Integration of Building Information Modelling (BIM) with Green Façade Retrofit Design in Malaysia

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The current concerns for sustainability and limitations on land use, has accelerated the shift of construction actions to green retrofitting of existing buildings, rather than investing on new construction. However, achieving very high levels of efficiency in green retrofitting design projects requires application of the optimal combination of several strategies, considering energy savings, environmental impacts of the buildings, availability of the materials, construction time and cost, and indoor environment quality. Promising benefits of Building Information Modelling (BIM) in supporting design decision making for new sustainable construction, motivated research to facilitate using BIM in design decision making for green retrofit activities, as well. Especially, 4D BIM, 5D BIM and 6D BIM referring to time, cost and sustainability issues can be adopted to solve the challenges of green retrofit design in practice. This paper presents a review of several literature on the topic to identify the design variables of green retrofit in current practice and their interrelationships with building performance parameters, focusing on office building envelope in Malaysian tropical context. The findings are compared with the BIM functions, for developing a BIM-based design decision making framework to support green retrofit. Compared to the traditional methods, using the proposed BIM-based framework, will enable the decision makers to make more and better informed decisions in green retrofit design projects.

Keywords: green retrofit, sustainable building, BIM, design decision making, tropical.

Introduction

Green architecture has been one of the most significant issues in new construction industry in the world. Likewise in Malaysia, especially, following Malaysia's target to reduce carbon emission of 40% from 2005 level by 2020 as Prime Minister of Malaysia mentioned at COP15 in Denmark, December 2009 (Anon 2010). In this regard, the energy sector has mentioned "intensifying energy efficiency initiatives" as one of the most important strategies, focusing on efficient lighting, air-conditioning systems and establishing a comprehensive energy management. In Malaysia, Green Building Index (GBI) is one of the guidelines being adopted by the building industry. GBI has six major parts consisting of Energy Efficiency (EE), Indoor Environmental Quality (EQ), Sustainable Site Planning & Management (SM), Materials & Resources (MR), Water Efficiency (WE) and Innovation (IN).

The studies show that in the building sector, existing buildings consume most energy while the replacement rate of existing buildings by the new-build is only around 1.0–3.0% per year (Roberts 2008). Thus, rapid improvement of energy performance in existing buildings is necessary for a quick reduction in global energy use and environmental impacts of the building industry. Besides, the energy efficiency of the existing building is very important because it has a direct impact on global emissions of greenhouse gases (GHGs). Because the main source of GHG emissions from the buildings is consuming the fuels for heating, cooling, and generating the electricity used in the operation of buildings (Ma et al. 2012). Moreover, the research reveals that improving energy efficiency of buildings is the lowest-cost source of GHG emission reduction (Ma et al. 2012).

Building information modelling (BIM) and other advances in building science will no doubt influence the green retrofits of the future. However, the main preconditions of adopting BIM in green retrofit design is presenting a clear framework to guide the decision makers in using BIM for their green retrofit projects. In the light of these indicators, this paper presents a critical review of green retrofit measures, integrating with BIM functionalities in order to developing a BIM-based framework for green retrofit design. As a case of study in specific details such as climatic information and environmentally responsive design the tropical context of Malaysia is considered.

Green Facade Retrofit design for Existing Office Building

In terms of office buildings, many will benefit from green retrofits. There are long lists of inefficient all-glass curtain walls, initially promoted by the modernist movement, that are due to retrofit. Those buildings rely mostly on artificial ventilation, cooling and heating, and suffer from poor insulation, which make them totally inefficient. Recent studies show that green retrofit measures have been successful in increasing energy efficiency, tenants' satisfaction and economic return while cutting down greenhouse gas emissions in older buildings. In addition, retrofitting existing buildings would be more cost effective than destroying them and rebuilding new ones. Although some demolition and replacement actions may remain a necessity to meet contemporary needs, there are significant opportunities to reduce energy consumption and carbon emission by green retrofitting them (Al-Kodmany 2014).

Green strategies aim to use the renewable energy sources to reduce energy consumption in buildings and enhance interior environmental quality (Stevanović 2013). In addition, lower energy use correlates lower green-house gas emissions (Carbon Dioxide, Methane and Nitrous Oxide) (Sozer 2010). This research will focus on the retrofit actions for the building facade which consists of four main components: external wall, insulation materials, openings and shading devices.

