ADAPTABILITY OF GREEN BIM TECHNOLOGY FOR THE GREEN BUILDINGS IN SRI LANKA

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ABSTRACT

To raise awareness of green building constructions, Building Information Modelling (BIM) has been incorporated with unique sustainable strategies. Green BIM technology is a significant innovation of BIM, emerged through the integration of BIM with sustainable strategies, which enhance the sustainable growth of buildings while making better opportunities to improve the performance of green buildings. However, the utilisation of Green BIM technology for existing buildings is less amongst green building practitioners though Green BIM is widely used for design and construction phases of buildings. In the Sri Lankan context, since BIM is not implemented yet in building construction, operation and maintenance, the inherent capabilities of Green BIM technology are hidden and invisible. Thus, an effort is needed to convince and prove the importance of Green BIM technology for green building practitioners. Towards this effort, the research is aimed at identifying the potential of implementing Green BIM technology for the existing green buildings in Sri Lanka where BIM is not applied. Accordingly, a mixed research approach was followed to accomplish the research aim. Literature review revealed that, the data availability required for Green BIM techniques and tools is the critical requirement to implement the Green BIM technology for the established buildings. A desk study was conducted to determine the required data and availability of the data was analysed through a questionnaire survey and a case study. The findings of questionnaire survey demonstrated that, there is an acceptable level of data within the current established green buildings. The results of the case study highlighted the potential of Green BIM implementation for the existing green buildings. Thus, the study concluded by identifying the ability of incorporating Green BIM technology for the existing green buildings considering the real-life context which ensure the Green BIM implementation for the green building sector in Sri Lanka.

Keywords: *Building Information Modelling (BIM); Building Performance; Green BIM; Green Building; Sri Lanka.*

1. INTRODUCTION

In this rapidly rising world population, with the increased demand for scarce resources, and continued pollution to the environment, sustainability has been receiving a major attention in this era (Ghosh, Chasey, and Cribbs, 2015). Consequently, "Green Building" movement has emerged, which later gained an impetus under the concept of sustainability (Krygiel and Nies, 2008; Waidyasekara and Fernanado, 2013). However, though it is proved that green buildings provide numerous benefits for building owners and consumers, according to Richardson and Lynes (2007), there are more deficiencies in green buildings rather than in conventional buildings. Thus, an increasing awareness has been developed in recent years for the use of information technology, to improve green building performance in relation to design, construction, and operation (Solla, Ismail, Elbeltagy and Yunus, 2016).

Since BIM is significantly appreciated in the world as an innovative technology derived from information technology development, building owners have focused to integrate BIM with sustainable design strategies (Wong and Fan, 2013). Moreover, Motawa and Carter (2013) have mentioned that BIM can play a vital role to improve green building performance. Thus, 'Green BIM' has become an enormously popular concept in today construction industry (Sollar *et al.*, 2016). Green BIM is considered as the use of BIM tools, to enhance the building performance and to achieve the sustainability objectives of a building (Krygiel and Nies, 2008).

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However, Wong and Zhou (2015) have mentioned that, the adoption rate of BIM for green building projects is still very less and hence its full potential needs to be explored. Further, Wong and Zhou (2015) have revealed that, the limited knowledge of building owners and practitioners towards Green BIM technology is the main reason for such lower adaptability. Moreover, as mentioned by Barbosa, Pauwels, Ferreira and Mateus (2016), there is a lack of awareness to model the existing buildings in BIM software environment though BIM has widely been used in design and construction phases of buildings. According to Wong and Fan (2013), a systematic review has not yet been carried out, identifying the ways of integrating Green BIM to the existing green buildings.

Hence, based on the aforementioned studies, the research was mainly focused to identify the potential of Green BIM implementation for the existing green buildings. Within the Sri Lankan context, though BIM is still not been implemented, with the growing concern for green building development, Green BIM technology could potentially be incorporated to the existing green buildings. To achieve the research aim, a comprehensive literature review was conducted in order to identify the Green BIM tools and inherent techniques of BIM tools. The input data required for Green BIM tools and techniques were further determined and the availability of identified data were analysed through the data collection and analysis. Finally a case study was conducted as a practical experiment of applying the Green BIM technology, to comprehend the actual capability of Green BIM implementation for existing green buildings. The scope of the research was limited to the population of LEED certified green buildings.

