An Assessment for the Use of Green Building Information Modelling for Sustainable and Green Buildings – Sri Lankan Perspective

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Abstract

The purpose of this research was to assess the applicability of integrating Building Information Modelling for sustainable and green buildings in Sri Lankan context. A comprehensive literature survey was conducted first to review the existing knowledge on BIM integration to green buildings, Green BIM techniques used and data requirements for the use of Green BIM. Subsequently, a single case study was carried out to practically apply the Green BIM technology. The selection of the case was based upon the availability of data required to use BIM integrated sustainable techniques. Thus, the data availability was analyzed first through a questionnaire survey including the data identified from literature. Based on the findings of questionnaire survey, an existing green building was selected for the case study. A framework was developed including the steps to be followed for the use of Green BIM for selected green building. The research findings revealed that, though BIM was not well established technology in Sri Lankan construction industry, there is a potential for the use of Green BIM in existing green buildings, if the required data are adequately and accurately available.

Keywords
Building Information Modeling, Green buildings, Sri Lanka.

1. Introduction

Increasingly, the need of green technology has come to the forefront in both developed and developing countries. (Bhattarai et al. 2013). Because of the higher environmental performance, green building construction has recently become a new trend in Sri Lanka as well (Waidyasekara and Fernanado 2013). Meanwhile, as a response for the massive energy consumption, number of subsequent technologies were evolved in the field of construction, which facilitate the achievement of sustainable outcomes.

In light of this, Green BIM as one of such modern technologies, has extensively been discussed in the field of research to be integrated with sustainable outcomes of buildings. Green BIM is considered as the use of BIM tools, to enhance the building performance and to achieve the sustainability objectives of a project (Krygiel and Nies 2008). Green BIM has significantly been appreciated in construction industry and thus, building owners have focused to integrate BIM with sustainable design strategies (Wong and Fan 2013). Green BIM offers various comprehensive building performance analysis in terms of energy, water, lighting, sustainable materials and life cycle cost analysis, which are important to evaluate the overall energy performance of buildings that leads to reduce the energy consumption (Wong and Zhou 2015).

However, when considering the Sri Lankan context, since BIM is not yet established, the need of using Green BIM technology is still unknown. Thus, this research was focused to assess the potential of Green BIM implementation for the existing green buildings in Sri Lanka. The scope of research was limited for the existing green buildings due to the practical barriers of conducting Green BIM for green building projects during design and construction phases.

2. Literature Review

2.1 Green BIM Technology

Green BIM technology is defined as a method of using BIM based sustainability tools, to achieve green objectives and improve sustainable outcomes of a green building development (Wong and Zhou 2015). Further, Green BIM has been considered as a technique which uses BIM with sustainable strategies for an effective decision making, which helps to enhance the building performance (Sollar et al. 2016). As defined by Wu and Issa (2015), Green BIM is a model-based development of generating and managing coordinated and consistent building data over the lifecycle, which helps to accomplish the desired sustainability goals. The application of Green BIM has provided countless benefits over the entire building life cycle including design, construction, operation, maintenance and demolition stages. Moreover, Green BIM technology allows designers, to produce high performance buildings through digital visualization by changing the traditional design practices (Wong and Fan 2013). As recognized by Bonenberg and Wei (2015), Green BIM has been incorporated with sustainable design methods which are used to examine the impacts of green buildings, with all necessary aspects including lighting, energy efficiency, sustainability of materials and other building performance parameters.

2.2 Green BIM Techniques

BIM software/tools are typically involved in designing the basic BIM model of the building. The developed model is then exported into BIM simulation tools to perform the Green BIM techniques (Biswas et al. 2008). The Green BIM techniques includes energy/thermal analysis, heating, ventilation and air conditioning analysis (HVAC), lighting/shading analysis, acoustic and value/cost analysis (Motawa and Carter 2013). The techniques available in Green BIM technology are presented in Table 01, as identified from the prevailing the literature. Features were not separately identified for some techniques in below table including value and cost analysis, acoustic analysis, water harvesting, space simulation and system simulation.

