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GREEN BIM FOR EXISTING BUILDINGS

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Abstract

There was a flourishing interest and cognizance on green building constructions in past few decades due to considerable negative impacts for the environment from traditional construction processes. In light of this, number of modern technologies have been invented to enhance the performances of sustainable and green strategies. Green Building Information Modeling (BIM) is one of such modern advanced technologies where BIM integrates to sustainable strategies to improve building performances. Though, the technological capabilities of Green BIM are evident, use of Green BIM has been limited only for design and construction phases of buildings. Professionals in construction industry are still struggling in implementing Green BIM for existing buildings, due to the difficulties of collecting information during operation and maintenance phases that are required for the use of Green BIM. As different Green BIM tool needs different data requirements, building owners and facility managers are reluctant in using Green BIM for existing buildings. Hence, the data requirements have been a considerable issue that should be addressed. Further, the way of utilizing Green BIM for existing buildings is also questionable to achieve sustainability. Besides, the actual barriers and hurdles of Green BIM for existing buildings are vague and different studies have highlighted subjective opinions from different views and insights. Hence, this study aimed to review the existing knowledge on aforementioned area and to identify the gaps in prevailing studies for the implementation of Green BIM in existing buildings. Findings of literature review revealed different data requirements for various Green BIM tools, techniques and how it can be used for sustainable strategies. The findings further highlighted the existing gaps where more studies need to be done in the same area.

Keywords: *Building Information Modelling, Green BIM, Building performance, Sri Lanka.*

1. Introduction

There is an increasing awareness to reduce the escalating demand of energy in buildings, while ensuring the effective utilization of environmental resources in constructions (Autodesk, 2005). In this regard, construction industry professionals have been exposed to number of challenges in assuring environmentally sound construction practices (Hong, Chou & Bong, 2000). However, sustainability as a contemporary conception has widely being used in construction industry as a solution for building energy (Wong & Fan, 2013). Though the concept of sustainability was attended as a tremendous approach to reduce the building energy, still the construction industry is the main contributor of carbon emissions in buildings (Oduyemi & Okoroh, 2016). As revealed in statistical findings, the quantitative value of use of energy is still recorded a considerable amount in constructions even though sustainable strategies are used during construction processes (Wong & Zhou, 2015).

Addressing the aforementioned issue, Building Information Modelling (BIM), resulted modern technological approaches, which could be used to analyse the building performances to cope with sustainability in construction industry (Azhar, 2011). Green BIM was one of such innovative technologies became through BIM by integrating BIM and green building strategies. Green BIM is acknowledged as the application of BIM based simulation tools which help to evaluate building performances comprehensively (McGraw-Hill Construction, 2010). From methodological point of view, Green BIM is defined as a model based process which comes through the generation as well as the management of building related data during its lifecycle to improve the energy efficiency in buildings while attaining sustainable goals (Wu & Issa, 2015).

As proved in the field of research, BIM has increasingly been used for new constructions (Gerber & Rice, 2010). As asserted by Volk et al., (2014), use of BIM for new constructions is high while existing buildings are still not maintained using BIM. Gursel, Sariyildiz, Akin and Stouffs (2009) have further mentioned that, efforts to model existing buildings in BIM environment is considerably less than new constructions. Indicating the same, Wong and Fan (2013) stated that there is a shortage in using BIM for existing buildings. Gu and London (2010) also mentioned that, even though the use of BIM has been expanded, its practical potential should be assessed for existing buildings. Volk et al., (2014) revealed that, there are challenges for the implementation of BIM technologies for existing buildings. Further to, Volk et al (2014), these challenges prevail due to the issue of incomplete and missing building information of existing buildings that are required for BIM. Moreover, as indicated by Wong and Zhou (2015), as the requirement of different data for different BIM based tools and techniques is unknown, there is an issue in the application of BIM technologies for existing buildings. Further, as stated by McArthura (2015), there are various risks and challenges in finding required data to implement BIM technologies for existing buildings.

According to the aforementioned information, use of BIM technologies for existing buildings is less and Green BIM as such technology has also been discussed with same issues when applying for existing buildings. Importantly, a correct method or a way of identifying the challenges associated with data acquisition and management that are required to implement Green BIM for existing buildings is also uncertain. Hence, this study focused to review the existing knowledge to identify what are the data requirements for the use of Green BIM for existing buildings and how to identify the challenges of getting and managing data requirements for Green BIM. Considering the literature findings, this study developed a conceptual framework to identify such challenges for the use of Green BIM for existing buildings addressing the issues discussed above.