2. LITERATURE REVIEW

2.1. BIM APPLICATIONS IN GREEN TECHNOLOGY

Three main areas of sustainable design, which have a direct relationship with BIM are indicated as material selection and use, site selection and management and system analysis (Shoubi, Shoubi, Bagchi and Barough, 2015). According to, Zanni, Soetanto and Ruikar (2014), BIM contribution to sustainable building design has undergone two perspectives as integrated project delivery and design optimization.

- **Integrated Project Delivery**

It has identified that, there would be numerous problems when handling a green building project, from its inception to completion due to the involvement of various stakeholders within the project. Every project stakeholder including green building consultant takes a part for the project and with clashing opinions and miscommunications of information, many of redundancies could be occurred throughout the project. As in the traditional practice, when resolving all these redundancies through documentation process, the frequency of cycling documents among the stakeholders would be high due to many of refinements, resulting in high costs, mistakes, delays and inefficiencies. As BIM allows an integrated approach for the green building project team, many of redundancies could be eliminated through the improved communication (Park, Park, Kim, and Kim, 2012).

- **Design Optimization**

Design optimization is identified through two steps as creating the basic models using appropriate BIM software (eg: Autodesk Revit) and exporting models to BIM based analysis tools (eg: EcoTest) for the various sustainability analyses / building simulations (Jalaei and Jrade, 2015). There are interoperability standards which functions as data modelling formats, between BIM softwares and analysis tools to ensure the proper data transferring. As examples, Industry Foundation Classes (IFC), IFCXML, COBie, gbXML and ecoXML could be recognized (Redmond, Hore, Alshawi and West, 2012). The building system analyses are incorporated with various functional aspects of a building including structural integrity, temperature control, lighting, ventilation, circulation, energy distribution and consumption (Moakher and Pimplikar, 2012). Hence, there is an ideal opportunity for the sustainability measures and performance analysis of buildings within the usage of Green BIM (Tae, 2012).

2.2. GREEN BIM TOOLS

It is important to identify the Green BIM tools/softwares to carry out various sustainability analyses. Green BIM tools can improve analysis and eliminate the errors of data handling, since it allows analysing the multidisciplinary information in a single model (Azhar, Carlton, Olsen and Ahmad, 2011). The most commonly used Green BIM tools have been identified as Autodesk ECOTECT, Autodesk Green Building Studio (GBS), Integrated Environmental Solutions (IES) Virtual Environment (VE), Energy Plus and DeST (Wong and Fan, 2013). Graphisoft Eco Designer STAR, Riuska, ArchiVIP and Design Performance Viewer have also been identified as popular BIM based analyses tools (Cemesoya, Hopfe and Rezgui, 2013).

- **Ecotect**

Ecotect owned by Autodesk, is an energy simulation tool which is compatible with BIM softwares (eg: Autodesk Revit Architecture) and used to perform comprehensive building energy performance analysis. Ecotect comprises thermal, lighting and acoustic analyses, including natural and artificial lighting levels, hourly thermal comfort, monthly space loads, project costs, acoustic reflections, reverberation time and environmental impact (Azhar, Brown and Farooqui, 2009).

- **Green Building Studio (GBS)**

Green Building Studio, also owned by Autodesk has been identified as an energy analysis tool to evaluate the environmental impact of individual building components, in the life cycle process of buildings. The lighting and shading analyses are used to assess day lighting and include the LEED Daylight Credit 8.1 feature. The value and cost functions include the lifecycle assessments and lifecycle costs. Green Building Studio is often used to assess multiple design alternatives while ECOTECT is more appropriate for a detailed design visualization and simulation over the performance of a specific sustainable design (Azhar *et al*., 2011)

- **Integrated Environmental Solutions' Virtual Environment (IES'VE)**

Integrated Environmental Solutions' Virtual Environment software is identified as an integrated building performance analysis tool. Analyses are addressed the issues of solar, lighting, energy, costs and many others (Hua, 2009). The energy/thermal functions include energy usage, carbon emissions, thermal analysis, heating/cooling load evaluation and ventilation. The lighting and shading analysis includes solar analysis, daylighting assessment, and LEED Daylight Credit 8.1 feature. The value/cost analysis functions are included lifecycle assessment and lifecycle costs (Azhar *et al*., 2011).