Table 1: Green BIM Techniques and Features

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 • Shading Design Analysis • Lighting Design Analysis • LEED Daylight credit 8.1 • Radiance analysis	• Calculations of solar energy absorption • 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: Adopted from Azhar et al. 2011)

2.3 Data Required for Green BIM

Bu et al. (2015) has mentioned typical inputs required for Green BIM as building type, system types (HVAC), construction materials, project location (weather files) and room type (zone management). Moreover, the input data including material properties, weather data, internal loads, operating strategy and schedules, HVAC systems and components and simulation specific parameters should be incorporated into Green BIM simulation tools (Wang et al. 2015). Input data such as material types and properties should be added as additional information required depending on the user's needs. Further, the data including the duration of simulation, site location, utility rates, report types and layer constructions should be included (Kim et al. 2016). The input data gathered from the literature that are required for Green BIM are included in table 02. These data were categorized basically as geometry data and simulation data for the model creation and simulation respectively.

Table2: Input Data Requirements

Geometry Data	**Simulation Data**
Floor Plan details	Number of occupants
Doors and Windows details	Number of days of occupancy per month
Specification Details (Azhar et al. 2010)	Number of hours of a working day
Elevation Details	HVAC system types, efficiencies and operating schedules

Roof Plan details	Hot water system types, efficiencies and operating schedules
Sectional Drawings	Lighting types, efficiencies and operating schedules
Foundation Details	Utility rates, Sound sources
Beams and Columns Details	Types of fixtures, Types of equipment
	Fixture count, Number of equipment
	Indoor temperatures, Number of occupants
	Types of materials
	Volume of materials
	Cost of capital of the building
	Costs of operation & maintenance & NPV indicators

Adopted from: (Source: Li et al.2012, Kim et al.2016, Azhar et al.2010, Wang et al. 2015, Bu et al. 2015, Wong and Fan 2013, Solla et al. 2015, Wu and Issa 2015)

3. Research Method

A comprehensive literature review was conducted first to identify the data required for the Green BIM. Subsequently, a questionnaire was developed including the data gathered from the literature. The questions formed in the questionnaire was to mention the available data and non-available data from the given data list which is identified from literature. Questionnaire survey was conducted focusing the existing green buildings which have been accredited LEED rating system. The sample for the questionnaire survey was selected using convenience sampling method. Mainly, out of 40 respondents, 33 answered questionnaires were received. The survey was conducted on existing green buildings certified under the categories of LEED certification including new construction and renovation, building core and shell development, design of commercial interiors and operation and maintenance of existing buildings. The findings of the questionnaire survey revealed the available and non-available data in each green building. Accordingly, the level of data availability was established with percentages for each case separately.

Finally, a single case study was conducted which involved the practical implementation of Green BIM technology for a selected green building. Accordingly, case study was carried out for the case with the highest data availability, among the surveyed green buildings. The highest data availability was selected as it presents the maximum number of available data and facilitates the implementation of Green BIM. The reason to analyse the data availability was, as the use of Green BIM is mainly depended on the availability of required Green BIM data. In the case study, two main steps were included as model creation and simulation. The model creation was carried out using the Autodesk Revit 2017 BIM designing software and simulation was done using web based Autodesk Green Building Studio. Only the energy simulation was performed for the selected case using the software.

4. Analysis of the Data Availability

Available data were separately marked under each respondent to identify the total data availability with the percentages. The available data and non-available data were identified in the analysis, in order to recognize the data maintainability. A summary of analysis is shown in table 02. Table shows the average total data availability of all respondents (green buildings) under each LEED rating category including new constructions and renovations, building core and shell development, design of commercial interiors and operation and maintenance of existing buildings. The average total data availability of all respondents (green buildings certified) under each LEED rating category is shown with percentages. The percentage values of data availability in each respondent are separately shown only in the operation & maintenance rating system as it showed the green building with highest data availability (respondent 03). There were seven green buildings certified under this rating system. Among all 33 respondents R03 was resulted with highest data availability which was certified under the rating of operation and maintenance of existing buildings.

According to the analysis, data availability of green buildings which have been certified under the new construction and renovation rating system is higher than the other rating systems as shown by the percentages. Data availability of buildings which are certified for operation and maintenance of existing buildings is less than the new constructions except for the respondent 03. Average total data availability of buildings certified under building core and shell development and design of commercial interiors, is lower than the buildings certified under both new constructions and renovations and operation and maintenance of existing buildings. However, according to the resulted percentages of available data, it could be identified that there are acceptable amounts of data which supports to implement the Green BIM. Although the results demonstrate, that data availability is high in green buildings which are certified for new constructions and renovations, the highest percentage of data availability could be recognized in respondent 03 under the rating system of operation and maintenance of existing buildings. It is indicated by red colour and that respondent (R03) has been certified for LEED platinum.

