Analysis of BIM-Based Digitising of Green Building Index (GBI): Assessment Method

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Abstract: There is currently an increasing demand for Building Information Modelling (BIM) to be integrated into green projects. BIM is able to evaluate green building assessment tools by digitising and assessing buildings during their development stage. In Malaysia, the Green Building Index (GBI) promotes sustainability in the built environment. Six categories of criteria will be assessed in three of the certification stages. This study focuses on how BIM applications can digitise the GBI criteria for GBI processes. It examines BIM uses and tools of each GBI credit and defines the responsibility and role of construction stakeholders in using BIM to examine the assessment methods used for new non-residential building construction based on GBI. The primary method for data collection is the focus group interview which involves the groups of stakeholders involved in a BIM and GBI project. The result of the BIM–GBI assessment method showed that BIM could digitise and assess 25 credits in Design Assessment (DA), which can achieve 55 points of the total 100 points. This study helps stakeholders define the design team and facility manager's roles to obtain GBI certification and maintain the certification during the building's operation stage.

Keywords: building information modelling; green projects; assessment; green building index

1. Introduction

1.1. Research Background

BIM and sustainability are relatively new concepts in the architecture, engineering, and construction (AEC) industry [1]. The growth increments using BIM contribute to innovative opportunities by making cost estimation more accurate for any building at various stages. Therefore, the possible relationship between BIM and sustainability is still being studied [2]. Krygiel and Nies (2008) have suggested several modifications to BIM, such as improving interoperability and integrating a carbon accounting tracker and weather data to facilitate the next steps in enhancing sustainability capabilities [3]. Azher et al. described the use of BIM to select building orientation, evaluate skin options, and perform daylight studies for positioning on selected sites during the design phase to enhance sustainability [4]. The main role for designer is to analyse the building as a fully integrated dynamic design, and the sustainability construction process has the potential

toward net-zero energy buildings and carbon emission reduction [5]. Stadel et al. (2011) suggested that BIM applications be used together with life cycle assessment (LCA) to perform carbon accounting by exporting the material schedule of the building and using BIM software plug-ins to calculate operational energy use and carbon emissions [6]. The BIM works through the applications for sustainable building and sustainability analyses, an extraordinarily advanced and necessary method for the digitisation process in the construction sector, and its considerable use is evident [7].

Among the benefits of BIM is its support for sustainable building in terms of design, construction, and operation; BIM data can also evaluate the green building assessment tools [8]. Although several sustainable building rating systems provide green building certification for design and operation, there is still a need to accomplish a green rating system [9]. Mohamed et al. (2018) pointed out that there is a need for the BIM application to solve some barriers to achieving green buildings [10]. Furthermore, the BIM can manage rating systems criteria within a double level of complexity which will be a problem of defining all the right attributes to fulfil the criteria calculation procedures for green building certification [11].

1.2. Literature Review

In the past decade, several studies on BIM for green buildings (Green BIM) have been extensively investigated. For instance, the BIM model data can be utilised as a green assessment tool [12]. However, the green BIM can improve performance analysis and evaluations such as energy analysis, carbon emissions, acoustic analysis, waste management, lighting analysis, operational energy use, and water use [13]. In recent years, innovative development in BIM has provided opportunities to support green building practices and is classified as Green BIM [14]. A fundamental definition of green BIM is a model-based process for generating and managing coordinated and consistent building data to accomplish established sustainability goals [15]. This BIM-based model can also evaluate post occupancy processes and maintain the green building certification of green rating system tools [16].

Azhar et al. (2008) have investigated the use of building performance analysis software tools to assess the suitability of using the tools such as BIM-based sustainability analysis methods [17]. Moreover, BIM-based energy simulation tools have been used to predict energy savings during sustainable buildings' design phase [18]. BIM tools are able to calculate and manage criteria from the early design stages and allow for a better and more sustainable design to be made based on the three pillars of environmental, economic, and social issues, and thus give better results during the construction and operation of the building; this can also be achieved for green building assessment [19,20]. BIM with sharing digital modelling and analysis tools can form an efficient basis for evaluating multiple design alternatives to improve the sustainability assessment process [21].

