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INVESTIGATION ON THE POTENTIAL OF INTEGRATING BIM INTO GREEN BUILDING ASSESSMENT TOOLS

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ABSTRACT

In recent years, there has been increasing awareness of the importance of using information technology in improving "green building" performance in terms of design, construction, and operation. Assessment tools help industry stakeholders evaluate the performance of green buildings. Building information modeling (BIM) enables architecture, engineering, and construction managers to evaluate the performance of green buildings during preconstruction. BIM-based sustainable analysis extracts the data from a building model, which supports the assessment for green building certification. This paper explores the use of BIM with other assessment tools, such as Leadership in Energy and Environmental Design, BEAM Plus and Green Star. The study also examines the potential use of BIM in green building rating systems and the possibility of achieving credit via BIM tools and analysis software. In a case study of a construction project, using green building assessment tools integrated with BIM has led to an improved green building and facilitated the performance assessment of this building during the certification process.

Keywords: Green building assessment building information modeling, leadership in energy and environmental design, beam plus green star green building rating system.

INTRODUCTION

"Green buildings" represent a relatively new trend in achieving sustainability in the construction industry. Related information and standards can refer to green building certification programs. At present, applicable standards and green building certification systems are used in most countries (Jun *et al.* 2015). Typical examples are the Leadership in Energy and Environmental Design (LEED) from the USA, Building Research Establishment Environmental Assessment Method (BREEAM) from the UK, Green Star from Australia, BEAM Plus from Hong Kong, Comprehensive Assessment System for Built Environment Efficiency (CASBEE) from Japan, Green Standard for Energy and Environmental Design (G-SEED) from Korea, and the Green Building Index (GBI) from Malaysia.

Sustainable construction development is a global concern. To solve environmental problems, different concepts and approaches have been developed over the past decades, including the green building certification (GBC) and building information modeling (BIM). However, an integrated strategy is required to stimulate further innovation and improve the process (Jupp, 2013).
The green building certification program promotes the adoption of green building principles. This relatively new program aims to increase the procurement of sustainable buildings or infrastructure. The public sector and private developers have begun to look for sustainable development strategies in light of rising energy costs and various environmental issues.

Recently, BIM has been implemented by construction companies to improve buildings in terms of long-term productivity. Architectural design uses BIM techniques to extract data from the digital architectural models and then determine the level of sustainability. BIM has been implemented by some architecture, engineering, and construction (AEC) firms because of the long-term benefits in terms of productivity gains (Nguyen, Shehab, and Gao, 2010).

By allowing system integration and optimization, BIM facilitates effective collaboration, which plays an important role in this transformation. When applied to green building design, BIM is capable of aligning the decision-making process goals and those of the project stakeholders; in some cases, the process allows for more effective and efficient green building certification (Azhar *et al.* 2009).

By effectively assessing building performance during the design and preconstruction phases, we are able to obtain comprehensive data regarding a building's form, context, materials, and electrical mechanical plumbing (MEP) systems. BIM also allows multi-disciplinary data to be superimposed for one model, thereby creating the opportunity for the sustainability of the measures to be incorporated into the entire design process (Autodesk, 2008)

Kriegel and Nies (2008) highlighted a series of simple design concepts that help guide a project towards a more sustainability-driven outcome. These concepts are listed below.

- Building orientation
- Building massing
- Daylighting analysis
- Water harvesting
- Renewable energy
- Energy modeling
- Sustainable materials

BIM is a recent development that is supported by a number of previous studies, which aim to improve BIM's applicability in design and construction. However, only a few studies have examined the impact of BIM on

sustainable construction practices (Bynum *et al.* 2013). Consequently, the current study investigates the perceptions of designers and constructors on the use of BIM in green building assessment tools for sustainable design and construction.

LITERATURE REVIEW

BIM has rapidly progressed over the past decade and has been used in the fields of architecture and traditional construction (AEC). BIM is composed of integrated facilities that are commonly used by the project team to monitor and manage construction work, and to design buildings and infrastructure, thereby making it an effective communication platform. Given the concern for the effects of the depletion of non-renewable resources, BIM has been increasingly applied and adopted to monitor the impact of construction on the environment (Azhar, 2009).

In a previous study in the US, BIM effectively provided assistance in different areas of sustainable design. That work demonstrated that BIM can support the LEED certification submission process (Hardin, 2009).
BIM applications also help stakeholders, such as clients and designers, share common information from one single source, when faced with a decision-making problem at an early design stage of construction.