Table 3: Analysis of Data Availability

Data identified from Literature	**New Construction & Renovation**	**Building Core & Shell Development**	**Design of Commercial Interiors**	**Operation & Maintenance of Existing Buildings**						
				Industrial						
				R1	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**
Total availability of the data	88.52%	63%	65%	53%	50%	92%	80%	61%	65%	73%

According to the above analysis and results, it could be mentioned that, the required Green BIM data are available for an acceptable level (more than 50%). Thus, as the next step, a framework was developed to practically use the Green BIM. This framework was developed so that the data availability can be further analyzed in the practical context. The reason for that was, the accuracy of data is also a significant factor to implement Green BIM in existing buildings since buildings have been constructed years ago. This framework was applied to use Green BIM for the case study green building which was resulted with highest data availability in the survey.

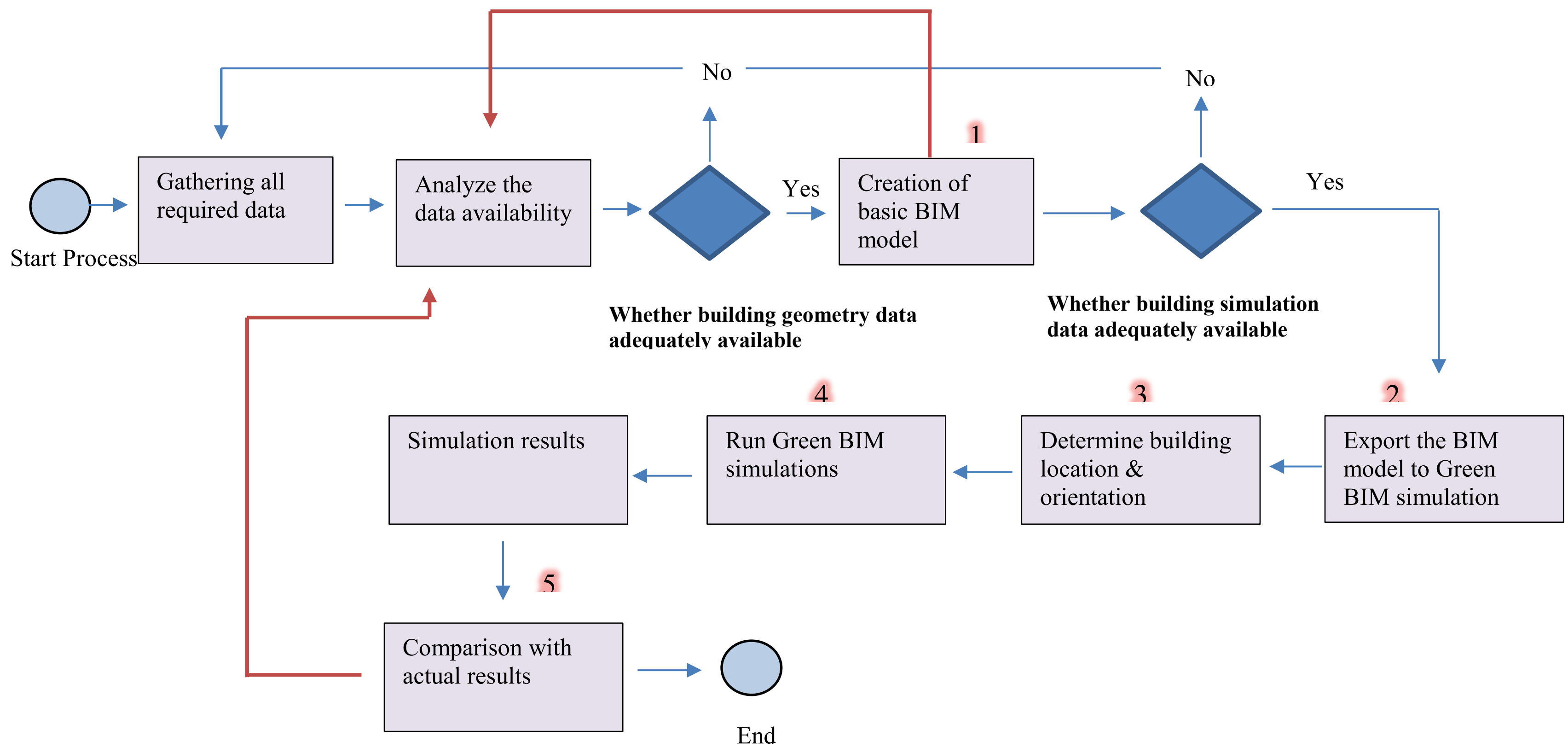

Figure 01: Framework of Green BIM Implementation

According to the framework, the required data are gathered first and secondly, the data availability is analyzed through the creation of building model in BIM and running Green BIM techniques using the model. The availability of building geometry data is analyzed by the process of creating the basic BIM model of the building. The availability of building simulation data is also analyzed while conducting the simulations by exporting the BIM model to a Green BIM simulation software and comparing the analysis results with actual results of the building. The comparison was limited to few of available actual results, since all the analysis results coming from the software, were not actually available. Such comparison was focused to analyze the availability of simulation data up to a certain level, for further clarification of data availability. Within these two processes, any deviations of available data would be recognized. These two steps are reconnected to the start as shown by red highlighted arrows. For simulations, the location and orientation of the building should be specified using the map given in the simulation software, after exporting the BIM model and before running the simulations. It is important to ensure that the directions of solar path over the building is corrected and weather data are properly specified, which directly affect to the simulation results such as energy analysis and day lighting analysis.