2.3. *GREEN BIM TECHNIQUES / BIM BASED SUSTAINABILITY ANALYSES*

BIM softwares are typically involved in designing the basic BIM model of the building and exported it into BIM based analyses softwares or building simulation tools for sustainability analyses (Biswas, Wang, and Krishnamurthi, 2008). The techniques used in Green BIM tools are included energy/thermal analysis, lighting/shading analysis, acoustic, value and cost analysis (Motawa and Carter, 2013). Basic techniques included in Green BIM tools are summarized in Table 1 and following techniques are applicable up to the operation and maintenance phase of buildings.

Table 1: Green BIM Techniques

Green BIM Techniques/ Simulations	Features	Outcomes
Energy and Thermal Analyses	• Energy usage • Carbon emissions • Resource management • Thermal analysis • Heating/cooling loads • Ventilation and air flow • Heat loss calculations • Simulation of indirect environmental effects such as atmospheric pollutants associated with building energy use	• Energy use intensity • Renewable energy potential • Annual carbon emissions • Annual energy cost and consumption • Building heating and cooling loads • Breakdowns of energy use for major electric and gas components such as HVAC and lighting • Energy end use charts
Lighting and Shading Analysis	• Solar analysis • Day lighting assessment	• Calculations of solar energy absorption

	• Shading design analysis • Lighting design analysis • LEED daylight credit 8.1 • Radiance analysis	• Glare and discomfort spaces • Spaces where solar directly enters • Cooling and heating energy consumption • Solar orientations for the building
Value and Cost Analyses		• Life cycle assessment • Life cycle cost
Acoustic Analysis		• Noise dispersion and its effect inside the building
Water Harvesting		• Monthly non- potable water usage • Monthly potable water usage • Monthly water savings • Total water reuse potential • Building water demand • Rain water capture from the roof
Space Simulation		• Comparisons of alternative indoor air quality levels • Comparisons of alternative windows and shades • Dimensioning of air conditioning equipment • Analysis of temperature problems of the building
System Simulation		• Comparisons of alternative HVAC systems • Optimization of zones for AHUs • Dimensioning of cooling equipment based on actual cooling loads

(Source: Adapted from Azhar *et al*., 2011)

2.4. DATA REQUIRED FOR BIM TOOLS

The implementation of Green BIM technology for the existing green buildings basically depends over the availability of input data which are required to be included to the Green BIM tools. The preliminary input data required for Green BIM tools are identified as geometry data of the building. The geometry data of every individual component of the building envelope are needed for a detailed simulation (Wang, Choa and Kim, 2015). Further, simulation data need to be included for the tools for accurate sustainability analyses (Kim, Shen, Kim, Kim, and Yu, 2016). Bu, Shen and Anumba (2015) have mentioned, the typical inputs required for the simulation tools as building type, system types (HVAC), construction materials, project location (weather files) and room type (zone management). Moreover, Wang *et al*. (2015) have mentioned the input data including material properties, weather data, internal loads, operating strategy and schedules, HVAC systems and components and simulation specific parameters which should be incorporated to the building simulation tools. Some of the examples for geometry data could be mentioned as wall area, floor area, roof area, ceiling area, dimensions of doors and windows and any other specifications. The requirement of input data is depended upon the type of sustainability analysis/simulation and the Green BIM tool which provides each analysis. Data required for Green BIM techniques are shown in Figure 1.