LEED, BEAM Plus, and Green star are similar green building rating systems, which feature their respective criteria and allocation of points and credits; thus, BIM may possibly be integrated with the green building certification process. This factor is a strong reason driving several countries to implement BIM in most construction phases. The BIM model assists project stakeholders, including designers, contractors and clients, in calculating, documenting, and measuring the green building rating system scores based on the LEED, BEAM Plus, and Green Star certification. In the future, the design team and construction approaches should meet the LEED, BEAM Plus, and Green Star rating systems for green building accreditation requirements (Azhar *et al.* 2011).

BIM Tools and Sustainability Analysis

Table-1 illustrates the BIM framework for sustainability analysis and the BIM software that is currently available in the construction industry (ACE). The BIM tools and workflow have two phases: Phase One creates the basic models with the appropriate inherent BIM software, while Phase Two exports these models to basic BIM analysis tools, as needed. This phase is explained in detail below, using Revit and Ecotect as examples. The investigation of different systems and BIM software models can be found in the literature (Azhar *et al.* 2011),(Kymmell, 2008),(Crawley *et al.* 2005). Some researchers have studied the ways by which BIM can interact with green building rating systems. For example, Azhar *et al.* (2011) found that the maximum LEED credits can be earned with the appropriate BIM or BIM-based analytical tools. Biswas *et al.* (2009) reported the link between the effective integration of green building tools with the durable application of BIM.

Phase 1: Inherent BIM features

The inherent function of BIM software is the selection of the best building orientation and the appropriate degree of massing. Inherent BIM software include Revit, ArciCad, and Bentley (Wong and Fan 2013).

Phase 2: BIM-based analysis tools

The construction industry (AEC) generally uses three BIM-based sustainability analyses software in the market, namely, Autodesk Green Building Studio (GBS), Autodesk ECOTECT, and the Integrated Environmental Solutions (IES) Virtual Environment (VE). Some authors have examined the integration of BIM with VE and GBS (Stumpf *et al.* 2009), (Rundell, 2007).

Table-1. BIM framework for sustainability analysis (Wong and Fan 2013).

	Phase 1:	**Phase2:**
	Inherent BIM Features	BIM-based Analysis Tools
Software	Revit, ArchiCAD, Bentley, Graphisoft, TriForma (Beta), etc.	Ecotect, IES-VE, Green Building Studio (GBS), EnergyPlus, TRACE700, eQUEST, etc
Green Strategies	Building Orientation; Building Massing; Load Data, etc.	Building Load Calculations; Energy Analysis; Lighting Design; Ventilation; Materials, etc.

BIM is an ideal fit for the dissemination of information that can help enhance building design and construction performance. Two main benefits of BIM compared with the design of sustainable buildings are their integrated project delivery (IPD) and design optimization. The traditional CAD-based design requires a heavy degree of human intervention, and the whole process is tedious and expensive. However, BIM enables designers to streamline the design of efficient buildings in the early stages and produce better solutions (Wong and Fan, 2013).

Table-2. Summary of BIM for sustainable analysis.

	Functions	Benefits	Sustainable achievements
BIM Inherency	3D Model Visualization Clash Detection Compliance with Regulations	Integrated Project Delivery , Design Optimization	Energy Reduction Water Conservation
BIM-based Analysis Tools	Energy Analysis; Solar Analysis Thermal Analysis Lighting Design Acoustic Analysis Ventilation and Air Flow Materials/Resource Management	Better Communication and Coordination More accurate and efficient	Wastage Lessen IEQ Improvement

Sustainability Assessment

Individuals and organizations worldwide have shown increasing awareness of the rising demand for green buildings. Several countries and international organizations have embarked on a rating system for sustainable construction. At present, several different scoring systems are being used to evaluate the environmental performance of buildings (Azhar *et al.* 2011). These rating systems have common criteria and are similar in terms of their evaluation of such factors as energy consumption, indoor environmental quality, water efficiency, and material use of a building.

LEED

The LEED system is currently the most widely used rating system in the US, which is commonly used to assess the environmental performance of buildings in the country. LEED identifies the owner or operator of the building, as well as the design of practical and measurable green building, construction, operation, and maintenance solutions, to provide a simple framework. LEED was first developed by the US Green Building Council (USGBC) in 1998 (USGBC, 2009).