The importance of green retrofit design has received much attention in recent years. Xing et al. (2011), Ma et al. (2012) and Chidiac et al. (2011) have discussed in their research that green retrofit strategies would slow down the global energy consumption and greenhouse gas emissions at almost low cost. But the main question is how to select the best possible retrofit measure which is the most applicable, energy efficient and cost effective solution among the all options (Diakaki et al. 2008) (Asadi et al. 2012b). Furthermore, making this decision is also affected by climate, occupancy, heating and cooling systems, envelope properties and building geometry (Asadi et al. 2012b). Also, indoor environmental quality and considering the occupant needs and requirements are as important as energy efficiency in a green retrofit project and it should be done cost-effectively as Asadi et al. (2012b) and Grete Hestnes & Ulrik Kofoed (2002) have shown in their research.

According to Lim et al. (2015) and other research done by Ma et al. (2012); Welle et al. (2011a); Asadi et al. (2012b); Volk et al. (2014) who have conducted a summary of sustainable building design decision making criteria, the most significant rules of thumb in designing a more sustainable facade are: 1. Use of solar shading and advanced daylighting; 2. Renewable energy systems; 3. Improved thermal facade (improved insulation and windows); 4. Natural ventilation systems (as opposed to forced-air heating and cooling); and 5. Reflective exterior surfaces (See Table 1).

Table 1: Main design variables and objectives in façade retrofit design

Green Design Variables		**Building Performance Parameters**	**References**
External	Window type		(Ma et al. 2012)

Design Variables	Window size		(Volk et al. 2014)
	Window placement		(Chidiac et al. 2011a)
	Glazing type		(Xing et al. 2011)
	Glazing area		(Asadi et al. 2012b)
	Wall type		(Chidiac et al. 2011b)
	Wall area		(Diakaki et al. 2008)
	Insulation type and level	Energy Performance	(Attia et al. 2013)
	External Shading devices type		(Azari 2014) (Mahlia et al. 2011)
	External shading devices geometry	Visual Comfort	(Shahsavari et al. 2015)
Internal Design Variables	Window to wall ratio (WWR)	Thermal Comfort	(Flourentzou & Roulet 2002)
	Window spacing		(Ardente et al. 2011)
	Window dimensions	Life cycle cost	(Roberts 2008)
	Window transmittance		(Coulter et al. 2012)
	Window to floor ratio (WFR)	GHG emissions	(Azli et al. 2015)
	Internal shading devices type		(Lim et al. 2015) (Al-Kodmany 2014)
	Space dimensions	Humidity	(Grete Hestnes & Ulrik Kofoed 2002)
	Floor reflectivity		
	Floor print shape	Inter air quality	(Evins 2013)
	Wall reflectivity		(Asadi et al. 2012a)
	Ceiling reflectivity		

Developing BIM-Based Green Retrofit Design Framework

Many researchers has discussed the benefits of implementing BIM in the AEC industry such as accurate data environment, effective design process, accurate project cost estimation, time saving, and other benefits (Azhar et al. 2008)(Gu & London 2010)(Sanguinetti et al. 2012)(Barlish & Sullivan 2012)(Bryde et al. 2013). Increasingly growing of Building Information Modelling (BIM) knowledge and technology, has made it easier to digitally illustrate complex building modelling with both precise geometry and accurate information in order to support decision making process in various project stages.

Using BIM in retrofitting existing buildings in Malaysia and other developing countries is facing huge challenges such as lack of efficient software, lack of experts, lack of financial justifications, lack of awareness of BIM benefits, lack of support mechanisms to enhance data interoperability between the BIM models and the analytical tools and lack of an effective and clear method (Enegbuma, W. I., Dodo, Y. A. and Ali 2014). Therefore, more efforts are needed to overcome the issues and barriers towards the implementation of BIM in Malaysia's AEC industry.

However, a recent survey conducted by Azli et al. (2015) in Malaysian revealed that nearly 20% to 32% of the respondents believed that BIM is a useful tool to analyse building performance, such as energy analysis, building structure, cost estimation, and quantity take off during design and pre construction phase. Moreover, the results of this survey show that the most common BIM functionalities used in the architectural firms in Malaysia, are scheduling, project management and sustainability analysis.