2. Findings of the Literature Review

Green BIM technology basically involves two steps including model crea- tion and simulation (Azhar et al, 2010). These two steps are separately conducted in this technology, using BIM designing software and BIM simulation software including variety of input data for each software. BIM simulation software integrates different types of Green BIM techniques or sustainability analysis including energy analysis, thermal analysis, solar analysis, lighting and shading analysis, acoustic analysis and value and cost analysis. To conduct these analysis, different input data should be entered in to BIM software. Figure 01 shows typical input data requirements exchanged between BIM design software and simulation software in BIM-based sus- tainability analyses as proposed by Bahar, Pere, Landrieu and Nicolle (2013)

Figure 01. BIM based sustainability analysis

While different studies have proposed different data requirements, this study identified input data requirements separately under Green BIM techniques and tools.

2.1. INPUT DATA REQUIREMENTS FOR GREEN BIM TECHNIQUES

Green BIM techniques are identified as green strategies or types of building performance analysis that are available in Green BIM technology. These techniques basically involved in building performance analysis or simulations in different criterion. Identification of correct input data was an issue highlighted in the literature in relation to the use of Green BIM for existing buildings. Thus, this study investigated various research papers considering the key words including BIM, Green BIM, and building performance analy- sis and simulation tools. As per the opinions and scientific knowledge identified from prevailing literature, Green BIM techniques require different input data to carry out Green BIM based building simulations. The input data iden- tified for Green BIM techniques in this study are summarized in table 01. It is important to note that different studies and authors have highlighted dif- ferent data requirements for each technique sometimes which are generally applicable for both BIM based and non-BIM based green strategies.

Table 1: Input data requirements for Green BIM techniques

Green BIM Techniques / Simulations / Analysis	**Input Data**
Acoustic Analysis	Building Geometry ✓ Volume of rooms ✓ Each face of the rooms ✓ Area of each face Sound Sources ✓ Position and power of the sound source ✓ Sound Intensity Level ✓ Power of the sound source ✓ Distance from the sound source Audience ✓ Position of the audience Finish materials of rooms Material Properties ✓ Sound absorption coefficient at series of octave band fre- quencies Absorption at various frequencies Time
Daylighting Analysis	✓ Building Geometry ✓ Information about interior spatial organization and zones ✓ Material properties ✓ Properties of shading surfaces
Thermal Analysis	✓ Building Geometry ✓ Information about interior spatial organization and zones ✓ Material properties ✓ Properties of shading surfaces
Value and Cost Analysis	✓ Operation and maintenance costs within an appropriate lev- el or elemental division of the project ✓ Specification of material in terms of the design brief and service life required ✓ Factors affecting component deterioration and failure ✓ Maintenance, preservation and operational cost variables ✓ Net present value indicators for the life cycle of assets
Energy Analysis	Element material constructions and associated thermal properties ✓ U-values or heat coefficients ✓ R-values or measure of thermal resistance HVAC and hot water system types and efficiencies Lighting types, density and efficiency Building occupancy Plug loads, such as appliances and electronic devices ✓ Power consumptions (w/kw) of appliances and devices ✓ Sensible heat gains ✓ Latent heat gains Internal heat gains from plug loads and occupancy Building natural infiltration rate (air leakage) Natural ventilation (eg: opening and closing of windows) Thermostat set point temperatures Operating schedules

3. Input Data Requirements for Green BIM Tools

BIM comprises a set of tools or software for structural, energy, costing, lighting, acoustic, airflow and other analyses which are integrated in design activities and simulations. Many of capabilities of these tools have been out- lined and realized its potential in the research literature (Middlebrooks, 2008). Green BIM tools can basically be divided into two categories as design tools and simulation tools. BIM design tools are used to model the basic design of buildings while simulation tools are used for building performance analyses (Rathnasiri, Jayasena & madushanka, 2017).

