VOL. 11, NO. 8, APRIL 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

BUILDING SUSTAINABILITY ASSESSMENT FRAMEWORK BASED ON BUILDING INFORMATION MODELLING

Syafiee Mohd Raffee[1], Mohd Sufian Abdul Karim[1] and Zainuddin Hassan[2]
[1]Department of Civil Engineering, Universiti Tenaga Nasional, Putrajaya Campus, Jalan Ikramuniten, Kajang, Selangor Malaysia
[2]Department of Information Technology, Putrajaya Campus, Jalan Ikram-Uniten, Kajang, Selangor Malaysia
E-Mail: smsyafiee@gmail.com

ABSTRACT

Throughout the globe, there are various types of sustainable assessment such as LEEDS, BREEAM, HK-BEAM and ENERGY Star. In Malaysia, Green Building Index (GBI) is the authorized agency who works on sustainable assessment. Different sustainable agencies provide different methods, have different documentation procedures and generate reports. To leverage the current information technology in construction industry, BIM is introduced as one of the greatest tools to assist information sharing among construction players. BIM concept provides platform for information sharing and integration requirements by promoting interoperability between various applications. Thus this paper presents sustainability assessment methods by applying in a single framework.

Keywords: sustainability, construction technology, sustainable assessment framework.

INTRODUCTION

Construction comprises of many stages namely the pre-design, design, construction, operational and demolition stage. All these stages are defined as life-cycle construction. Construction industry requires effective ~~a~~ management in order to complete its project with the best performance. With global warming concerns are now the main issue in project development, it is a necessity for construction industry to make use of sustainable development for a better environment.

It is well known that to design sustainable buildings, massive data, information and multiple knowledge are required. C.D Plessis (2001) highlighted that the processes are excessively complex and the required data are scattered to be effectively utilized in the design and construction of green projects. Designers need to choose the best method by referring to a suitable sustainability assessment framework (C.D. Plessis, 2001) and (C.D. Plessis, 2002). However, current sustainable assessment lacks comprehensive coverage and approach to evaluate all factors or systems involved in the development and construction of a project. Many are still using manual assessment method compare to automation method and applied various scope of the assessment. This research paper proposed a sustainability assessment framework using. The framework was further developed into a computer application system for sustainable assessment. It can be computed automatically through user input from CAD to improve the efficiency of the assessment.

SUSTAINABILITY

Sustainability assessment in construction industry

Construction industry is one of the major players in sustainable development issue. According to the World Commission on Environment and Development, sustainable development is "the development that satisfies the needs of the current time period without jeopardizing the ability of future generations to satisfy their needs". In 1999, the International Council for Research and Innovation (CIB) had proposed Agenda 21 for Sustainable Construction (C.D.Plessis, 2001). One of the highlight is Construction industry has a major impact towards environmental pollution, human activities as well as cost efficiency (C.D.Plessis, 2002). Agenda 21 on Sustainable Construction outlines directions to prevent sustainable impact. N.Z. Abidin recommended some approaches which contribute to a sustainable development is (N.Z. Abidin, 2010):

1) Environmental planning, management and control.
2) Prudent use of natural resources.
3) Generating profit without compromising future needs.
4) Maintaining economic growth.
5) Social progress for everyone.
6) Protection of the environment.

Most agree that the concept of sustainable construction is to satisfy social, environmental and economic goals although it remains difficult to be expressed in conditional and operational terms (C San D Corp, 2002) and (B Moldan *et al*., 2012).

Currently, there are many sustainability assessments available that can be used to measure building performance. Many countries have their own sustainability assessments which depend on their local circumstances to come up with solutions for sustainable buildings (Z. Shari, 2012). Table below shown some of the example in sustainable assessment with a different stakeholders.

Table-1. Sustainable assessment in a different stakeholder (L Reeder, 2011 and Green Building Index, 2013).

Type of Assessment	ENER GY STAR for Homes	LEED for Homes	NAHB Model Green Home Building Guidelines	National Green Build ing Standard	Green Buildin g Index New Reside ntial
Site selection		√	√	√	√
Site Develop ment		√	√	√	√
Energy Efficiency	√	√	√	√	√
Water Conserv ation		√	√	√	√
Material and Resources Efficiency		√	√	√	√
Indoor Environmental Quality		√	√	√	√
Owner/ Tenant Education		√	√	√	
Other		Innovation and Design	Global Impact		Innovation

Site selection: Site selection need to be planned for public transportation, community services, open spaces and landscaping. This would avoid and conserve the environmentally sensitive areas through the redevelopment of existing sites and brownfields (Green Building Index, 2013).