In the process of green retrofit design, detailed data on the location of the project, materials and their associated information such as warranties, manufacturers, cost, installed components and equipment, installation dates and type, water use, service zones and internal loads is needed (Volk et al. 2014). To highlight BIM potentials in green retrofit design, Figure 1 shows a number of green retrofit design requirements which can be met by using various BIM functionalities.

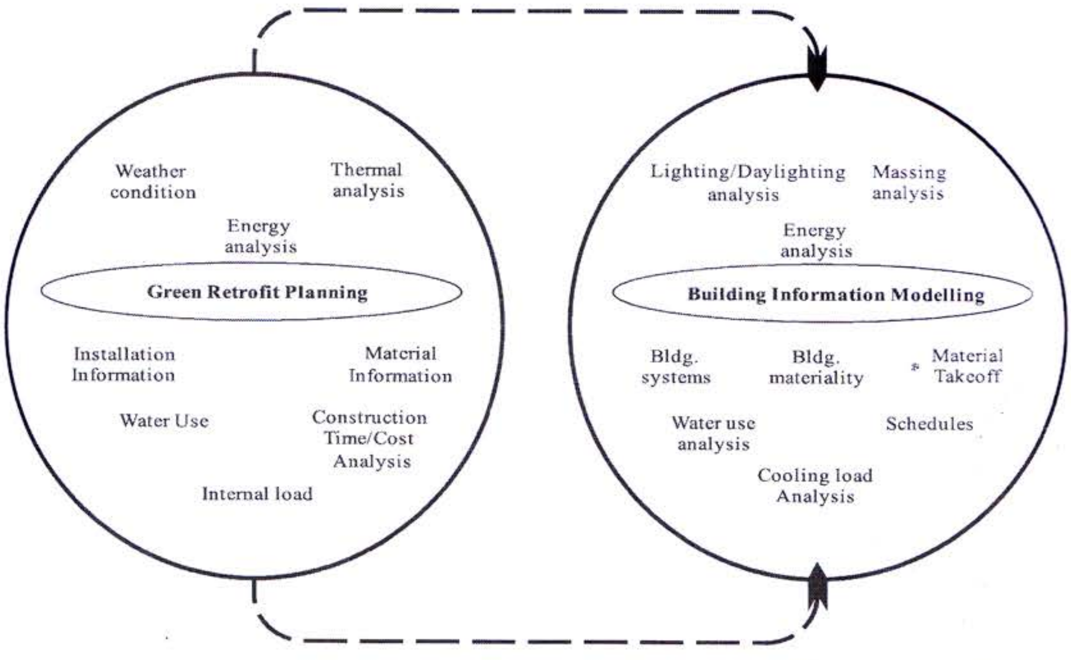

Figure 01: Interrelationship between Green Retrofit Design and BIM

During a building LC, numerous responsible stakeholders and subcontractors are involved and often withdraw their specialized information e.g. on components' installation. Thus, there is a need for a simplified green retrofit design framework to provide instant comparative performance evaluations and to improve decision making by interdisciplinary design teams (Gultekin et al. 2015). Furthermore, selecting the best possible green retrofit measures depends on the results of various kinds of analysis, like energy analysis, cost analysis, comfort analysis, etc.

From the recent development on BIM-based sustainability or GreenBIM (Lim et al. 2015), it indicates great potentials of extracting data from BIM for green retrofit design. Hence, a clear framework is needed to understand the extent and benefits of applying BIM in selecting the best green retrofit measures. A BIM-based framework can give the decision makers a well-defined workflow to support the DM process using BIM based on regional sustainable building certification systems. Figure 2 presents the proposed conceptual framework of integrating BIM with green retrofit design.