The LEED criteria are divided into six categories (LEED var. 2.2), namely, sustainable sites, energy and atmosphere, water efficiency, materials and resources, indoor environmental quality, and innovation in design (USGBC, 2009). The point allocation in the LEED system must reach up to 34 total credits. A total of 69 points are available within the confines of the credits. Credit categories are based on the plurality of points and can indicate a higher level of environmental performance. In addition to credit, every part of the LEED system contains the prerequisites that must be earned, although it does not depend on the number of points in the building (USGBC, 2009). As shown in Table-3, points are not evenly distributed among the categories.

Table-3. The LEED rating system.

No	LEED Categories	Maximum Points
1	Sustainable Sites	14
2	Water Efficiency	5
3	Energy and atmosphere	17
4	Materials and resources	13
5	Indoor environmental quality	15
6	Innovation and design process	5
Total		69

The LEED certification is divided into four levels: LEED Certified, LEED Silver, LEED Gold and LEED Platinum (LEED v. 2.2). The LEED certification level is determined by the number of points awarded, as shown in Table-4: (1) 26–32 points for Certified, (2) 33–38 points for Silver, (3) 39–51 points for Gold, and (4) 52–69 points for Platinum (USGBC, 2009). During the construction of a new project, the supporting documents and proof are compiled and submitted to the US Green Building Council (USGBC). Based on the information found in the submitted documents, the allocated points will determine whether the project could be awarded. No certification is given until the project is completed. Should there be changes made during construction, the supporting documentation must be resubmitted.

Table-4. Levels of point scores for LEED.

Certification Level	Point Score
Certified	26–32
Silver	33–38
Gold	39–51
Platinum	52–69

BEAM Plus

Hong Kong currently uses BEAM Plus as its main green building rating system. This is similar to those used in several countries, such as LEED in the US, Green Star in Australia, and GBI in Malaysia. BEAM Plus provides green building guidance in the planning and construction of sustainable buildings. The BEAM Plus scheme was first established in 1996, and in that year two assessment tools were published: one for new buildings and another for existing office buildings. The BEAM Plus Version 1.1 for new buildings and existing buildings was the first method founded in April 2010. The BEAM Plus grade during the assessment is determined by the percentage of credits gained under each category and their corresponding weighting factors (Wong and Kuan, 2014). As shown in Table 5, the BEAM Plus rating system is divided to five categories with one additional category, namely, Site Aspect, Water Use, Energy Use, Materials Aspect, Indoor Environmental Quality, and Innovation and Additions.

Table-5. The BEAM plus rating system.

No	BEAM Plus Categories	Weighting %
1	Site Aspects (SA)	18
2	Materials Aspects (MA)	12
3	Energy Use (EU)	30
4	Water Use (WU)	15
5	Indoor Environmental Quality (IEQ)	25
Total		100

The assessment grade in BEAM Plus is allocated by the percentage given for each criterion or credit earned under each performance category and the corresponding weighting factor. Higher points give importance to specific aspects of each site. For Energy Use and IEQ, it is necessary to obtain a minimum percentage of credits in the other three categories to qualify for the overall grade. Table 6 shows the level classifications divided into four items, namely, (1) Platinum, (2) Gold, (3) Silver, and (4) Bronze. The award is based on the number of credits earned by a building (HKGBC, 2010).

Table-6. Levels of point scores of BEAM plus.

Certification Level	Weighting %
Bronze	40–54
Silver	55–64
Gold	65–74
Platinum	75–100

Green Star

The Green Building Council of Australia (GBCA) was launched in 2002. The first decision was made with a Green Star assessment tool for new office buildings in 2003 due to the growth in the demand for Green buildings at that time (Gandhi and Jupp, 2013).

The Green Star Rating system categories have several points called "credits." These credits are assigned to the project based on the incorporated sustainability measures, in accordance with the Green Star Rating Credit Criteria (each rating tool has a different credit). Based on the number of credits achieved, a Green Star Rating Category Score will be calculated for that project (GBCA, 2007).

Table-7 shows the rating criteria and certification stages for a commercial office building, in accordance with Green Star's Office Design Tool (version 3) (GBCA, 2013).

Table-7. Green star rating system.

