Building Information Modelling (BIM); How it Improves Building Performance

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1. Introduction

In order to visualize and facilitate the creation of a project, paper-based drawings and physical models are widely used in the construction industry. The main difficulty in the utilization of drawings is their lack of integration and coordination among each other. Conradi (2009) claimed that, although hundreds of drawings are used for a particular project, they all are individual, stand alone segments of the total design. There is no central integration of information to represent the total project and these components require human intervention to connect them into a meaningful whole. As effective communication of information between the designers and the people in the field is vital, central integration of information has become a critical issue in construction management. Although this situation has significantly changed with the introduction of Computer Aided Drafting (CAD), there are difficulties in exchanging mostly graphical information from one CAD system to another due to compatibility issues.

Meanwhile, the construction industry has undergone a paradigm shift and new focal points for construction emerged. The designer's spectrum has changed from merely designing the building to the management of the building throughout its life cycle. Today's building designers need to satisfy many different criteria to provide high quality, comfortable buildings that also comply with building regulations, minimize life cycle costs to the clients, optimize energy costs, reduce environmental impacts and confirm with internationally accepted energy performance levels.

These requirements prompted the development of a far more sophisticated digital based information system known as Building Information Modelling (BIM).

2. Applications of Building Information Modelling (BIM)

A building information model is described as a digital representation of the physical and the functional characteristics of a facility (American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 2008). It contains all the elements of the building such as the floors, spaces, walls, doors, windows and a large number of attribute information associated with each of these elements. Building Information Modelling uses digital modelling software to design, build and manage projects more effectively and is providing a powerful tool to the construction firms who adopt it.

In BIM, the database serves as the central repository of all physical and functional characteristics of a construction project. Documents are still used, but they do not have the centre stage, as they are produced on demand from the most current information of the database. The database, as a shared resource for reliable, collaborative decision making plays a leading role in the overall creation and management of the construction project. Using BIM, a single building model can be developed which is capable of being used throughout the project lifecycle. A visualization model created by a BIM is shown in Figure 1.

Figure 1: A model of a biomedical facility developed by BIM

Source: SmartMarket Report: the business value of BIM, 2009, McGraw-Hill construction.

Although a BIM model has many common features of a 3D geometrical model, it contains a much higher level of intelligence. A BIM can normally be viewed in 3D, but the model also integrates information used by other building analysis applications such as cost estimating, energy simulation, daylighting, Computational Fluid Dynamics (CFD), space planning and building code checking. The importance of BIM is emphasized as a means of open interchange of information across different platforms and the ability of transfer records of building information throughout the building life cycle. BIM serves as a reliable foundation for decision making and provides a platform for automated analyses that can assist in planning, design, construction, operation and maintenance activities as shown in Figure 2.

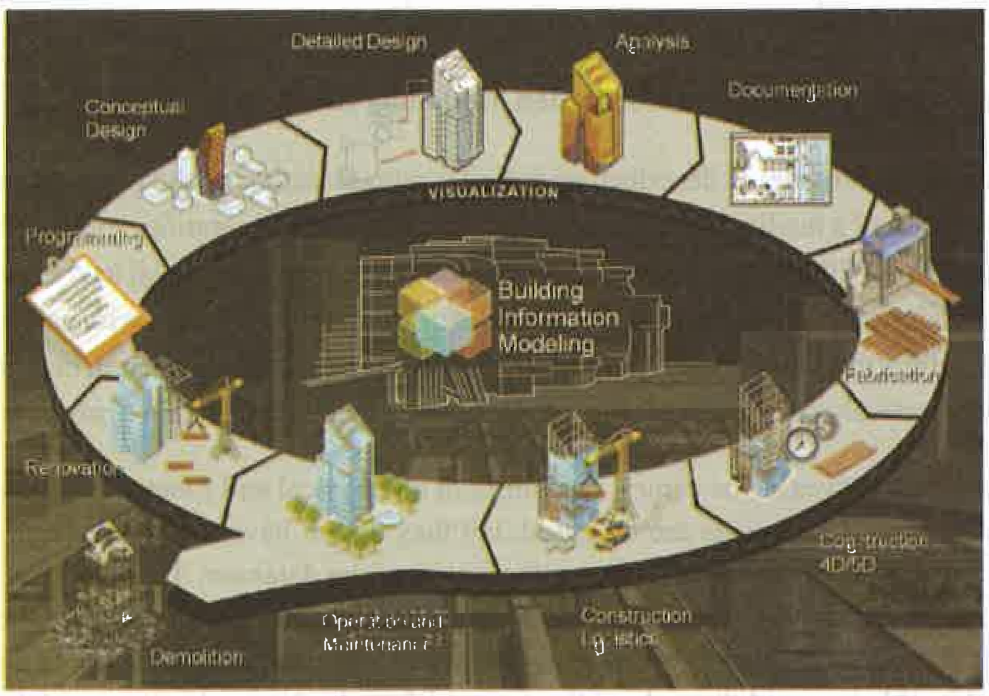

Figure 2: Building Information Modelling

Source: http://buildipedia.com/in-studio/design-technology/the-daily-life-of-building-information-modeling-bim

