Building Information Modeling (BIM) to Increase the Efficiency of Construction Projects

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ABSTRACT
several technologies, including CAD technology, have provided competitive advantages to the Architecture, Engineering and Construction (AEC) industry in terms of cost and productivity. CAD has passed through evolutionary developments until it reached what it is today, starting with the first in-house developed two-dimensional CAD system in the early 1960's, involved feature-based parametric modeling; which is one of the main origins of what is known in the AEC industry as BIM. Building Information Modeling (BIM), the current state of the art in CAD development, is mainly based on both feature-based CAD and parametric modeling technologies. These technologies provided new powerful tools that caused a huge development to the AEC industry. BIM is currently being implemented by a significant number of architectural and engineering firms. This thesis traces the chronological development of different CAD. It also explores BIM technology, the relationship between BIM and the construction process, and opportunities of development in order to enhance productivity by saving time and effort, and reduce human errors. Two suggested tools are proposed, Auto-Finish Macro (AFM) and Auto-TAG Macro (ATAGM), with the purpose of accelerating the BIM workflow by reducing the time involved in building the architectural BIM model and 4D BIM models respectively. The thesis introduces the conceptual basis of AFM and ATAGM, their main input requirements, and working sequence, in addition to case studies. It also proposes extensions to the current AFM capabilities to address different phases in the design process.

Keywords: BIM Technology , CAD Techniques, AEC development, Building Process, Construction Development, Architectural Technologies, BIM Automation, BIM Macros.

INTRODUCTION

Since the term "Building Information Modeling" (BIM) was first introduced in the AEC industry in the last decade; it has changed many aspects of the design, construction, and operation of a building. BIM has not just introduced transformation in terms of technology, but also in terms of process. It added a new working methodology that is based mainly on adding building-related "Information" to 3D objects, which becomes responsible for controlling their behavior, shape and determining their constraints and relationships. Adding information to such 3D elements has changed them from dummy objects to intelligent ones. The element in a BIM model is more than just lines, surfaces and solids; it is a system that has its own entity. The result of adding building-related information is a virtual replica of the building. It is a database from where all 2D drawings are generated, all quantities are calculated, coordination of the whole building is conducted, visualization and 4D simulations are performed, etc. BIM has many competitive advantages such as the increased speed of delivery (time saved), better coordination (fewer errors), decreased costs (money saved), greater productivity and higher-quality work along with new revenue and business opportunities.

BIM can be used in any phase of a given project, and it has different benefits that serve each phase. It is being developed with the development of the project. In the early concept design phase, it is used in developing space planning and analyzing design alternatives in terms of energy, structure, spatial configuration, way-finding, costs, constructability, and so on. In the construction phase, it acts to serve the coordination process, the generation of shop drawings, from which buildings are constructed, and the fabrication process that is mostly performed by a sub-contractor, etc. In the post construction phase, it acts to serve operational and maintenance-related issues. BIM impacts each of these phases by bringing in more intelligence and greater efficiency.

Most of the world's leading Architecture, Engineering, and Construction (AEC) firms have realized the benefit of using BIM in projects, which was a motivation for leaving the earlier CAD systems and use BIM.
Problem Definition:
The initial motivation for creating the first 2D CAD system was the need for a computer-based system that facilitates drafting issues related to automotive and aerospace industries. CAD started to get developed with growing manufacturing and production needs.
The AEC industry faced the difficulty of missing the integration between software and the information needed for implementing CAD technologies. Feature-based modeling technology was created to overcome those difficulties through embedding information into geometry.
Implementing feature-based modeling in the AEC industry suffered from a lack of coordination between the different feature objects in the model. Parametric modeling technology was then proposed to address these coordination problems.
The term Building Information Modeling (BIM) was introduced in the AEC industry as the latest generation of feature-based parametric modeling technology. It uses a single database model from where all the information needed for construction is driven. The process of building this database model involves huge manpower (cost) and time; as it requires determining a lot of information in the process of building the model. According to Eastman (2009):
". . . BIM related disadvantages include the large upfront manpower cost and time involved to build the 3D model." 1
This research investigates the possibility of overcoming the challenges of the upfront manpower cost and time involved to build the BIM model by proposing tools that accelerate the process of building it.

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Value of Research

From the results conducted in this research, the presented tools, Auto-Finish Macro (AFM) & Auto-TAG Macro (ATAGM), were shown to accelerate BIM workflow. This was achieved by automating the typical sequenced procedure of building the BIM model and tagging its elements, which saves time, money and effort, reduces human errors and raises the level of quality. Saving the time of the sequenced procedure of building the BIM model and tagging its elements, allows for more room to manage more important tasks, which helps to make the building process more efficient.