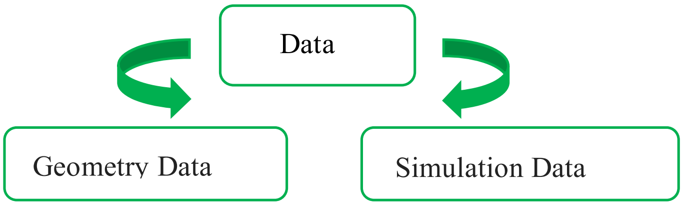

Figure 1: Green BIM Techniques

3. Research Methodology

The aim of the research was to identify the adaptability of Green BIM technology for the existing green buildings. Initially, through the literature review Green BIM tools, techniques and basic input data categories were determined. Even though, literature revealed the input data requirements as geometry data and simulation data, the types of data required under each category were not separately recognized and thus, types of input data had to be recognized through the data collection. To attain this, a desk study was first carried out to identify the input data requirements. Accordingly, desk study was undertaken using the published manuals of Green BIM tools. These manuals were included each data requirements separately for building geometry and simulation data categories. For collecting and analysing the identified data, content analysis was done using Nvivo 10 software.

The identified data were then subjected to a questionnaire survey to analyse the availability of data within the current LEED certified green buildings. The total population of forty LEED certified green buildings in Sri Lanka was considered for the analysis and availability of data was calculated as percentages under each building. The results showed that there is an acceptable level of data availability in buildings since the data were readily available through drawings and specifications. Nevertheless, it was required to further analyse the data availability to realize the required accuracy and reliability of data. Hence, a case study was conducted as a practical study for the research. The building with the highest data availability was selected for the case study and it was conducted by applying the Green BIM technology for the selected green building.

The application of this technology was mainly consisted with two stages as the creation of building model using basic BIM software and simulation of the created building model using BIM based sustainability software. These two stages were important to comprehend the accuracy and reliability of identified data for the appropriate application of Green BIM technology. Hence, within the application of Green BIM technology for the selected green building, basic BIM model of the building was needed to be created first, since BIM was not used for the design and construction phase of the building. Thus, the building was created with correspond to the electronic drawing of the building using Autodesk Revit BIM software.

Geometry data of electronic drawing were used to model the building due to convenience even though, both electronic and paper drawings were available. Within the process of creating the building model, it was realized that the geometry data of electronic drawing were not acceptably accurate since there were undesired errors due to inaccurate dimensions. Thus, the model was recreated using the paper drawing of the building since it was accurate as required. The actual building and its created BIM model is shown in Figure 2.

Figure 2: Actual Building and the Created BIM Model

After creating the model, it was exported to the Autodesk Green Building Studio from Revit, which was BIM based simulation software. Once the model is exported the geographical location of the building was specified for the energy simulations. The location data resulted with the information including latitude and longitude, altitude, city and state and time zone. The importance of location selection is to set the related climatic conditions and other related weather data, which affect to the entire building energy performance. After selecting the location, simulation data were entered to the GBS software including HVAC system types and efficiencies, lighting types and efficiencies, indoor temperatures, total occupancy, number of occupancy hours and operating schedules of the building systems, to run the simulations. The results obtained through the energy simulation are given in Table 2.

Table 2: Energy, Carbon and Cost Summary

Energy, Carbon and Cost Summary	
Annual Energy Cost	RS. 18,900,000
Life Cycle Cost	RS. 121,172,875.320
Annual CO^2 Emissions	
Electric	21.7 Mg
Onsite Fuel	85.2 Mg
Annual Energy	
Energy Use Intensity (EUI)	532 MJ/m2/Year
Electric	2,542,324 kWh
Fuel	359,124MJ/kg
Annual Peak Demand	10,800 KVA

Energy end use charts were further obtained from the GBS relating to the building cost (refer Figure 3).