4.1 Application of Green BIM Techniques in the Case Study

After the development of framework, the case study was carried out following the steps formed in framework, with the aim of identifying the potential of Green BIM technology. Case study was done for respondent 03 which had the highest percentage for overall data availability. R03 was resulted in 92% of data availability and it was certified for LEED platinum under the rating system of operation and maintenance of existing buildings. In the case study, the selected green building was first subjected to the creation of its building model in BIM using Autodesk Revit software and subsequently, the energy analysis was conducted for the created building model, using the Autodesk Green Building Studio, which is a popular BIM based energy simulation software. The steps followed for the case study are discussed in this section.

Step 01 – Creation of the Building Model in BIM

Using Autodesk Revit BIM software, the BIM model of the selected case was created first as shown in the figure 02. In the process of creating the model, it was identified that there was a difference between CAD drawing and the paper drawing of the building. There were considerable changes in the building model elements which are difficult to correct and thus the model was uncompleted. This was basically occurred due to the error dimensions of the AutoCAD drawing which included error roof dimensions, error wall dimensions and spaces. Thus, it was clear that, though data were readily available, accuracy and the reliability are uncertain in this data. Hence, depending on mere the availability of data, accuracy cannot be proved and thus the potential to implement Green BIM is also uncertain. Hence, identifying the errors, model was recreated according to the as- built paper drawing.

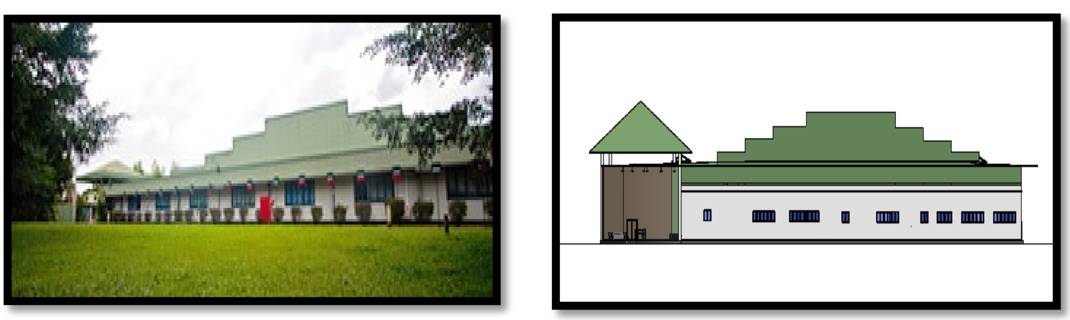

Figure 02: Actual Building and Created BIM Model

Step 02 – Exporting Model to the Simulation Software

After creating the model, it was exported to the Autodesk Green Building Studio from Revit, which is a BIM based simulation software. The model was exported through the gbxml data transferring format as the interoperability standard between Revit and GBS. After exporting the model to the simulation software, basic parameters were specified including building type, location, project phase, building envelope, ground plane and export category which are important for simulation.

