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Building rating tools integration in building information modeling (BIM)

K E Lai[1], N A Rahiman[1], K N Ali[1], T Kamaruddin[1], N M Shukery[1], I A Razak[1]
[1]Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia, Johor, Malaysia

Corresponding author: b-nafisah@utm.my

Abstract. Building Information Modelling (BIM) has a high potential to assist in designing a green building. Integrating BIM and building rating tools can help designers design buildings that fit the minimum requirements of green certification. Without BIM, green certifications are performed manually and after project completion. Incorporating BIM and building rating tools in the early decision-making process of a project is more significant to enhance building sustainability. The study aims to review the extent of integration of building rating tools with BIM for green certification in the current research. Upon screening the relevant publications, it is discovered that only a small number of studies have been conducted that link BIM and green assessment tools. Only a total of 19 studies are eligible for the review process. The content analysis results of these studies point out that LEED is the most used building rating tool for integration with BIM. The integration is mostly made by using Autodesk Revit and Dynamo. The major focus for the integration is on the energy and atmosphere sub-category as the credit allocation is the highest. More studies integrating the BIM-building rating tool are needed to automate the green certification process.

Keywords: Building Information Modelling (BIM); green rating tools; building sustainability performance; green buildings.

1. Introduction

Construction has become one of the targeted industries to improve environmental sustainability as it consumes 40% world's energy consumption, 30% of total raw materials consumption, 25% of total water consumption, 12% of land consumption, and produces 25% of overall solid waste [1, 36]. To reduce the environmental impact, the concept of sustainable building is introduced [21]. Sustainable buildings are able to reduce energy and water consumption without compromising the health and comfort of the occupants. However, designing sustainable buildings is considerably more complicated than designing conventional buildings because multidisciplinary design teams have to meet a wide range of environmental, social, and economic needs [21]. Accordingly, building rating tools for sustainable buildings are developed to evaluate the building's environmental performance [8] and at the same time promote sustainability in designing, constructing, and operating the buildings [18]. Numerous building rating tools have been developed to measure and recognize the sustainable performance of a building [31]. These building rating tools can assist in measuring the environmental performance of the building

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so that best sustainable practices will be adopted in designing, constructing, and operating the building [4]. Building rating tools are important to guide the decision-making process of a sustainable building [1]. The building rating tools are necessitated to be integrated into the design process to produce a building that is resource-efficient throughout its life cycle [30].

Decisions made to the design of the sustainable building are the most significant during the conceptual stage [8,9,11,22]. Early decision-making is more impactful, more effective, cost lesser, and is more easily introduced [16]. Incorporating building rating tools at the conceptual stage can assist the designers to classify the materials and components that have the potential to earn credits based on the selected building rating tool [23]. However, at present, the process for green building assessment is mostly performed manually starting from data collection, data analyses, points calculation, and documents preparation and submission, which takes more time and effort, especially for large and complex projects [12,26].

Furthermore, it is necessary to conduct a sustainability analysis to assess environmental performance to produce sustainable buildings. Traditionally, building performance analysis will be conducted once the architectural design and construction documents were completed [8]. However, traditional 2D tools are not capable of performing building performance analysis with the same tools used for design. So, a separate sustainable analysis is required at the end of the design process using other additional tools. [1]. The traditional modelling process is also inconvenient as it is time-consuming and requires tremendous efforts to incorporate the architectural information into the simulation software [34]. Failure to analyse building sustainability performance during the design phase leads to an inefficient process of retrospective design adjustment to meet the requirements in the building rating tool [8]. These issues can be resolved by BIM due to its ability to overlay multidisciplinary information in a single model as well as its ability to incorporate sustainability metrics throughout the design process [8,11]. BIM is also capable to analyse and integrate different design alternatives with minimal resources at the early design stage [11,24]. BIM is a great tool for information management and has a high potential to aid the green building certification process [6]. BIM allows the design team to handle complex simulation programs and analyses [23] as BIM models could provide vast material information and generate a bill of quantity (BOQ) for the building materials [13] and thus have great potential to automate the green certification process.