Table 02. Input data for Green BIM tools

Input Data	**Green BIM Tools**						
	Ecotect	**GBS**	**IES VE**	**Energy Plus**	**Eco-Designer**	**eQUEST**	**Design Builder**
Building Geometry	☐	☐	☐	☐	☐	☐	☐
Building orientation	☐	☐	☐	☐	☐	☐	☐
Weather data	☐	☐	☐	☐	☐	☐	☐
Building envelop	☐	☐	☐	☐	☐	☐	☐
HVAC type	☐	☐	☐	☐	☐	☐	☐
Building type/	☐	☐	☐	☐	☐	☐	☐
Glazing type	☐	☐	☐	☐	☐	☐	☐
Lighting power density	☐	☐	☐	☐	☐	☐	☐
Equipment power	☐	☐	☐	☐	x	☐	☐
density	☐	×	☐	☐	x	☐	☐
Occupancy Sch	☐	×	☐	☐	x	☐	☐
Lighting Schedule	☐	×	☐	☐	x	☐	☐
Equipment **Sche.**	☐	×	☐	☐	☐	☐	x
Fuel type	☐	×	☐	☐	☐	☐	☐
Operable windows	☐	×	☐	☐	☐	☐	☐
Operable window schedule	☐	×	☐	☐	☐	☐	x
System energy efficiency	☐	×	☐	☐	x	☐	x
Roof Reflectance	☐	×	☐	☐	☐	☐	☐
User-defined glazing **spec.**	☐	×	☐	☐	☐	☐	☐
construction properties							
MEP BIM Model	×	×	☐	x	x	x	×
Water efficient							
fixtures	×	×	☐	x	x	☐	×
HVAC Compo. Customizable occupancy schedule Customizable lighting schedule Customizable equipment **sche.** HVAC fan power Interior tempera- tures Utility Rates	× ☐ ☐ ☐ ☐ ☐ ☐	× × × × ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐ ☐ ☐	☐ x x x x x x	x ☐ ☐ ☐ ☐ ☐	× x x x x x x

After the identification of input data requirements that need to be entered for Green BIM tools and techniques, this study intended to identify the way of utilizing Green BIM for existing buildings. Often, the studies which were related to BIM and Green BIM have highlighted the use of Green BIM for design and construction phases of buildings. Kriegel and Nies (2008), have indicated the ways that BIM can aid in the aspects of sustainable design in- cluding,

- Building orientation (which can reduce the cost of the project),
- Building massing (to analyze building form and optimize the building envelope),
- Day lighting analysis,
- Water harvesting (reducing water needs in a building),
- Energy modelling (reducing energy needs and analyzing how renewable energy options can contribute to low energy costs),
- Sustainable materials (reducing material needs and using recycled materials) and
- Site and logistics management (to reduce waste and carbon footprints)

Azhar et al. (2009) developed a conceptual framework for BIM-based Sustainability Analysis as presented in Figure 02. The figure indicates project phases, sustainability analysis/Green BIM techniques and interactions of external entities such as customers or project partners. Though this framework presents the use of Green BIM techniques at project phases with project participants, a systematic guidance for Green BIM implementation and to avoid its challenges is not provided.