The Green Building Index (GBI) is a green building assessment tool used in Malaysia [22]. It is similar to the rating system tools used in other countries, such as Leadership in Energy and Environmental Design (LEED) in the USA, Building Environmental Assessment Method (BEAM) Plus in Hong Kong, Green Star in Australia, and Green Mark in Singapore [23]. The GBI, which was developed by the Malaysian Institute of Architects in 2009, is composed of 14 rating tools with different criteria and point allocations; the criteria comprise six categories, namely, Energy Efficiency (EE), Sustainable Site Management and Planning (SM), Indoor Environmental Quality (EQ), Water Efficiency (WE), Materials and Resources (MR), and Innovation in Design (IN) [24,25]. A total of 100 points is allocated by the GBI criteria that are divided into four levels of certification, namely, GBI-certified (50–65), silver (66–75), gold (76–85), and platinum (86–100) [26,27].

The GBI assessment process is divided into three stages: (i) Application and registration. The GBI application form, which contains the applicant's contact details, project information, and GSB supporting documents, must be completed and submitted [28]; (ii) Design assessment (DA) pertains to the submission of the project for GBI DA, directly

or through an appointed GBI facilitator, during the final stage; (iii) In the completion and verification assessment (CVA), the applicant must undergo CVA within 12 months after the completion of the building or when the building is 50% occupied, whichever comes first [28].

The capability of BIM as a green building assessment tool in comparison with other tools, such as LEED, BEAM Plus, and Green Star, has been highlighted by several researchers [29]. BIM for energy efficiency (EE) model has been proposed to evaluate sustainable building design for GBI [30]. According to Solla (2019), BIM has substantial effects on GBI design assessment, especially BIM tools' capability to digitalise GBI criteria and render the application useable for GBI assessment [8]. BIM assesses 38 of the total 69 credits for LEED, where 31 credits require supporting documents that cannot be provided by the BIM software [31]. Barnes and Castro stated that BIM could assess 13 credits and 1 prerequisite by directly evaluating and documenting the LEED rating system using Autodesk Revit [32]. BEAM Plus has 80 credits, whereas BIM has 26 credits. A total of 30 credits requires calculations or tests that cannot be achieved using BIM [33]. In addition, 97 of the 146 points can be achieved using BIM, which is a rating of 66% in the Green Star rating system [34]. BIM can be integrated with GBI by implementing a suitable approach and tools into the BIM execution plan [35].

1.3. Research Motivation

Based on the literature review, few researchers highlighted the importance of BIM-based digitising with GBI as an assessment approach during the building's operation stage guidelines [36–38]. Therefore, the motivation is to conduct an in-depth study to analyse the scope to which the process of implementation in BIM application analysis with GBI assessment certification will show the professional's team how to analyse each GBI criteria credit with the certification process being scientifically researched. This research also enables us to establish a basis for working within this framework for integrating the BIM methodology.

1.4. Research Objectives

The research objectives are based on highlighting the importance of BIM-based digitising with GBI as an assessment approach during the building's operation stage guidelines. Moreover, this study also explores the ability of BIM to achieve GBI credit by using BIM directly or indirectly by providing external information for each GBI credit in the DA and CVA stage.

2. Methodology

This study adopts a qualitative approach through a focus group interview, a valuable tool for collecting qualitative data [39]. The focus group interview's primary purpose is to analyse the BIM–GBI assessment method framework using five constructs: BIM uses, BIM tools, GBI criteria, GBI process, and responsible party, as shown in Figure 1.

Invitation letters, consent forms, research frameworks, and primary questions were distributed to potential respondents to confirm that they consent to participate in the study and give them a general idea about the interview's objectives [40]. This step is vital to reduce the duration of meeting with each group and help the respondents answer the questions accurately [41].