NO	Green Star Categories	Weighting%
1	Management	9%
2	Indoor Environment Quality	20%
3	Energy	25%
4	Transportation	8%
5	Water	12%
6	Materials	14%
7	Land Use and Ecology	6%
8	Emissions	6%
Total		100

Green Star certification is independently based on an evaluation panel review, similar to a formal process wherein the documentary evidence is reviewed to meet the benchmark Green Star in each of the credits. The Green Star rating results are awarded based on the comparison of the overall scores in the scale of assessments (GBCA, 2013).

Table-8. Levels of point scores in green star.

Certification Level	Point Score
4 Star	45–59
5 Star	60–74
6 Star	75–100

Table-8 shows the point scores of the Green Star rating tools for the construction, layout, design, and construction of community loyalty projects, which realize the best practices or more. Therefore, ratings of 1, 2, or 3 are not released because the buildings assessed by Green Star can achieve a rating of 4–6 stars (GBCA, 2013).

METHODOLOGY

The method used in the current paper is content analysis of materials in the form of articles, journals, and reports. Content analysis is a research technique that aims to achieve objective and systematic description of manifest content for communication (Bernard, 1952). Content analysis is used to determine the presence of certain words or concepts in the text or text sets. The researchers measure the presence of these words and their meanings to analyze the relationship between words and concepts, which represent part of the message in the text, the author, and the audience, within a certain context. Textbooks, book chapters, essays, interviews, discussions, newspaper headlines, articles, historical documents, speeches, conversations, advertising, and theater, are broadly defined as informal conversations representing the actual occurrence of any communication in a language. The analysis and discussion in this paper match the BIM application on green building certification, as well as the applicable assessment criteria, point scoring, and ratings awarded for LEED, BEAM Plus, and Green Star.

DATA ANALYSIS

BIM and sustainability are relatively new concepts in construction and are related to the improvement of the AEC industry. Krygiel and Nice (2008) proposed several innovations in BIM and further measures to enhance sustainability and functionality and to increase the integration of carbon accounting software trackers and weather data. Meanwhile, Azhar (2011) defined the use of BIM to select building orientation and evaluation; the author performed daylight studies for positioning on a selected site during the design phase, thereby enhancing its sustainability.

Integrating BIM with the LEED Rating System

The LEED rating system has a total of 69 credits. Based on an analysis of BIM software and sustainability, 38 credits can be found directly from BIM, whereas 31 credits require supporting documentation that cannot be prepared by BIM software. For example, some credits require a narrative that is submitted along with the necessary computations. These credits are classified as indirect credits, which require supporting documentation or some key information that can be provided by BIM software. Table-9 illustrates the total points that can be achieved with a BIM tool and the examples of the BIM tools. As shown in the table, LEED has six criteria with the maximum points. Water efficiency has full points that can be earned by BIM and minimum points achieved with indoor environmental quality. In this case, the project receives a silver certification in the LEED rating system.

Table-9. BIM achievement in LEED rating system.

Criteria	Maximum Point	Weighting %	BIM Point	BIM Weighting	BIM tool
Sustainable Sites	14	20.3%	6	8.7%	Revit
Water Efficiency	5	7.2%	5	7.2%	Revit, VE
Energy & Atmosphere	17	24.6%	10	14.5%	VE
Materials & Resources	13	18.9%	9	13.1%	Revit
Indoor Environmental Quality	15	21.8%	4	5.8%	Revit, VE
Innovation & Design Process	5	7.2%	4	5.7%	Revit, VE
Total	69	100%	38	55%	

Integrating BIM with BEAM Plus Rating System

The Hong Kong rating system has 80 BEAM Plus credits with 128 total points, of which 26 credits (56 points) can be achieved with the support of the documentation produced by BIM. Table 10 illustrates the BEAM plus criteria, in which BIM can earn 4 credits (6 points) in the Site Aspect category, and 13 points in the Material Aspect (comprising 8 credits, 3 credits in Water Use, 6 credits in Energy Use, 4 credits in Indoor Environmental Quality, and 1 credit in Innovation and Additions).

A total of 30 credits require calculations or tests that could not be achieved by BIM, such as noise, acoustic calculations and vibration, whereas 11 credits require on-site testing or measurement, such as acoustic measurements and water testing. The 11 credits require modeling work, which could not be performed by BIM at this stage of development.

BIM can achieve 26 BEAM Plus credits by providing the supporting documentation, including 15 and 11 credits that can be achieved by scheduling and simulation, respectively. Table 10 shows the allocation points that can be earned by BIM. Similarly, 13 LEED credits were achieved, with an additional prerequisite by direct calculation of the point score in the LEED case using such BIM tools as Revit.