Integrating BIM and building rating tools is able to help the designers to analyse and modify the building design to best suit the minimum requirement of sustainability so that the building will be certified as a green building [23]. The integration is also able to increase productivity by saving time and effort during the certification process [12] and at the same time promoting more environmentally and economically sustainable construction practices [19]. This is because BIM is able to assist in coordination and collaboration among the stakeholders for better information exchange [32]. To find out the extent of the integration of BIM-building rating tools, it is important to identify the types of building rating tools that have been integrated with BIM and the areas of focus of its integration in current research.

Hence, the study aims to review the current state-of-art of integration of building rating tools with Building Information Modelling (BIM) for green certification. The main objective of this paper is to discuss studies linking BIM and green building rating tools.

2 Building Rating Tools

Building rating tools or building assessment tools are commonly used to measure the environmental performance of a building. These include but are not limited to Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), Green Building Index (GBI), GreenRE, Green Mark, and many more. LEED was developed by U.S. Green Building Council (USGBC) in 1998 while BREEAM was established in the UK in 1990. Both GBI and GreenRE were developed in Malaysia, and Green Mark was developed in Singapore. Different countries have developed their building rating tools to suit the local conditions and requirements. All the rating tools serve the same purpose, which is to rate the sustainable performance of a building

according to different criteria such as energy efficiency, water efficiency, indoor air quality, transportation, and the like.

3. Building Information Modelling (BIM)

In recent years, Building Information Modelling (BIM) has been used to solve sustainability issues [17]. BIM provides a platform for visualising the physical and functional characteristics of a building. BIM also provides a large amount of data, including geometric and semantic data (Carneiro et al., 2018). This information can be superimposed into a BIM model and used in proposing sustainable measures during the design process [8]. Integration with BIM allows for more accurate environmental performance analysis and better sustainability assessments [7,14]. It is often used as a collaborative platform for information sharing among construction project stakeholders [15]. BIM is used in conjunction with Life Cycle Assessment (LCA) to improve a building's sustainability assessment. For instance, [41] introduced automated tools that use the BIM platform and LCA to calculate energy consumption and carbon emissions to assist decision-makers. [37] investigate the potential interconnections between BIM and LCA and concluded that BIM can aid in designing high-performance buildings. [5] established that integrating BIM and LCA can help designers choose more environmentally friendly materials and products. However, the focus of LCA is not on certification, classification, or meeting sustainable minimum requirements, but rather on comparing two sustainable buildings [1]. This study, on the other hand, focuses on reviewing research that uses BIM to aid in the certification process and the compliance of minimum sustainable requirements from building rating tools.

4. Research Methodology

This research adopts the systematic review method as suggested in the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) to examine the current state-of-art of the BIM application in assisting the building rating assessment. Two searches have been conducted in two journal databases, which include Scopus and Web of Science (WoS). A total of 352 papers have been returned from the searches and 19 papers are selected for review purposes after removing the duplicated papers, examining the inclusion and exclusion criteria, and abstract reviews. The review started with searches in Scopus and Web of Science that include the keyword of “BIM” and “building rating tools” and the search domain specified on “title/abstract/keywords” for Scopus and “all field” for WoS. 100 numbers of duplication have been excluded and 252 publications were initially identified. These publications were then narrowed down by excluding the non-English publications, conference papers, review papers, book series, book chapters, and papers not related to “BIM” and “building rating tools”. 123 journal articles have been detected and the abstract was assessed to identify the relevant publication. As a result, only a total of 19 studies from journal publications are selected for the review process as the rest either do not include BIM, focus on enhancing building efficiency but do not include building rating tools, survey studies, or studies that focus on developing new rating tools. Following the identification of publications that incorporate BIM and building rating tools, subcategories and the focus of publications are extracted and further analysed through manual content analysis to evaluate and theme research works in this area based on pattern identified. The paper then summarises the extent to which BIM is integrated with green rating tools for future research directions.

Table 1. Search string according to each journal database.