Step 03 – Determination of the Geographical Location

As the third step, location data were included to the software for the energy simulations. In this step, different types of contextual information were included to simulate the energy analysis, such as geographic location, site location and related information including weather data for a typical year. Once the location data included, information of the building location including latitude and longitude, altitude, city and state and time zone were obtained. The importance of location selection is to set the related climatic conditions and other related weather data, which affect to the building energy performance. After building location is selected, simulation data were entered to the GBS software which were identified previously. Simulation data included HVAC system types and efficiencies, building occupancy, lighting types and efficiencies and indoor temperatures.

Step 04 – Running Energy Simulations

Once the required simulation data were entered, the gbxml file of the building model, which transfer the building data to GBS was uploaded to the GBS software to run the energy simulations. The resulted energy simulation information are discussed in this section.

Table 4: Energy Simulation Results

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/m^2/Year
Electric	2,542,324 kWh
Fuel	359,124MJ/kg
Annual Peak Demand	10,800 KVA

Following energy end use charts were further resulted from GBS relating to the building energy performance.

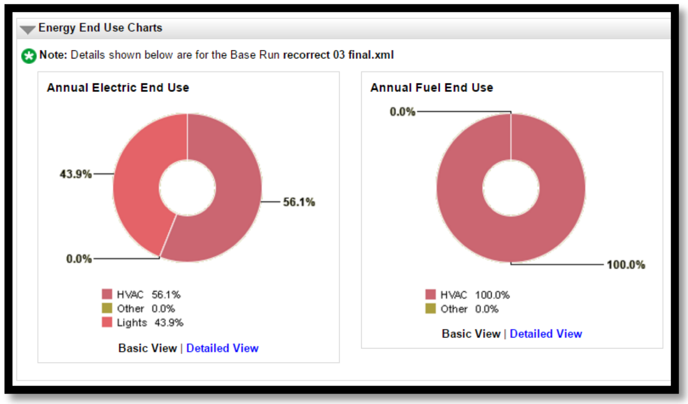

Figure 03: Energy End Use Charts

Step 05 - Comparison with the Actual Results

Simulation results were then compared with the available actual results of the building. The difference of the values was calculated as in table 04.

Table 5: Comparison with Actual Results

	Simulated Value	**Actual Value**	**Difference**
Annual energy cost	Rs. 1,740,000.00	Rs. 1,650,000.00	-5.45%
Electric Consumption	2,542,324 kWh	2,555,150 Kwh (Annual consumption)	0.5%
Fuel Consumption	359,124 MJ/kg	351,123.75 MJ/kg (Annual consumption)	-2.28%
Annual Peak Demand	10,800KVA	9600KVA	-12.5%

As presented in the table, there are slight differences between the simulated value and actual value. The reasons for the differences basically depends on the simulating method used in the software. It considers weather condition and data, geographical location of the building and building orientation in order to determine the impact of solar radiation to the building. However, this comparison was limited for several parameters as all simulation results given from Green BIM software cannot be manually calculated or taken. Due to the ability of Green BIM software to provide comprehensive energy simulation and performance results, Green BIM simulation results are more reliable and important for energy management of buildings. Comprehensive Green BIM simulations can be used to evaluate the energy performance of buildings. As this study focused to assess the ability of using Green BIM, it can be concluded that, it is possible to generate Green BIM simulation results to enhance the energy performance of existing buildings. To facilitate the research aim, this study focused on a single case study and come up with a conclusion that since the data are available in existing green buildings, there is a potential to use Green BIM technology for the existing green buildings in Sri Lanka, even though BIM has not been implemented during the early stages.

5. Conclusions

According to the aforementioned findings, though the data availability appears to be numerically satisfactory, there could be issues due to the lack of accuracy and reliability of data, which are hidden and invisible until practical implementation is initiated. Hence, even though the data are available apparently, a proper examination should be carried out in order to realize the accuracy and actual availability of data up to the accepted level. However, as this study was able to conduct energy analysis of Green BIM, it can be concluded that, there is a possibility of using Green BIM techniques for existing green buildings in Sri Lanka. However, further studies need to be undertaken to identify and evaluate this applicability when the level of data availability is different in green buildings.

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