3. Key concepts of BIM

Jones (2008) highlighted three fundamental concepts to which most of the benefits of BIM can be referred to

- Use of database instead of drawings
- Concept of distributed model
- Value addition to BIM

3.1 Use of database instead of drawings

In BIM, the designs are developed as a digital database rather than a series of separate drawings. The database serves as the central repository of all the physical and functional characteristics of a product. In order to build the digital data base, a BIM project uses intelligent objects that represent the project elements. An intelligent object is termed as an object or a set of objects that represent not only the geometry required to represent the component or assembly graphically (visually) but also having the ability to have much more information about that object associated with it or related to other intelligent objects associated with it (American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 2008).

All pertinent information is built into the intelligent object, and once placed in the BIM, it will automatically represent itself in any plan, elevation, section, detail, schedule, 3D rendering, quantity takeoff, budget, maintenance plan etc. As the design changes, the object can adapt itself parametrically to adjust to the new design.

3.2 Concept of distributed model

There are two basic types of BIM tools available today; authoring tools and analysis tools. BIM takes a distributed approach, so that the value of authoring tools is combined with the power of analysis tools. In a distributed BIM environment, separate models for design, construction, scheduling (4D), cost (5D), fabrication, operations etc. are authored and appropriate analysis functions are carried out as shown in Figure 2.

As all these models are BIM databases, they can be viewed together to identify clashes between architectural, structural and Mechanical, Electrical & Plumbing (MEP) systems that can be fixed virtually to avoid field problems.

Jones (2008) pointed out that since the BIM database holds the information from each of the intelligent objects in the BIM, it can publish specific subsets of that data to analysis tools on demand. For example, an energy analysis tool can extract just the relevant information about a project's site orientation, glazing, doors, mechanical system performance, equipment electrical loads and heat generation, surface reflectivity of the exterior materials and envelope insulation properties. The energy analysis tools incorporate the annual solar path, temperature and wind conditions for the site, hence it can analyze a proposed design solution in terms of for energy performance. The stakeholders can then modify the BIM accordingly and retest multiple times until satisfactory results are achieved.

This process takes place digitally with no manual re-entry of information from multiple sources into separate tools. It is seamless, fast and highly effective. Additional analysis tools which can be used for model checking, scheduling, estimating, ingress and egress etc. are rapidly being developed and refined which will increase the value of the BIM systems in future.

3.3 Value addition to BIM

Jones (2008) stated that the value of BIM is not only in the Modelling tools and the models produced, but also in the use of the power of Modelling to facilitate the collaborative decision making. Hence, a trend known as Integrated Project Delivery (IPD) is rapidly emerging. IPD brings key construction management, trades, fabrication, suppliers and product manufacturer expertise together with design professionals and the owner, earlier in the process to produce a design that is optimized in terms of quality, aesthetics, constructability, affordability, timeliness and seamless flow into life-cycle management. Using model checking applications to detect system clashes is an effective IPD activity. It is easy to use and has powerful visualization capability. Also, it offers the opportunity to resolve conflicts in a non-confrontational, collaborative process during design, while they are still relatively inexpensive to correct. This productive activities around clash detection improves the collaboration among different stakeholders.

Overall, BIM is a powerful combination of modelling and analysis tools with integrated, collaborative process that is adding further value to BIM.

4. BIM and Building Sustainability

Green Building or Sustainable Building concept focuses on the practice of creating structures and using processes that are environmentally responsible and resource efficient. It encompasses factors such as site selection, design, construction, operation, maintenance, renovation, and deconstruction. The concepts of sustainable building and carbon footprint assessment make valuable contributions in controlling and reducing the effects of global warming and climate change.

BIM plays a major role in meeting the global need for sustainable construction and climate protection as it allows a design team to take a 'reduce and optimize' approach in reaching the sustainability and climate protection goals of the building project. As stated in the BIM Guide (American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 2008), whole building Life Cycle Assessment (LCA) is an important aspect of providing sustainable, high performance buildings. BIM allows rapid and economical consideration of alternatives and game scenarios in the design stage to optimize the building's lifecycle impact on sustainability.