Site development: Development of non-arable land for construction purpose which link by energy efficiency mass transportation system (P.O. Akadiri *et al.*, 2012).

Energy efficiency: Most of the factor that influence the sustainability is energy used. The energy efficiency depending on building orientation, minimizing solar heat gain through building envelope and harvesting natural lighting. Less energy consumption provide the highest green building design (Green Building Index, 2013).

Water conservation: Reduce the water consumption through building life cycle such utilizing water-efficient plumbing fixtures, design for dual plumbing, collecting rainwater using rainwater and grey water storage, employer circulating system, designing low-demand landscaping, and pressure reduction (P.O. Akadiri *et al.,* 2012)

Material and resources efficiency: Material have to meet a certain eco-friendly criteria such as low emitting materials, reuse and recyclable materials, regional materials, construction waste management, certified forestry products and rapidly renewable materials (S. Kubba, 2010)

Indoor environmentally quality: Achieve good indoor environmental performance in indoor air quality, acoustic, visual and thermal comfort. These will involve the use of low volatile organic compound materials, application of quality air filtration, proper control of air temperature, movement and humidity (Green Building Index 2013).

Owner/tenant education: Sustainability Stakeholders provide an education of sustainable building towards tenant. This will enlighten their knowledge through many aspect of education such as campaign, motivation, competition, and consultation.

Other: New innovation for sustainability design purpose

CONSTRUCTION TECHNOLOGY

What Is BIM

Building Information Modelling (BIM) have various definition and meaning among the researchers. Building Smart Alliance as an authorized company defines BIM as "BIM can be thought of as a database of the building project. The information in this database span the full range of data as an integrated data set" (Building Smart Alliance, 2007). Other than that, BIM Malaysia through it steering committee of Construction Integrated Development Board (CIDB) Malaysia describes BIM as "a modelling technology and associated set of process to produce, communicate and analyze digital information models for construction lifecycle" (H. Ismail, 2015). The

concept of the BIM plays a pivotal role in the construction industry. The concept of BIM which integrate all information from many expertise of construction players into one platform. This technology provides platform for different applications to gather their own database and create the interoperability function between them.

BIM is a workable integration for managing construction database that has been created by the Architect, Engineering and Construction (AEC) industry. BIM is not only useful for geometric modelling of building performance but it can assist in the management of construction projects. Such benefits was explore on cross-section of construction project as follow (D. Bryde *et al*. 2013) and (H. Ismail, 2015).

1) Cost reduction or control
2) Time reduction or control
3) Communication improvement
4) Coordination improvement
5) Quality increase or control
6) Negative risk reduction
7) Scope clarification
8) Reduction of variation order
9) Exploit Automation at early stage

Unfortunately, majority of construction players are not keen to participate applying the concept of BIM. BIM adoption is found more popular in the United States than in the rest of the world. Although a few construction players are using BIM in their project, but majority are still not aware of it and show an interest in BIM (H. Yan and P. Damian, 2008). In UK, the government encourages construction players to apply BIM will ward those players who work collaboratively through the use of BIM (D. Bryde *et al*. 2013).

The use of BIM in sustainability assessment of buildings has been identified as one of the approaches to increase the benefits construction. Currently the use of digital tools for sustainability assessment is still lacking (S. Azhar 2011). Even though, there are many BIM that have been produced for sustainability purposes such as Autodesk Green Building Studio, Autodesk Ecotect and BEES 4.0, there are still not adequate to satisfy the sustainability rating measurement. These applications need some improvement to enhance the sustainability assessment by designers for their green building project.

Current framework of sustainability assessment

Tajin Biswas *et al* (2009). They presents a way of creating a flexible framework to be an ultimately integrated with a design system to facilitate endeavors in sustainable design. The framework lays the groundwork for a process of ultimately analyzing a given building with respect to the requirements given by different rating systems. Thus, it will structure the map rating system requirements to their comprising elements; identify processes involved; identify missing information and manage changes in rating systems in a cohesive way.