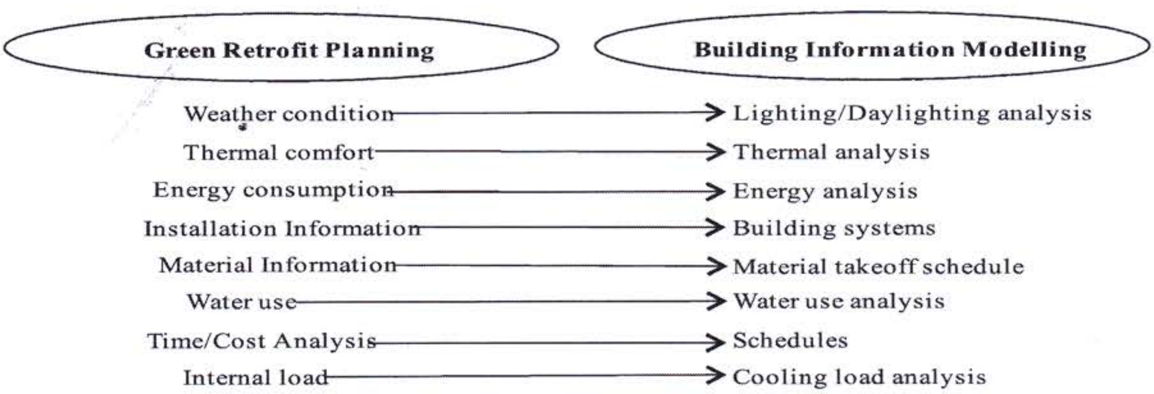

Figure 2: BIM-based Green Retrofit Design Support Framework

Conclusion

As Building Information Model (BIM) is a tool to manage accurate building information over the whole life cycle (LC), it is adequate to support green retrofit design. When it comes to choosing energy retrofit measures to improve energy performance of the buildings, BIM can play its role to facilitate making decisions of choosing precise optimum retrofit strategies and technologies. BIM combines information from multiple disciplines allowing for faster and better information exchange that streamlines the retrofit design process and has the potential to reduce or eliminate coordination errors. Indeed, BIM are files (often but not always in proprietary formats and containing proprietary data) which can be exchanged or networked to support decision-making about a place.

The approach to this research reveals great contribution to the professionals to understand BIM functions in green retrofitting practice. Therefore, this paper can contribute to overcome some of the limitations of adopting BIM in green retrofitting, with developing a BIM-based decision making framework and facilitate decision making process in green retrofitting of office buildings in Malaysia. However, the use of BIM-based energy performance simulation in the design phase of a retrofit projects is still controversial. In terms of automation in analysing the building performance and selecting the best possible design option, it is important to have an automatic system of optimisation for selecting the optimal green retrofit measure which needs further research.

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References

Al-Kodmany, K., 2014. Green Retrofitting Skyscrapers: A Review. *Buildings*, 4(4), pp.683–710. Available at: http://www.mdpi.com/2075-5309/4/4/683/.

Anon, https://sites.google.com/site/reeetech/energy-efficient-home/green-building-design.

Ardente, F. et al., 2011. Energy and environmental benefits in public buildings as a result of retrofit actions. *Renewable and Sustainable Energy Reviews*, 15(1), pp.460–470. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1364032110003096 [Accessed November 10, 2014].

Asadi, E. et al., 2012a. A multi-objective optimization model for building retrofit strategies using TRNSYS simulations, GenOpt and MATLAB. *Building and Environment*, 56, pp.370–378. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0360132312001217 [Accessed March 7, 2015].

Asadi, E. et al., 2012b. Multi-objective optimization for building retrofit strategies: A model and an application. *Energy and Buildings*, 44, pp.81–87. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378778811004609 [Accessed September 8, 2014].

Attia, S. et al., 2013. Assessing gaps and needs for integrating building performance optimization tools in net zero energy buildings design. *Energy and Buildings*, 60, pp.110–124. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378778813000339 [Accessed July 9, 2014].

Azari, R., 2014. Integrated energy and environmental life cycle assessment of office building envelopes. *Energy and Buildings*, 82, pp.156–162. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378778814005234 [Accessed November 26, 2014].

Azli, N.F.M.N., Lim, Y. & Shahsavari, F., 2015. Survey on BIM Application for Sustainable Building Design and Analysis in Malaysia Architectural Practice Survey on BIM Application for Sustainable Building Design and Analysis in Malaysia Architectural Practice. *Journal of Sustainable Building Technology & Urban Development*, (1).