As shown in Figure 2, the research framework is presented, introducing the main phases of the qualitative approach that covered two focus group meetings (sessions). The focus group meeting was conducted with BIM, GBI, and facility management teams. The focus group interview with the combined groups was conducted in two sessions; the interview with the BIM and GBI teams for DA was carried out on 12 February 2018, while 12 participants for the second session of the interview with the BIM, GBI, and facility management teams for CVA was carried out on 5 June 2018.
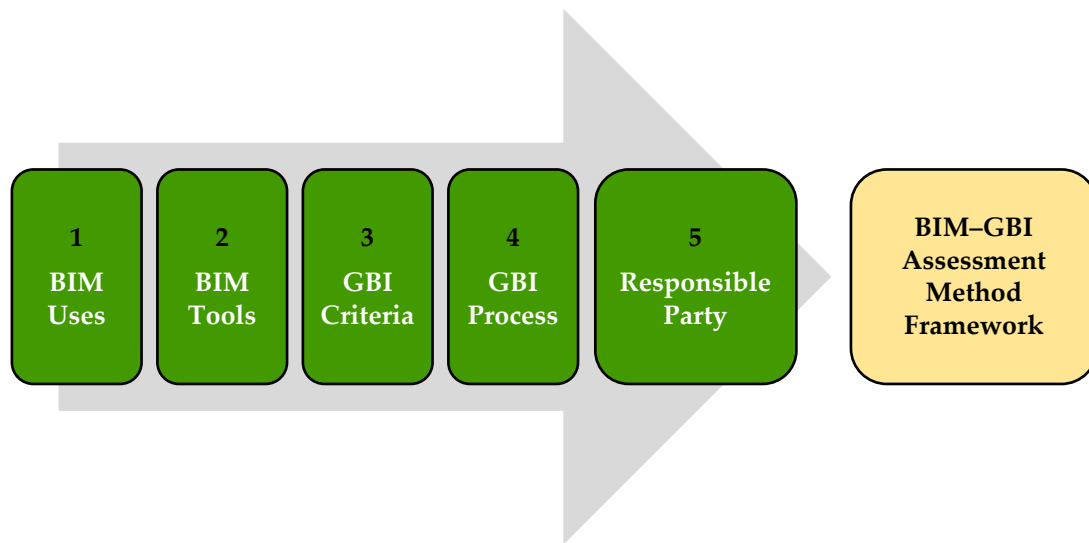
Figure 1. BIM–GBI assessment method framework.
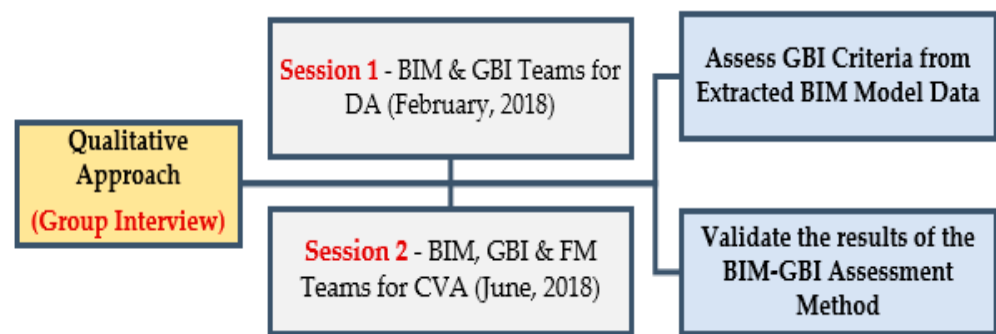
Figure 2. Research framework.

The group sessions' primary focus is BIM tools' ability to assess the GBI criteria from the extracted BIM model data (Table 1). This process helped interviewees to validate the result of the BIM–GBI assessment method.

Table 1. The Focus Group Session.

Focus Group Session	Involved Group	Tasks	Deliverable
Session 1	➢ BIM Team ➢ GBI Team	➢ Define the development project stage for each credit. ➢ Define the direct and indirect BIM assessment for each credit. ➢ Define the BIM uses during design assessment for each credit.	Determine the BIM assessment method for GBI credits in design assessment (DA)
Session 2	➢ BIM Team ➢ GBI Team ➢ FM Team	➢ Validate the development project stage for each credit from the first sessions. ➢ Define the method for assessing the indirect assessment for each credit. ➢ Define the BIM uses during the operation assessment of each credit.	Determine the BIM assessment method for GBI credits in operation assessment (CVA)

3. Discussion of the Results

The BIM tool was developed to examine the feasibility of linking and processing parametric building information related to each GBI subcategory. However, this study aims to develop a BIM–GBI assessment method for the Malaysian construction industry. Results show that BIM must be used for GBI assessment during the DA and CVA stages. A qualitative approach was used to analyse the BIM–GBI assessment method. This method was used to assess each GBI credit using BIM tools, either through authoring or analysis tools with a specific parameter, such as project (BIM direct credit) or new parameters (BIM indirect credit), for both GBI process stages. This method is also used to define the elements of each GBI credit. Table 2 shows the final result of the BIM–GBI assessment method.