Journal Database	Search string	Frequency of hits
WoS	"building information model*" OR "BIM" (All Fields) and "rating tool*" OR "assessment tool*" OR "rating system*" OR "LEED" OR "GreenRE" OR "GBI" OR "BREEAM" OR "GreenMark" (All Fields)	139

Scopus	(TITLE-ABS-KEY ("building information model*" OR "BIM") AND TITLE-ABS-KEY ("rating tool*" OR "assessment tool*" OR "rating system*" OR "LEED" OR "GreenRE" OR "GBI" OR "BREEAM" OR "GreenMark"))	213

5. Discussion

Out of 19 publications, 15 publications integrate LEED with BIM, and 1 publication each integrates BIM with BREEAM, GBI, GreenRE, Green Mark, and BEAM Plus as shown in Table 1. As a result, it is possible to infer that LEED is the most commonly used building rating tool for integration with BIM, and the integrations are more established than with other building rating tools. The integration is primarily accomplished using BIM tools such as Autodesk Revit and Dynamo. These tools allow the building model to be embedded with the parameters required for the sustainable analysis. Additional parameters and formulas can be added to Revit libraries to automate the calculation of energy consumption, carbon emissions, and other variables [28]. Meanwhile, Dynamo functions as a Revit plug-in, allowing data to be exchanged between Revit and other design tools [29]. Furthermore, BIM data can be extracted and imported into building simulation software such as Green Building Studio and Ecotect [34].

Table 2. Building rating tools that have been integrated with BIM in current research.

No.	Building Rating Tools	Number of Publication
1	Leadership in Energy and Environmental Design (LEED)	14
2	Building Research Establishment Environmental Assessment Method (BREEAM)	1
3	Green Building Index (GBI)	1
4	GreenRE / Green Mark	1
5	BEAM Plus	1

The integration of BIM and building rating tools can be divided into several subcategories. The integration can aid the designers to obtain desired credit with minimum cost [2], simulate energy consumption [3,34], and assist in credit calculation for certification process [4,12,20,23,35,39]. Based on the publications reviewed, it can be concluded that research integrating BIM and building rating tools is very limited. Nonetheless, some publications discuss the use of BIM to improve energy efficiency, water efficiency, indoor air quality, and other aspects without mentioning the building rating tools that are used. The emphasis in these publications is not on meeting the minimum sustainable requirement in building rating tools.

Most of the publications focus solely on energy and the environment because the credit allocation for this subcategory is the highest of any subcategory. Although many studies focus on calculating energy consumption by integrating BIM with energy simulation software, the energy simulation software used varies across publications. Sefaira [2], TRACE 700 energy simulation software [34], AECOsim Energy Simulator [39], and others are examples of energy simulation software. This has demonstrated BIM's ability to interoperate with various software, and BIM has great potential to aid the energy simulation process. Following energy and the environment, the second focus of these publications is on location and transportation, materials and resources, and water efficiency. The most common approach for locations and transportation analysis in the green certification process is the integration of BIM with web services [12,29], followed by Google Maps [12,21].

Table 3. Overview of current research on the integration of BIM and building rating tools.

No.	Author, Year	Title of the Study	Type of Publication	Green Rating Tool	BIM Tool (Software)	Other Software	Focus Area / Scope (Sub-categories of Building Rating)