A BIM as a living, historical database of every material, component, assembly and system used in the building. It can contain design, construction and lifecycle assessment information, operation, and service and maintenance data, along with energy use down to the system and component level that could be used for intelligent strategic planning for the adaptive re-use or re-cycling of a building with respect to renovation, restoration or demolition where necessary.

With the increasing awareness of sustainable development in the construction industry, implementation of energy rating procedure to assess buildings is becoming important. Energy assessment schemes such as Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEM), Green Star etc. rates buildings with respect to key areas related to environmental and human health including energy efficiency, indoor environmental quality, materials selection, sustainable site development and water savings. Therefore, a building which utilizes a properly designed and well functioning BIM well aligned with the requirements of energy assessment schemes will be able to achieve globally recognized energy ratings.

5. Software Tools in BIM

There is a wide variety of software tools both for modelling and analysis which are available in the market as shown in figure 3. In selecting appropriate software tools for a particular BIM project, the functionality characteristics and the interoperability are the main concerns.

Figure 3: Software tools for BIM
Source:http://buildipedia.com/in-studio/design-technology/the-daily-life-of-building-information-modeling-bim

5.1 Modelling Tools

The kind of information that is required from the BIM determines the type of model required, which in turn leads to the nature of the modelling tool that can accomplish this. Models are simulations that are the abstraction of the real object. Kymmell (2007) pointed out that as there is always a difference between the model and the reality, in decision making, the level of abstraction and the reliability of the model should be considered.

There are two types of modelling tools used; surface modelers and solid modelers. Kymmell (2007) stated that all volumes are represented by their surfaces in surface modelers, hence they create only edges, from which all planes and forms are constituted. They cannot show a distinction between the mass of a solid component and the space between these components. Hence, if a drawing is needed, some editing is required to convert it into an understandable document, with the necessary graphic information. Software programs such as Google-SketchUp make surface models.

Solid modelers are actual representations of real objects in 3D space, having the correct dimensions, location and ability to contain other information about the object characteristics, for example, a wall can consist of various thicknesses of specific materials that can then be used to calculate material quantities from the model. Solid objects represent the real objects both inside and outside; the walls have an actual thickness and look solid in a sectional view. Solid model components have volume; even the thinnest element will have a measurable thickness, unlike the surfaces in a surface model.

Therefore, the level of abstraction of a solid model reflects the project, its stage of development and its needs. It is less dependent on the software model chosen to create the model. The organization of the model refers to the manner in which the model components and connected information are organized in a software file. The components of the model therefore need to be well organized in layers, so that at any given time they can be easily selected in the model.

The user will create actual 3D components in the software and assemble them into a single model, of which multiple views are possible. The views do not exist independently – they are actual views of the single model entity. Hence when a change is made in any of the views, it will actually be a change in the model, and therefore be reflected in all views of the model. Revit Architecture, Tekla, ArchiCAD, Vico Constructor, Microstation TriForma are some of the solid modelling tools among a wide range of tools available.

5.2 Model analysis

Two types of model analysis namely qualitative and quantitative are usually performed. The qualitative analysis considers the nature of the issues, often irrespective of the quantities associated with it. Kymmell (2007) highlighted a variety of purposes of carrying out qualitative analysis. They include

- Communication and marketing: The visual content of the model provides an impression of the project. Both surface and solid models will generally create good 3D images from a model.

- Constructability: This refers to a visualization of the methods necessary to construct a project. It is an inspection for practicality and is intended to detect practical difficulties. This can be achieved by surface or solid models.

- Systems coordination and clash detection: The clash analysis will find objects in the 3D model that take up the same space causing clashes. This can be achieved by surface or solid models as shown in Figure 4.
- Energy analysis: This will generally require a solid model due to the information that needs to be available on the materials used for construction. The nature, size and location of thermal zone boundaries need to be calculated to evaluate heat gains and losses for each thermal zone of the model.

Figure 4: Applications of system coordination and clash detection
Source: SmartMarket Report: the business value of BIM, 2009, McGraw-Hill construction.

