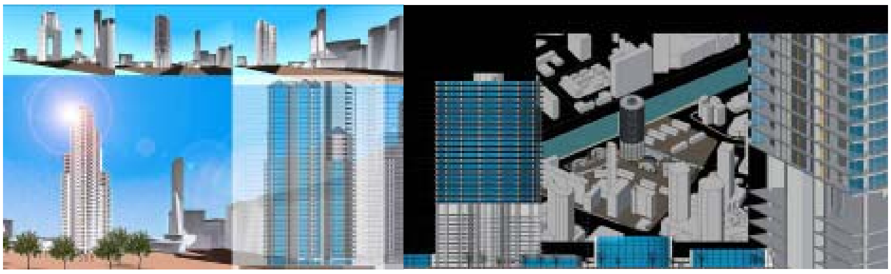

Figure 4. Student designs

Most students using this strategy were very comfortable with *AutoCAD* 2D and 3D modelling processes. Before using BIM applications, students constructed a complete geometric model of the project. Their inclination to use *AutoCAD* delayed the use of BIM applications. It caused an ineffective design communication. With only the geometric models, it was difficult to incorporate the design communication with four different mentors. BIM was employed as a mere tool for constructing another set of geometric models and preparing detailed construction documentations. Students using this strategy spent about 160 hours for this project. They employed BIM for about 50% of the total amount of time, of which. 40 ~ 57 % of BIM usage was concentrated in the documentation stage. During the schematic design phase, 30 ~ 36 % of BIM usage was made. For the conceptual design phase, just 12 ~ 22 % of the BIM usage was applied.

3.2. EXISTING PROBLEMS

The steep learning curve for current building information modeling (BIM) applications in combination with other existing design applications and the built-in limitations of the current BIM applications remain as main obstacles for adopting BIM at the early design stage. Some of the students in the studio already had the basic skills, and for a month, all students underwent intensive training in the use of BIM applications. However, when a BIM application was introduced as a method in combination with other geometric modelling applications, the students had to deal with an integrated design environment with which they were not familiar. Therefore, the problem was how to exchange their design outcomes from various applications along with the BIM application, rather than how to use the BIM application alone in the design process.

Current BIM applications require a relatively high level of understanding of architectural elements. The applications require students to define various architectural details early in the process of exploring various geometric forms. This is not generic to the traditional architectural design process, which is based upon a form-making that most designers are familiar with. This can be a huge burden to students with relatively limited knowledge of construction and material. It becomes overwhelming for them to decide what kind of wall, how high, how thick, how wide, with what materials, and on what level, etc., from the beginning of the design development.

In addition, when geometric models, which are generated as a basic spatial container or placeholder in *SketchUp* or *AutoCAD*, are transferred to *Autodesk Revit*, a BIM application, the models essentially need to be reconfigured with a set of information within the application. For example, *Autodesk Revit* stores and treats various walls imported from *SketchUp* as the same family members, while there might be a number of differences among the walls in the family. This requires extra time and efforts to reconfigure the different types of walls. The current management system of *Autodesk Revit* needs more convenient information changes in order to define and refine various design components as architectural elements.

4. Discussion

During this 16-week pilot design studio, students made conceptual design, schematic design, and the documentation for a partial design development of a new residential high-rise condominium complex. The students learned the importance of an integrated design environment for increasing both the productivity and the creativity of the project. They developed their own design strategy for exchanging different types of design data within manual modelling (MM), geometric modelling (GM), and building information modelling (BIM).

Current building information modelling (BIM) applications provide a low degree of design freedom. Moreover, they are difficult to learn. In addition, due to the short history of the BIM applications, their interoperability with other existing applications is not fully achieved. The outcomes from this studio show that geometric modelling (GM) applications such as *SketchUp*, *FormZ*, or *AutoCAD* have a great potential for developing various geometric models as spatial containers or placeholders, in order to afford the detailed information of architectural elements when the models are transferred to BIM applications. With this object-oriented concept of spatial container- or placeholder-making, a designer is able to maximize flexibility in form-making using GM applications while minimizing additional efforts for establishing building information from GM to BIM. It illustrates the use of GM and BIM applications as a design method, not as mere drafting or construction tools. In addition, a "massing" tool built in the BIM applications shows another possibility to enhance a connection between BIM and GM from the BIM side. Such a "massing" tool allows a designer not only to perform basic geometric explorations but also to apply an object-oriented concept to making various spatial containers or placeholders in BIM. The enhancement of a "massing" tool in BIM will increase the portion of GM within BIM and ease the learning curve of BIM applications. It will invite more designers to employ BIM at an early design stage while providing more freedom in the form-making process.

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