Tajin Biswas *et al*., (2009). They had developed a framework to encompass the categories and subcategories of commonly used rating system. The framework is an attempt to capture broad categories and group them according to their inherent scopes. Their features of framework as below.

1) Presents SBIM as an interface based which provide major elements such as sustainable building information modelling environment, calculating engines, database and evaluation output.
2) Calculating engines (external energy simulation engine which run baseline performance and internal estimation engine which check values from building information that correspond to LEED requirements).
3) Database is automatically construct which correspond to LEED, Embodied Carbon and Building Assumption.
4) Evaluation output will show a results of sustainability rating system.

P.O. Akadiri *et al,* (2012). Framework which presents the conceptual of sustainable assessment according to the triple bottom line. This will allow design teams to have an appropriate balance between economic, social and environmental issues. Changing the way construction practitioners think about the information they use when assessing building projects, thereby facilitating the sustainability of building industry.

Salman Azhar *et al*. (2011). They develop the framework to establish the relationship between BIM based sustainability analyses and the LEED certification process. Documentation supporting LEED credits may be directly or indirectly prepared using the results of the BIM-based sustainability analyses software (IES).

J.K-W. Wong and K-L Kuan (2014). The framework was produced to explore the potential use of BIM in the case of a residential building project seeking BEAM-plus sustainable building certification in Hong Kong. Their framework was verified using two sampled public housing modular flat models. Based on their results 26 BEAM-Plus credits achieved (11 credits achieved by further simulation work and 15 credits by scheduling under BIM). 13 credits and one pre-requisite in the LEED system can be directly calculated and documented using Autodesk Revit. BIM would enhances the accuracy of BEAM-Plus submissions. Further investigation can be manage the assessment framework by using Autodesk API function to set up the corresponding programming

PROPOSED FRAMEWORK

Based on the literature review, authors propose the sustainable assessment framework as illustrated in Figure-1. Using BIM concept, this framework could enhance the method of sustainable assessment in construction industry.

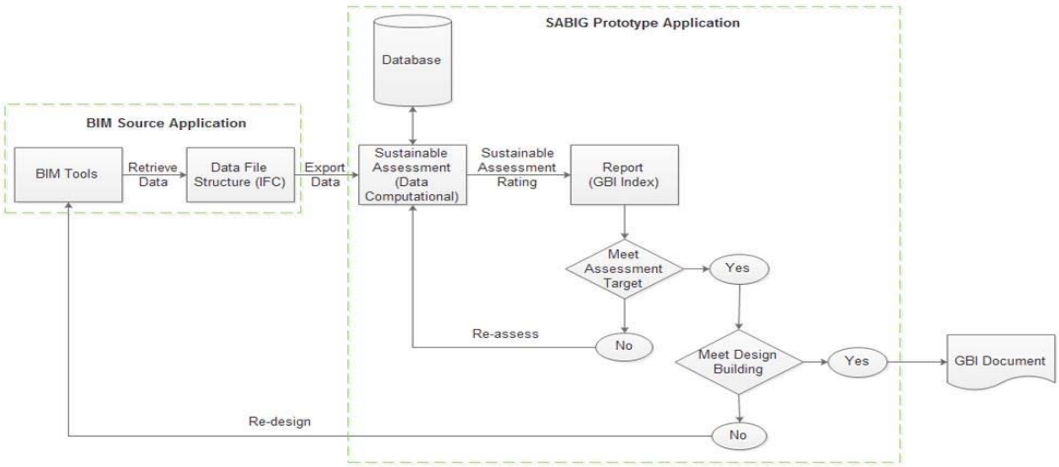

Figure-1. Sustainable assessment framework.

BIM source application

There are two main applications which needs to be used in this proposed framework. First of it is a BIM Source Application. Designer should design their building using particular BIM based tools with available current software such Revit Autodesk, ArchiCAD, and Bentley AECOsim. These BIM based tools provide an informative database such as value of its properties, type of material, coordination, color, and 3 dimension drawing. Each drawing in different BIM tools will be saved in a different file format as example for Autodesk Revit is ".rvt".