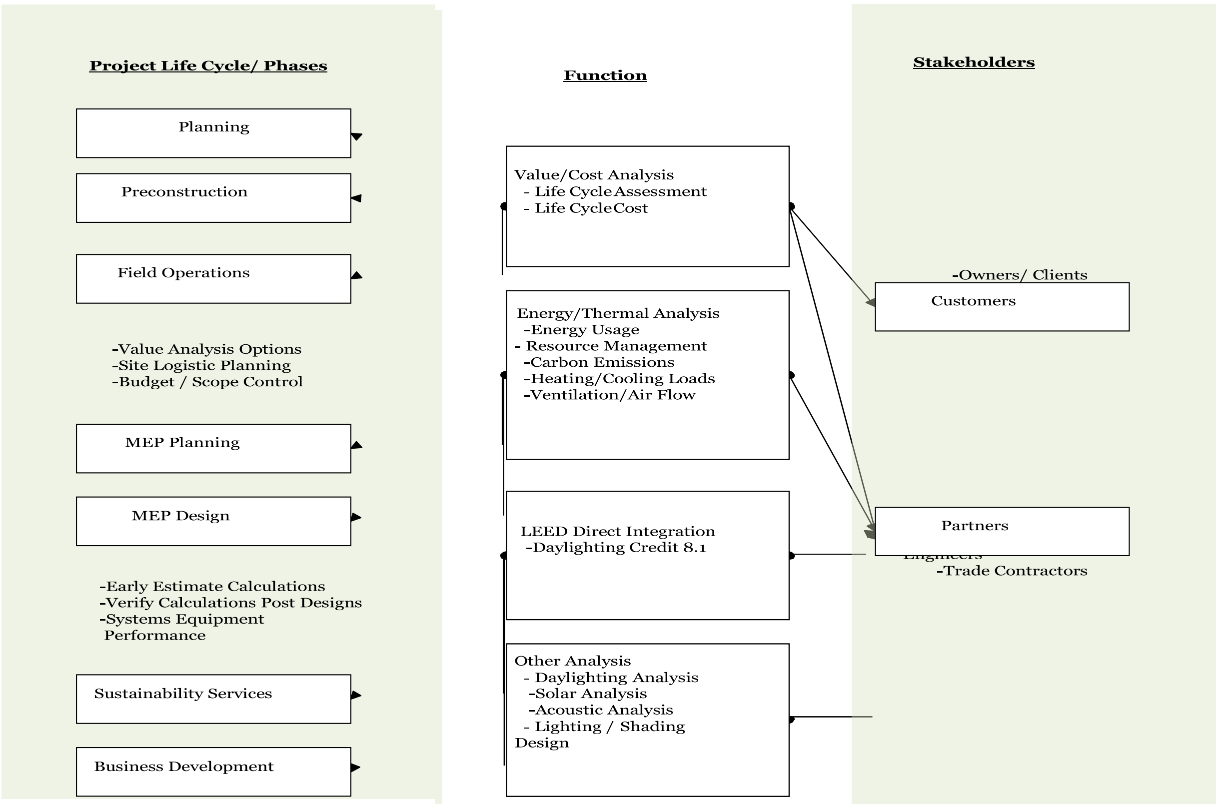

Figure 02. Conceptual Framework BIM based analysis

Similarly, Bahar et al (2013), have proposed a workflow for thermal analysis. This workflow presents the involvement of BIM only for thermal analysis in Green BIM. Azhar et al. (2009), have also developed a conceptual framework for BIM based sustainability analysis of a project. Further, Krygiel and Nies (2008), have conducted several case studies by implementing BIM for LEED and other green building projects. Biswas et al. (2013), have developed a tool incorporating BIM technology to the rating and certification of green buildings to evaluate the environmental consequences of design decisions. Barnes and Castro-Lacouture (2009), have suggested that 13 cred- its and 1 prerequisite in the LEED rating system can be directly acquired by using the Autodesk Revit.Gandhi and Jupp (2014), have examined the potential application of BIM for the Australian Green Star Building certification.

However, even though, several studies have been undertaken discussing the ways of integrating BIM for sustainability, a systematic way of applying Green BIM and identifying its challenges for existing buildings is still not reviewed. It is noteworthy that aforementioned studies have been basically proposed for the use of Green BIM during the design and construction stages. Thus, according to the literature, it is obvious that there is a need of more studies to investigate how Green BIM can be utilized for existing buildings. Further, Volk et al. (2013) mentioned that there are challenges in implementing BIM technologies for existing buildings. Khaddaj and Srour (2016), have also stated that there are challenges faced by modellers in handling the uncertainties of existing data for BIM based refurbishment methods. According to Li (2012), as design and construction phases are finished for a long period ago, availability of required BIM information for existing buildings is a significant issue. Wang and Cho (2015), have further stated that, as built data required for BIM implementation, are always not available in existing buildings. Liu et al (2015), has also described the main reason which hinders utilization of BIM technologies for operations and maintenance phase as unavailability of proper information to develop 3D as built models. Moreover, Liu et al (2015), has proved that existing 2D as built drawings are inefficient and inaccurate at the operation phase of buildings. In addition, as mentioned by Khaddaj and Srour (2016), developing a BIM model for existing buildings requires a significant effort of data collection. Accordingly, the aforementioned literature reveals that there are uncertainties and gaps in the field of research, in relation to data requirements for the application of Green BIM for existing buildings.