Goal of Research

The goal of this thesis is to overcome issues associated with the huge manpower and time required to build a BIM model by accelerating the process using suggested tools that can cut the related tedious and repetitive tasks. Reducing the time associated with these kinds of tasks will save time for more important tasks such as: performing quantity takeoff, clash detection, fabrication, etc. as shown in Fig. (1).

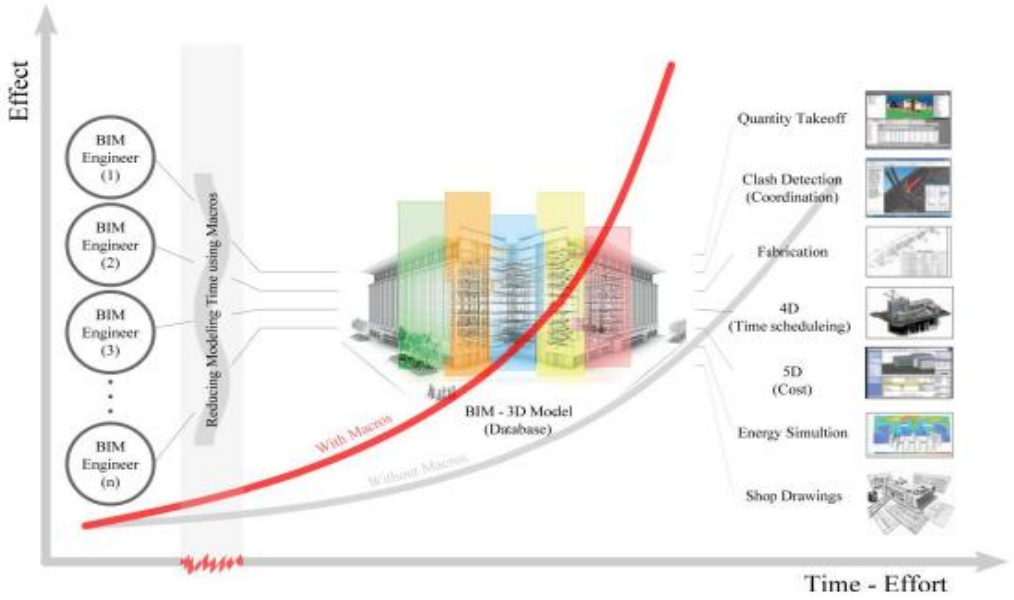


Fig. 1: Reducing time and human effort in BIM Process

Objectives

Objective 1: Tracing the evolution of CAD technologies and its impact on the AEC industry.
Reviewing and exploring the development of CAD technologies and techniques to date, and the impact of these technologies on developing and enhancing the AEC industry.
Objective 2: Exploring BIM as a new technology that offers new tools.
Reviewing and exploring BIM as an evolution of the latest CAD based technology by discussing its new tools, workflow and processes.
Objective 3: Exploring the impact of BIM on the AEC industry.
Reviewing and exploring the impact of using BIM on the AEC industry compared to the use of conventional CAD systems.
Objective 4: Exploring macros and their ability to accelerate and enhance BIM.
Reviewing macros and their ability to accelerate and enhance the BIM process during its different phases.
Objective 5: Proposing a tool Auto Finish Macro (AFM) that reduces the time of building an architectural BIM model.
Proposing a conceptual tool (AFM) that accelerates BIM in the phase of building the architectural models by automating the process, such that the whole process is expedited consequently.
Objective 6: Proposing a tool Auto TAG Macro (ATAGM) that reduces the time of converting 3D BIM models to 4D BIM models.
Proposing a conceptual tool (ATAGM) that accelerates BIM in the phase of building 4D models by automating the process of tagging elements, such that the whole process is expedited consequently.
Objective 7: Evaluating the proposed tools (AFM & ATAGM).
Applying the proposed conceptual tools on a specific application and comparing process time results using two methods; the first using regular BIM tools and workflows, and the second using BIM enhanced by the proposed conceptual tools, and calculating the percentage of the time saved.
Objective 8: Suggesting further works for the proposed tool (AFM).
Suggesting further modifications to be added to the current conceptual tool (AFM) to produce variations that serve different project phases.

Scope and limitations

- The proposed AFM was used for reducing the time of building the architectural BIM model and not the other structural, MEP or firefighting models. In addition to another macro (ATAGM) was used to accelerate the process of converting the 3D BIM models of all systems to 4D/5D models.
- Bentley software was used in the applications. Bentley software was chosen as the author has more than three years of experience with Bentley BIM applications.
- Visual Basic Application (VBA) programming language was used for writing the macros, as it is compatible with the Bentley software.
- **Methodology**

The Methodology for this research included:

1. Conducting a literature review.
2. Processing and analyzing data reached from this review.
3. Writing and developing the macros using VBA.
4. Conducting a comparative analysis of case studies.
5. Analyzing results and deducing added value.