Besides that, BIM based tools also can be exported in other file format. CAD Formats, DWF/DWFx, Building Site, FBX, gbXML, Mass Model gbXML, IFC, ODBC Database, Image and Animation and Reports are an example of exchange file in Revit BIM tool. In this paper, the author had chosen IFC file format as a parameter of research. The building information is retrieved and saved in IFC format to enable it to be exported and used in the sustainability assessment application. Industry Foundation Classes (IFC) is the platform of open and neutral data format for openBIM which is not controlled by a single vendor or a group of vendors. It is intended to describe the building information and construction industry data (www.buildingsmarttech.org). Figure below shown an IFC file format using notepad file.

```
#44= IFCSIUNIT(*,.AREAUNIT.,$,.SQUARE_METRE.);
#45= IFCSIUNIT(*,.VOLUMEUNIT.,$,.CUBIC_METRE.);
#46= IFCSIUNIT(*,.PLANEANGLEUNIT.,$,.RADIAN.);
#47= IFCDIMENSIONALEXPONENTS(0,0,0,0,0,0,0,0);
#48= IFCMEASUREWITHUNIT(IFCRATIOMEASURE(0.0174532925199433),#46);
#49= IFCCONVERSIONBASEDUNIT(#47,.PLANEANGLEUNIT.,'DEGREE',#48);
#50= IFCSIUNIT(*,.MASSUNIT.,.KILO.,.GRAM.);
#51= IFCSIUNIT(*,.TIMEUNIT.,$,.SECOND.);
#52= IFCSIUNIT(*,.THERMODYNAMICTEMPERATUREUNIT.,$,.KELVIN.);
#53= IFCDERIVEDUNITELEMENT(#50,1);
#54= IFCDERIVEDUNITELEMENT(#52,-1);
#55= IFCDERIVEDUNITELEMENT(#51,-3);
#56= IFCDERIVEDUNIT((#53,#54,#55),.THERMALTRANSMITTANCEUNIT.,$);
#58= IFCDERIVEDUNITELEMENT(#43,3);
#59= IFCDERIVEDUNITELEMENT(#51,-1);
#60= IFCDERIVEDUNIT((#58,#59),.VOLUMETRICFLOWRATEUNIT.,$);
#62= IFCSIUNIT(*,.POWERUNIT.,$,.WATT.);
#63= IFCUNITASSIGNMENT((#42,#44,#45,#49,#50,#51,#52,#56,#60,#62));
#65= IFCAXIS2PLACEMENT3D(#6,$,$);
#66= IFCDIRECTION((2.,6.12303176911189E-17,1.));
#68= IFCGEOMETRICREPRESENTATIONCONTEXT($,'Model',3,1.00000000000000E-5,#65,#66);
#71= IFCGEOMETRICREPRESENTATIONSUBCONTEXT('Axis','Model',*,*,*,*,#68,$,.GRAPH_VIEW.,$);
#73= IFCGEOMETRICREPRESENTATIONSUBCONTEXT('Body','Model',*,*,*,*,#68,$,.MODEL_VIEW.,$);
#74= IFCGEOMETRICREPRESENTATIONSUBCONTEXT('Box','Model',*,*,*,*,#68,$,.MODEL_VIEW.,$);
#75= IFCGEOMETRICREPRESENTATIONSUBCONTEXT('FootPrint','Model',*,*,*,*,#68,$,.MODEL_VIEW.,$);
```

Figure-2. Industry foundation classess data file format.

IFC is not only a data file format but it also allows the interoperability functions between different software of BIM. Thus this file can be used and utilized by anybody from a different discipline within the construction players. Interoperability will be able to reduce the lack of information exchange between them in order to solve some conflicts and issues in construction works. This would enhance the effective performance of sustainable assessment.

SABIG prototype application

Secondly, Sustainable Assessment Building Information Green Building Index (SABIG) was developed to assess the sustainable in building design. It is develop using Microsoft Visual Studio (MVS) with a certain programming language producing the prototype. SABIG prototype is use to assess multiple choices of sustainable assessment following the Green Building Index (GBI) requirements and its principles.