1	(Akcay & Arditi, 2017)	Desired points at minimum cost in the "Optimize Energy Performance" credit of LEED certification	Case study	LEED	Revit	Sefaira (energy simulation), RSMeans (cost database)	Energy and atmosphere
2	(Al-Ghamdi & Bilec, 2015)	Life-cycle thinking and the LEED rating system: Global perspective on building energy use and environmental impacts	Case study	LEED			Energy and environmental impact
3	(Alwan et al., 2015)	Rapid LEED evaluation performed with BIM-based sustainability analysis on a virtual construction project	Case study	LEED	OpenBIM, Revit	IES software, Project Vasari	Energy
4	(Azhar et al., 2011)	Building information modeling for sustainable design and LEED ® rating analysis	Conceptual framework, case study	LEED			Energy and atmosphere, water efficiency, and indoor environmental quality only
5	(Chen & Nguyen, 2017)	Integrating web map service and building information modeling for location and transportation analysis in the green building certification process	Framework development	LEED	Revit	Web Map Service (WMS)	Transportation and location
6	(Chen & Nguyen, 2019)	A BIM-WMS integrated decision support tool for supply chain management in construction	Framework development	LEED	Revit	Web Map Service (WMS):: Google Maps	Transportation and location
7	(Ilhan & Yaman, 2016)	Green building assessment tool (GBAT) for integrated BIM-based design decisions	Framework development	BREEAM	Graphisoft ArchiCAD ®	MC Access Database Engine®, IFC File Analyzer	Material selection
8	(Jalaei & Jrade, 2015)	Integrating building information modeling (BIM) and LEED system at the conceptual design stage of sustainable buildings	Conceptual framework, Model development	LEED	Revit		Energy atmosphere; and material and resources
9	(Jalaei et al., 2020)	An integrated BIM-LEED application to automate sustainable design assessment framework at the conceptual stage of building projects	Model development	LEED	Revit, Green Building Studio (GBS)	Google Map, KNN algorithm	Location and transportation; Sustainable sites; Water efficiency; Energy and atmosphere; materials and resources; IEQ; Innovation; and Regional priority
10	(Kang, 2019)	Rule-Based LEED Evaluation Method considering BIM Linkage and Variability	Method development	LEED			All categories
11	(Khoshdelnezamiha et al., 2020)	Evaluation of BIM application for water efficiency assessment	Tool development	GBI	Revit, Green Project Template, GBS, Dynamo		Water
12	(Krishnamurti et al., 2012)	Modeling water use for sustainable urban design	Prototype development	LEED	Revit	Grasshopper and Rhino	Water
13	(Li et al., 2019)	Integration of Building Information Modeling and Web Service Application Programming Interface for assessing building surroundings in early design stages	Method development	LEED	Dynamo	web service APIs	Transportation and location

14	(Marzouk et al., 2018)	BIM-based approach for optimizing life cycle costs of sustainable buildings	Framework development	LEED	Revit	Monte-Carlo Simulation	Material selection
15	(Ryu & Park, 2016)	Guidelines for using building information modeling for energy analysis of buildings	Guideline development	LEED	Revit	TRACE 700 energy simulation software	Energy simulation
16	(Seghier et al., 2017)	Building Envelope Thermal Performance Assessment Using Visual Programming and BIM, based on ETTV requirement of Green Mark and GreenRE	Framework and model development	Green Mark, Green RE	Revit, Dynamo	Visual Programming Language (VPL)	ETTV
17	(Wong & Kuan, 2014)	Implementing 'BEAM Plus' for BIM-based sustainability analysis	Survey study, framework development, case study	BEAM Plus	Revit		Site aspect, material aspect, energy use, water use
18	(Wu & Issa, 2012)	Leveraging Cloud-BIM for LEED Automation	Review, framework development	LEED	Revit, Cloud	AECOsim Energy Simulator, LoraxPro	Energy
19	(Wu & Issa, 2015)	BIM Execution Planning in Green Building Projects: LEED as a Use Case	Case study	LEED			Energy

6. Conclusion

The integration of BIM-building rating tools can help to accelerate the green certification process. Upon reviewing the publications, it can be summarized that the research integrating BIM and building rating tools is very limited, which explains why the manual approach to green building ratings is still extensively adopted. LEED, as opposed to BREEAM, GBI, GreenRE, Green Mark, and BEAM Plus, is a widely used building rating tool for integration with BIM software. As the integration method is conceivably not established, research on BIM-green building tools must be expanded.

It was also discovered that research on the BIM-building rating tool is primarily focused on extracting information from the BIM model to improve building sustainability rather than automating the green certification process. Furthermore, it can be summarised that the uses of BIM to obtain credit under energy efficiency subcategories are more mature than other subcategories. Water efficiency, location and transportation, material and resources, sustainable site, indoor environmental quality, innovation, and regional priority are some of the other sub-categories under green certification that are deemed understudied within the context of BIM-building rating. Future research can focus on these sub-categories to increase the use of BIM for green ratings. The limitation of this research is that the publications included for review focus solely on the integration of BIM and building rating tools, rather than on publications that improve sustainability through the use of BIM software.

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