- **Methodology of Objective 1:**
- A literature review of books, periodicals, papers and technical reports was conducted. The review included topics related to CAD software techniques in early stages, their chronological evolution and their impact on industry.
- **Methodology of Objective 2 & 4:**
- A literature review of books, periodicals, papers and technical reports was conducted. The review included topics related to BIM as a new approach based on feature-based parametric CAD, in addition to macros and their ability to automate BIM workflow.

Case of study : Crowne Plaza Changi Airport
Case Study: Crowne Plaza Cheghi Airport Extension
Introduction

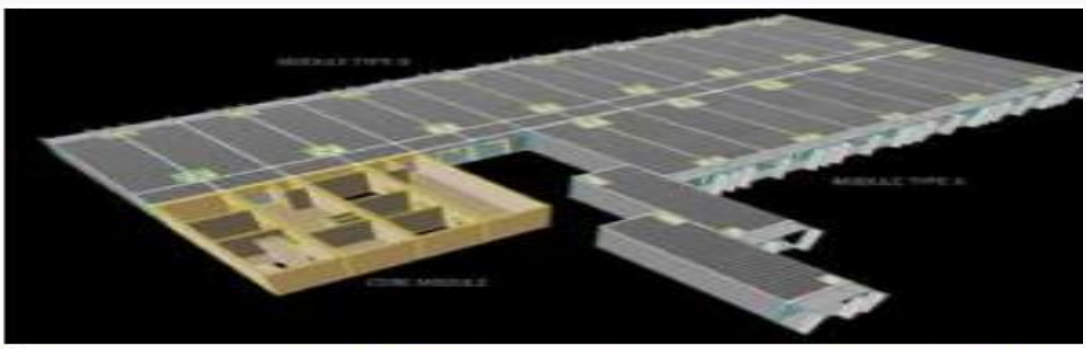
Adding the Crowne Plaza Hotel at Sanghai Airport to a stand-alone building consisting of ten lines connected to a hotel currently connected via the link on the second floor, in a way that expands its area by approximately (10,000) meters and will add an additional 243 square rooms to the hotel, bringing the number of seats to 563.(2).

Construction approach

Artist's impression of finished building and existing hotel
(Images source: Dragages Singapore)

Internal view of a completed typical PPVC hotel room module

The building was originally conceived as a conventionally built project but early in the project the design was modified to accommodate the anticipated use of a range of DFMA technologies. As part of its successful bid for the contract, Dragagaes proposed the use of prefabricated modular construction (PPVC**).(3).**



Arrangement of PPVC modules on a typical floo
(Image source: Dragages Singapore)

View of site from Terminal 2 during PPVC module installation
(Image source: Dragages Singapore)

Design format
The structural, mechanical and electrical designs were developed as separate but coordinated BIM models before the contract was awarded. They were transferred to Dragages who used the BIM model to coordinate the MEP services with the PPVC units. The BIM model was also passed to UB to develop contact details for the PPVC units, and 2D deliverables were created. To design the unit for approval by the design team.

Opportunities
The adoption of DFMA technologies in this project involves shifting the mindset and operational processes of all parties involved in the project and by modifying working practices across the industry will be the starting point for DFMA in Singapore**.(4)**

Recommendations of study
From the analysis done and the tools presented in this thesis, the author came to some recommendations that might help in improving the BIM applications and the AEC industry as well:

1. For AEC Companies and Firms
It is highly recommended for all engineering offices and firms not to delay their decision of moving from using CAD to the use of BIM to get advantage of its effective and powerful tools, raise the level of quality and control the building process in a much better way, which will improve the entire industry. On the other hand, it is important to keep in their consideration that BIM requires more time and manpower (cost) for its implementation compared to conventional CAD.
It is highly recommended for all engineering offices and firms to leverage the competitive advantage of BIM expertise by exploring 4D (schedule integration) and 5D (cost modeling), which provide extremely powerful process efficiencies.

2. For Higher Education Institutions
It is highly recommended for all higher education institutions that provide AEC-related studies to integrate and utilize BIM in in their educational programs.
It is highly recommended for all higher education institutions that already integrated BIM into their educational programs to increase the emphasis on the construction core rather than teaching BIM software, and consider BIM software not more than mere helping tools.

3. For BIM Software Developers
It is highly recommended for all BIM software developers to develop the idea of Auto-Finish Macro (AFM) to be compatible with their BIM software and embed it to be a part of the package.
BIM case studies

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