SABIG needs to retrieve the IFC file and would require certain user inputs to demonstrate the data and

information in 3D visualization together with their properties. The user input forms will be regarding the building's energy efficiency, indoor environmental quality and material resources to be assessed by designer. SABIG creates a database to store and manage the current sustainable assessment for computation purposes. Computation method is develop by integrating the specific rules, protocols and algorithms. Once completed, all information will be computed to give out a rating sustainable index. The higher index denotes a better performance for a particular building design. SABIG application will determine the overall GBI Rating of the designed building. This will allow the designer to check whether the desired GBI Rating has been achieved or not.

Besides that, SABIG provides a report of sustainable assessment based on the GBI principle to facilitate decision makers to achieve their targeted sustainability index. There are two looping process within the SABIG application namely the re-assess and the redesign. Users will have to re-assess the assessment when the changes that needs to be done can be done within the SABIG software. Whereas, the users have to re-design the building when the information can only be changed in the BIM Source Application. To identify these two processes, users will only have to study the temporary report produced by the SABIG.

Lastly, sustainable assessment will fully completed through a printing document as shown in the Figure-1 above.

CONCLUSIONS

Based on the increasing demand of a green building design in construction nowadays, many researchers struggle to produce the best way to conduct sustainability assessment using different framework. This paper shows a way to improve the framework of sustainability assessment using using BIM and rating system. As an expected outcome, this framework will be able to simplify the processes of the sustainability assessment rating index which are directly obtained without using any secondary software. This will facilitate the construction players in decision making based on the resulting rating index which is produced by SABIG. Eventually, the framework can be promoted as an effective measurement of green building assessment in the construction industry.

REFERENCES

C. d. Plessis. 2001. Agenda 21 for Sustainable Construction in Developing Countries," Council for Research and Innovation, Pretoria.

C. d. Plessis. 2002. Agenda 21 for Sustainable Construction in Developing Countries, CSIR Building and Construction Technology, Pretoria.

N. Z. Abidin. 2010. Investigating the awareness and application of sustainable construction concept by Malaysian developers. Habitat International, no. 34, pp. 421-426.

C SanD Corporation. 2002. Sustainable Development and Sustainable Construction," C SanD, Loughborough.

B. Moldan, S. Janouskova and T. Hak. 2012. How to understand and measure enviromental sustainability; Indicators and targets," Ecological Indicators, vol. 17, pp. 4-13.

Z. Shari. 2012. Building Performance Assessment System: The Emergence and the Variety," Housing Research Centre, Serdang.

L. Reeder. 2010. Guide to Green Building Rating system, Hoboken: John Wiley and Sons.

Greenbuildingindex Sdn Bhd. 2013. Green Building Index. August. [Online]. Available: http://www.greenbuildingindex.org/. [Accessed 26 March 2015].

P. O. Akadiri, E. A. Chinyio and P. O. Olomolaiye. 2012. "Design of A Sustainable Building: A Conceptual Framework for Implementing Sustainability in the Buidling Sector. Building, no. 2, pp. 126-152.

Building Smart Alliance. 2007. Approches to Transforming the Construction Industry. Building Smart Alliance, United States.

H. Ismail. 2015. Getting To Building Information Modeling (BIM)," Construction Integrated Development Board (CIDB) Malaysia, Kuala Lumpur.

D. Bryde, M. Broquetas and J. M. Volm. 2013. The project benefits of Building Information Modelling (BIM)," International Journal of Project Management, no. 31, pp. 971-980.

H. Yan and P. Damian. 2008. "Benefits and Barriers of Building Information Modelling. in 12th International Conference on Computing in Civil and Building Engineering, Beijing.

S. Azhar, W. A. Carton, D. Olsen and I. Ahmad. 2011. "Building Information Modelling for sustainable design and LEED rating analysis," Automation in Construction, vol. 20, pp. 217-224.

S. Kubba. 2010. Green Construction Project Management and Cost Oversight, Burlington: Architectural Press.

Biswas, Tajin; Wang, Tsung-Hsien; and Krishnamurti, Ramesh, "Framework for Sustainable Building Design. 2009. School of Architecture. Paper 47.

Biswas, Tajin; Wang, Tsung-Hsien; and Krishnamurti, Ramesh. 2009. " Integrating Sustainable Building Rating Systems with Building Information Models. School of Architecture.

J.K wai Wong, Ka-Lin Kuan. 2014. implementing BEAM-Plus' for BIM-based sustainability analysis. Automation in Construction. vol. 44, pp. 163-175.