Table-10. BIM achievement in the BEAM Plus rating system.

Criteria	Maximum Point	Weighting %	BIM Point	BIM Weighting	BIM Tool
Sites aspect	22	25%	6	7%	Revit, IES
Material aspect	22	8%	13	5%	Revit
Energy use	42	35%	26	22%	Revit,IES
Water use	9	12%	4	6%	Revit
Indoor Environmental Quality	32	20%	6	4%	IES
Innovation & Design Process	1	0	1	0	Revit, IES
Total	128	100%	56	44%	

Integrating BIM with the Green Star Rating System

Table-11 illustrates Green Star credit requirements and the BIM tools. As can be seen, 97 of 146 points can be achieved by BIM, which is 66% of the level certification, thus leading to a 5-Star rating. BIM can achieve full points for water efficiency and emission at 6%. However, the area total of 49 points could not be met by BIM tools and were leveraged to their full potential on this project to meet the Green Star criteria.

Table-11. BIM achievement in the green star rating system.

Criteria	Maximum Point	Weighting %	BIM Point	BIM Weighting	BIM Tool
Management	12	9%	0	0	Revit
Indoor Environmental Quality	27	20%	19	14%	IES
Energy Efficiency	29	25%	15	13%	Ener –Win, Trace
Transport	11	8%	5	7%	Revit
Water Efficiency	12	12%	11	11%	Revit
Material	21	14%	20	13%	Revit, Navisworks
Land use and	8	6%	2	2%	Revit,
Emissions	16	6%	15	6%	Revit
Innovation	10	0	10	0	
Total	146	100%	97	66%	

CONCLUSIONS

BIM in AEC has been applied by several construction companies to ensure the long-term productivity of buildings. Based on the standard process and information model format, sustainability assessment is performed for architectural design. BIM technology can be used to extract data from digital architectural models to support sustainability evaluation. The architectural design of a project is used as a case study to verify the application of BIM in achieving credits for each specific rating system.

The sustainability assessment of the case study is conducted using the LEED, BEAM Plus, and Green Star rating systems. The results show that BIM can achieve some credits to certify a green building. Figure-1 below illustrates the percentage that uses BIM in each assessment tool.

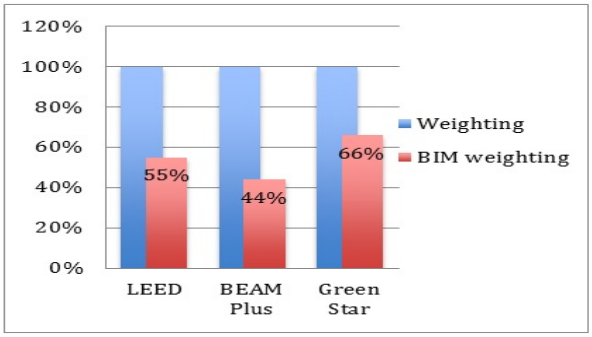

Figure-1. BIM achievement.

BIM can earn 55% of the LEED credit, which is equivalent to a Silver level certification. Each credit has been determined to have a direct, semi-direct, or indirect relationship between BIM and the obtained LEED points. BIM-based sustainability of the software has been quickly achieved compared with the conventional method; this produced a different result by analyzing the building information model. In this case, a company can save substantial time and resources.

The results also show that BIM can achieve 44% of the specific BEAM Plus credit assessments, equivalent to a bronze certification. A total of 26 BEAM Plus credits is obtained using BIM, comprising 15 credits by scheduling and 11 credits from the initial simulation work. These credits have been identified as a prerequisite in the evaluation system using direct calculation and documented with the Autodesk Revit.

Finally, with BIM tools, 66% of the Green Star credits can be used to support Australian Green Star certification, resulting in a 5-Star rating. This rating is higher compared with the LEED and BEAM Plus results. The levels of BIM adoption during green building assessment and building development should be met across the AEC industry. Integrating BIM into different green building rating systems offers the opportunity to move these objectives forward. The paper demonstrates the possible credits that can be earned via BIM and the benefits of applying this approach.

In a future study, we will determine the relationship between BIM and the Malaysian Green Building rating system, namely, the Green Building Index (GBI). The integration of BIM into GBI is expected to have a positive impact on the construction industry, especially in a developing country such as Malaysia.

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