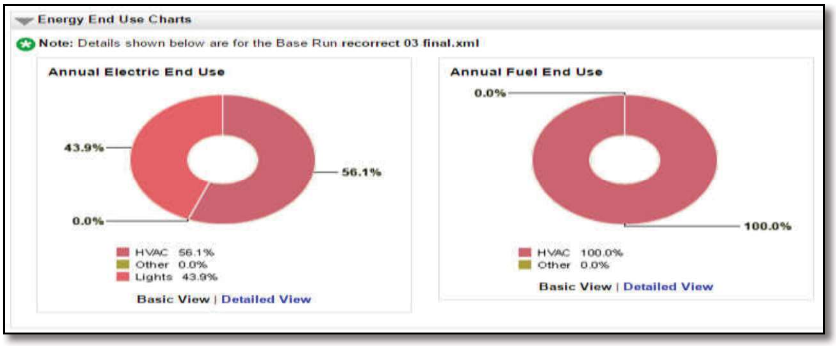

Figure 3: Energy End Use Charts

Monthly cost data of the building were also resulted by the simulation, relating to area lights (yellow), space cooling (dark blue) and vent fans (light blue) as shown in Figure 4.

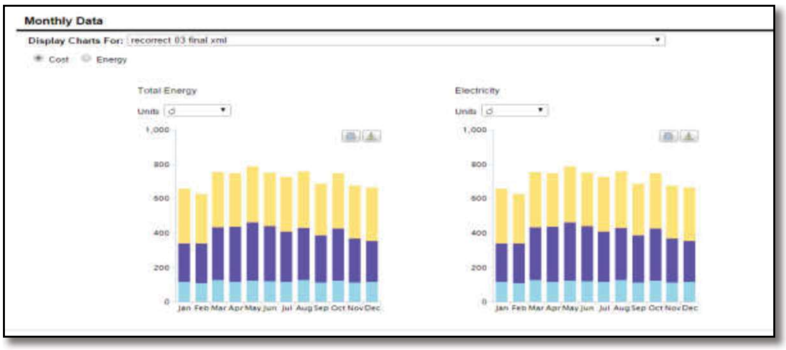

Figure 4: Monthly Energy Cost Data

4. RESEARCH FINDINGS AND DISCUSSION

The results of the case study indicate that though BIM has not been utilized for the design and construction phases of the building, the Green BIM technology could successfully be implemented for the existing green buildings in Sri Lanka. According to the findings of the case study, Green BIM technology could be incorporated successfully to the existing green buildings, if the required input data are adequately and sufficiently available. Further, it was found that though data were available, the accuracy of data is needed to be considered to avoid the potential technical errors. The input data are basically important for both model creation and the simulation, but however literature findings did not review the types of required input data for the implementation of the technology.

As per the findings of the case study, the data availability with required accuracy and reliability is the critical requirement for the successful application of Green BIM technology. Thus, the effort of this research towards the implementation of Green BIM technology for an existing building within the non-existence of early utilized BIM, will make better opportunities to eliminate the hurdles of Green BIM usage for green building owners and practitioners.

5. CONCLUSIONS

Building Information Modelling (BIM) is an innovative technology and process which has quickly transformed the way of designing, constructing, analysing and managing the buildings. Green BIM technology is a part of BIM and a model-based process which undertakes generation and management of coordinated building data during the building life cycle, to improve energy performance of buildings while facilitating the accomplishment of sustainability goals. The integrated design information and collaboration of Green BIM, supports environmentally sustainable building development while reducing the adverse impacts to the environment. Though Green BIM is a well-known technology in today construction industry, it is seemed as an unprecedented concept in green building sector as its adaptation is less for existing buildings with compared to the new building constructions. Hence, it has been revealed that, the adoption rate of Green BIM for existing buildings is needed to be considered.

The aim of this research was to identify the potential of implementing Green BIM technology for the existing green buildings in Sri Lanka where BIM is not applied. According to the findings applicability of Green BIM technology is basically relied upon the availability of necessary data relating to the building design, construction and management. Utilization of Green BIM technology is more convenient in design and construction phases of buildings since all the data related to the building design and construction are readily available as required, with compared to an existing building. Hence, when it comes to an existing building, the implementation of Green BIM technology is highly depended upon the availability of drawings and specifications. Finally, it could be concluded that if the accurate data are available, Green BIM technology could successfully be implemented for the existing green buildings in Sri Lanka.

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