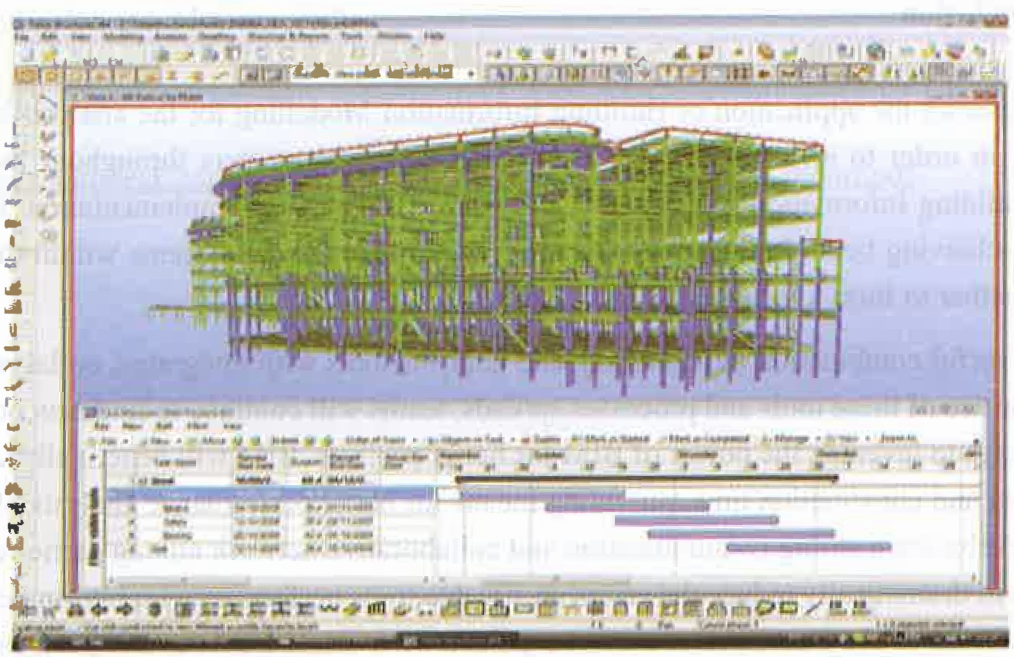

Figure 5: Linking between a Tekla model and scheduling software
Source: http://www.tekla.com

Quantitative analysis is involved with measurement and often combines it with other information. This type of analysis includes quantity takeoff, construction cost estimation, cash flow analysis and lifecycle cost analysis. Sequential analysis relates to studies that include time and sequence and provide good visualization facilities as well as useful quantitative information as shown in figure 5.

6. Interoperability of BIM Models

Interoperability of BIM models is defined as the ability to manage and communicate electronic products and project data between collaborating firms' and within individual companies' design, procurement, construction, maintenance and business process systems (American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 2008).

A BIM consists of a variety of models produced by various people, with different levels of detail, and with diverse software tools in various formats. Hence, interoperability between operating systems, BIM software, engineering analysis software, cost estimating software, scheduling software, energy management software, and others is critical in BIM. The models that need to be combined in particular software have to be provided in a compatible format.

There is a number of software such as Autodesk NavisWorks, Solibri, Bentley Project-Wise Navigator etc., which act as model viewers and has many useful applications in almost all phases of the use of the BIM. The primary function of these software is to provide 3D model interoperability. Also, they can be used for model checking applications to detect system clashes.

They can read different file types from various sources, import and handle large files, combine different file types and facilitates graphical communications across the entire project team.

7. Conclusion

This paper reviews the application of Building Information Modelling for the analysis of building performance in order to arrive at the optimum performance parameters throughout its lifecycle. Although, Building Information Modelling is still in its early stage of implementation, it has huge potential in achieving better building performance, as it integrates all systems within the building life cycle together to form a meaningful framework.

BIM is a powerful combination of Modelling and analysis tools with integrated, collaborative processes. As the use of these tools and processes spreads, teams will continue to find new productivity enhancing ways to leverage the power of BIM for better projects. BIM will benefit all stakeholders by saving cost and construction time, providing means for better performance analysis of buildings as well as developing a strong communication and collaborative network among parties concerned. The model will dramatically reduce the errors on site due to its performance monitoring capabilities when all members of the construction team are guided by a single BIM model, from early design to completion, changes are automatically coordinated across the project and information generated is shared among all leading to of high quality work. Furthermore as well as enhancing the building performance, the utilization of a BIM satisfies the sustainability goals of construction.

Sustainable building concept focuses on the practice of creating structures and using processes that are environmentally responsible and resource efficient. The concepts of sustainable building and carbon footprint assessment make valuable contributions in controlling and reducing the effects of global warming and climate change. Therefore, a properly designed and well functioning BIM system will achieve goals of sustainability and reduce the carbon foot print as well as satisfying the requirements of energy assessment schemes enabling the building to achieve globally recognized energy ratings. The role of BIM in providing value addition to buildings is evident and it also provides competitive advantages to the firms who adopt it. Hence, BIM will play a lead role in the future of the construction industry.

This paper forms the initial step towards extensive work for developing a Building Information Model for a sample building, in the Sri Lankan context leading to its optimization of performance throughout the lifecycle of the project.

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