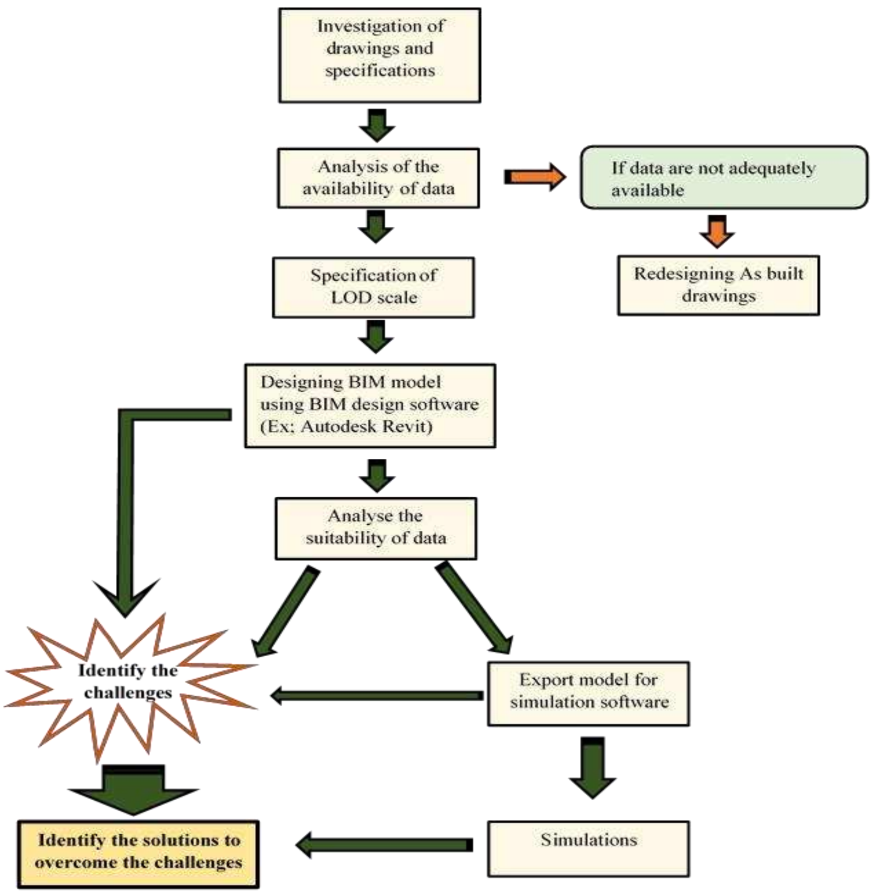

Figure 03. Conceptual Framework to identify the challenges

Though this literature mentioned that there are challenges and risks in acquiring and using BIM data from existing buildings for BIM technologies, the actual challenges and issues are still not unknown. Thus, it is needed to identify first, what are the actual challenges which occur in practical context in implementing BIM technologies (in this study, Green BIM technology) for existing buildings. Focusing on the existing literature and this research gap, this study intended to develop a conceptual framework to identify those challenges for the use of Green BIM technology for existing buildings. The developed framework is presented in figure 03. The application of Green BIM technology is basically involved in BIM model creation and simula- tions (Azhar et al. 2010), and thus, this framework has been developed identifying these two steps. The first step of the framework is to investigate the drawings and specifications of existing buildings to which Green BIM is going to be applied. This step is important as the literature reveals that data are not adequately available at operation phase of existing buildings. Hence, it is important to identify the available drawings and specifications of the existing building first. As the second step, an analysis is recommended to carry out for the availability of data by conducting a comparison with the input data identified from literature. At this step, it is needed to recognize the level of data available in the existing building and in case that the level of data availability is not sufficient to proceed, it is recommended to redesign as built drawings for the building. As the next step, Level of Detail (LOD) scaleneed to be specified to determine at which scale Green BIM can be applied. LOD specifies the applicable level to implement BIM technologies with the available data. After the specification of LOD scale, basic BIM model for the building can be designed with the available data. Autodesk Revit can be suggested as the most popular BIM designing software. This step is important to identify the practical challenges adhered with basic BIM model creation of the building and at the same time, it is needed to analyse the suitability of available data so that the challenges and issues of available data can be realized. It also helps to confirm the reliability of input data used for model creation. After the creation of BIM model, the next step is suggested to conduct Green BIM techniques or simulations and again it is important to identify the challenges during this step. Within the model creation and simulations, it is important to identify the challenges and finally these challenges can be analysed to identify possible solutions to overcome the challenges.

4. Conclusion

This study focused to identify what are the actual data requirements needed for Green BIM and to determine possibilities to develop a conceptual method to identify the challenges related to input data requirements of Green BIM and its implementation. Through a thorough literature review, this study come up with findings highlighting the data requirements needed for Green BIM tools, techniques and existing knowledge upon the use of Green BIM for existing buildings. Finally, considering the available literature, a conceptual framework was developed for the identification of challenges. This framework will be a guidance for further studies to determine actual challenges and how to overcome challenges for the effective use of Green BIM for existing buildings.

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