Chidiac, S.E. et al., 2011a. A screening methodology for implementing cost effective energy retrofit measures in Canadian office buildings. *Energy and Buildings*, 43(2-3), pp.614–620. Available at: http://linkinghub.elsevier.com/retrieve/pii/S037877881000399 [Accessed November 2, 2014].

Chidiac, S.E. et al., 2011b. Effectiveness of single and multiple energy retrofit measures on th energy consumption of office buildings. *Energy*, 36(8), pp.5037–5052. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0360544211003756 [Accessed December 2, 2014].

Coulter, T.L.S. et al., 2012. Construction Research Congress 2012 © ASCE 2012 737. , pp.737–746.

Diakaki, C., Grigoroudis, E. & Kolokotsa, D., 2008. Towards a multi-objective optimization approach for improving energy efficiency in buildings. *Energy and Buildings*, 40(9), pp.1747–1754. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378778808000649 [Accessed January 12, 2015].

Enegbuma, W. I., Dodo, Y. A. and Ali, K.N.., 2014. Building Information Modelling Penetration Factors in Malaysia. *International Journal of Advances in Applied Sciences (IJAAS)*, 3(1), pp.47–56.

Evins, R., 2013. A review of computational optimisation methods applied to sustainable building design. *Renewable and Sustainable Energy Reviews*, 22, pp.230–245. Available at: http://dx.doi.org/10.1016/j.rser.2013.02.004.

Flourentzou, F. & Roulet, C., 2002. Elaboration of retro ® t scenarios. , 34, pp.185–192.

Grete Hestnes, A. & Ulrik Kofoed, N., 2002. Effective retrofitting scenarios for energy efficiency and comfort: results of the design and evaluation activities within the OFFICE project. *Building and Environment*, 37, pp.569–574.

Gultekin, P. et al., 2015. A RELATIVE ENERGY PREDICTION METHODOLOGY TO SUPPORT. In *5th International/11th Construction Specialty Conference*. Vancouver, pp. 1–10.

Lim, Y.-W. et al., 2015. Developing a BIM-based Process-driven Decision-making Framework for Sustainable Building Envelope Design in the Tropics. In *International Conference on Building Information Modelling (BIM) in Design, Construction and Operations*. Bristol.

Ma, Z. et al., 2012. Existing building retrofits: Methodology and state-of-the-art. *Energy and Buildings*, 55, pp.889–902. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378778812004227 [Accessed July 10, 2014].

Mahlia, T.M.I., Razak, H.A. & Nursahida, M. a., 2011. Life cycle cost analysis and payback period of lighting retrofit at the University of Malaya. *Renewable and Sustainable Energy Reviews*, 15(2), pp.1125–1132. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1364032110003618 [Accessed November 10, 2014].

Roberts, S., 2008. Altering existing buildings in the UK. *Energy Policy*, 36(12), pp.4482–4486. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0301421508004692 [Accessed December 2, 2014].

Shahsavari, F. et al., 2015. Better Daylighting for Existing Office Buildings, Case: "Qazvin Construction Engineering Organization (QCEO), Iran. In *COHAS*. Kuala Lumpur.

Sozer, H., 2010. Improving energy efficiency through the design of the building envelope. *Building and Environment*, 45(12), pp.2581–2593. Available at: http://dx.doi.org/10.1016/j.buildenv.2010.05.004.

Stevanović, S., 2013. Optimization of passive solar design strategies: A review. *Renewable and Sustainable Energy Reviews*, 25, pp.177–196.

Volk, R., Stengel, J. & Schultmann, F., 2014. Building Information Modeling (BIM) for existing buildings — Literature review and future needs. *Automation in Construction*, 38, pp.109–127. Available at: http://linkinghub.elsevier.com/retrieve/pii/S092658051300191X [Accessed July 12, 2014].

Welle, B., Haymaker, J. & Rogers, Z., 2011. ThermalOpt: A Methodology for BIM-Based Passive Thermal Multidisciplinary Design Optimization. , (June).

Xing, Y., Hewitt, N. & Griffiths, P., 2011. Zero carbon buildings refurbishment—A Hierarchical pathway. *Renewable and Sustainable Energy Reviews*, 15(6), pp.3229–3236. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1364032111001572 [Accessed November 26, 2014].