Table 2. BIM-GBI Assessment Method.

1	2	3	4	5		
GBI Credit	**GBI Criteria**	**BIM Uses**	**GBI Process**			
EE1	Minimum EE Performance	Energy analysis	DA			Preconstruction Stage
EE2	Lighting Zoning	Lighting analysis	DA			
EE3	Electrical Sub-metering	Energy analysis	DA			
EE4	Renewable Energy	Energy analysis	DA	1		
EE5	Advanced or Improved EE Performance-BEI	Energy analysis	DA			Construction Stage
EE6	Enhanced or Re-commissioning	Asset Management	CVA			
EE7	Post Occupancy Commissioning	Project system analysis	CVA			
EE8	EE Monitoring & Improvement	Project system analysis	CVA			Postconstruction Stage
EE9	Sustainable Maintenance	Maintenance scheduling	CVA			
EQ1	Minimum IAQ Performance	Energy analysis	DA			
EQ2	Environmental Tobacco Smoke	Space Management	CVA			
EQ3	Carbon Dioxide Monitoring	Space Management	CVA			
EQ4	Indoor Air Pollutants	Asset management	CVA			
EQ5	Mould Prevention	Project system analysis	CVA			
EQ6	Thermal Comfort: design	Maintenance scheduling	CVA			
EQ7	Air Change Effectiveness	Maintenance scheduling	CVA			
EQ8	Daylighting	Daylighting analysis	DA			Direct BIM Credit
EQ9	Daylight Glare Control	Daylighting analysis	DA			
EQ10	Electric Lighting Levels	Lighting analysis	DA	2		
EQ11	High-Frequency Ballasts	Lighting analysis	DA			
EQ12	External Views	Daylighting analysis	DA			Indirect BIM Credit
EQ13	Internal Noise Levels	Project system analysis	CVA			
EQ14	IAQ Before/During Occupancy	Maintenance scheduling	CVA			
EQ15	Occupancy Comfort Survey: Verification	Project system analysis	CVA			

Table 2. *Cont.*

1	2	3	4	5		
GBI Credit	**GBI Criteria**	**BIM Uses**	**GBI Process**			
SM1	Site selection	Site analysis	DA			
SM2	Brownfield Redevelopment	Space management	CVA		Preconstruction BIM Uses	
SM3	Development Density	Site analysis	DA			
SM4	Environment Management	Space management	CVA			
SM5	Earthworks - Construction	Construction system design	DA			
SM6	QLASSIC	Site utilisation	DA	3	Construction BIM Uses	
SM7	Workers' Site Amenities	Site utilisation	DA			
SM8	Public Transportation Access	Site analysis	DA			
SM9	Green Vehicle Priority	Asset management	CVA			
SM10	Parking Capacity	Site analysis	DA			
SM11	Stormwater Design – Quantity	Asset management	CVA		Postconstruction BIM Uses	
SM12	Greenery & Roof	Design authoring	DA			
SM13	Building User Manual	Space management	CVA			
MR1	Materials Reuse and Selection	Site utilisation	DA			
MR2	Recycled Content Materials	Site utilisation	DA			
MR3	Regional Materials	Site utilisation	DA			
MR4	Sustainable Timber	Site utilisation	DA			
MR5	Storage, Collection	Site utilisation	DA			
MR6	Construction waste management	Site utilisation	DA			
MR7	Refrigerants & Clean Agents	MEP analysis	DA			
WE1	Rainwater Harvesting	Water& MEP analysis	DA		Design Assessment (DA)	
WE2	Water Recycling	Project system analysis	CVA			
WE3	Water Efficient	MEP analysis	DA	4		
WE4	Water Efficient Fittings	Project system analysis	CVA			
WE5	Metering & Leak Detection	Maintenance scheduling	CVA			
IN1	Innovation in design and environment design initiatives	Engineering analysis	DA		Compilation and verification assessment (CVA)	
IN2	Green building index accredited facilitator	Asset management	CVA			

BIM tools can be applied directly or indirectly to assess GBI criteria. The direct method involves using authoring and analysis tools to assess each GBI credit from the BIM model. In the indirect approach, some GBI credits require further information, such as documentation, calculation, and testing, to be assessed using the BIM application. Figure 3 shows the BIM tools' applicability in assessing GBI credits for each of the direct and indirect methods.
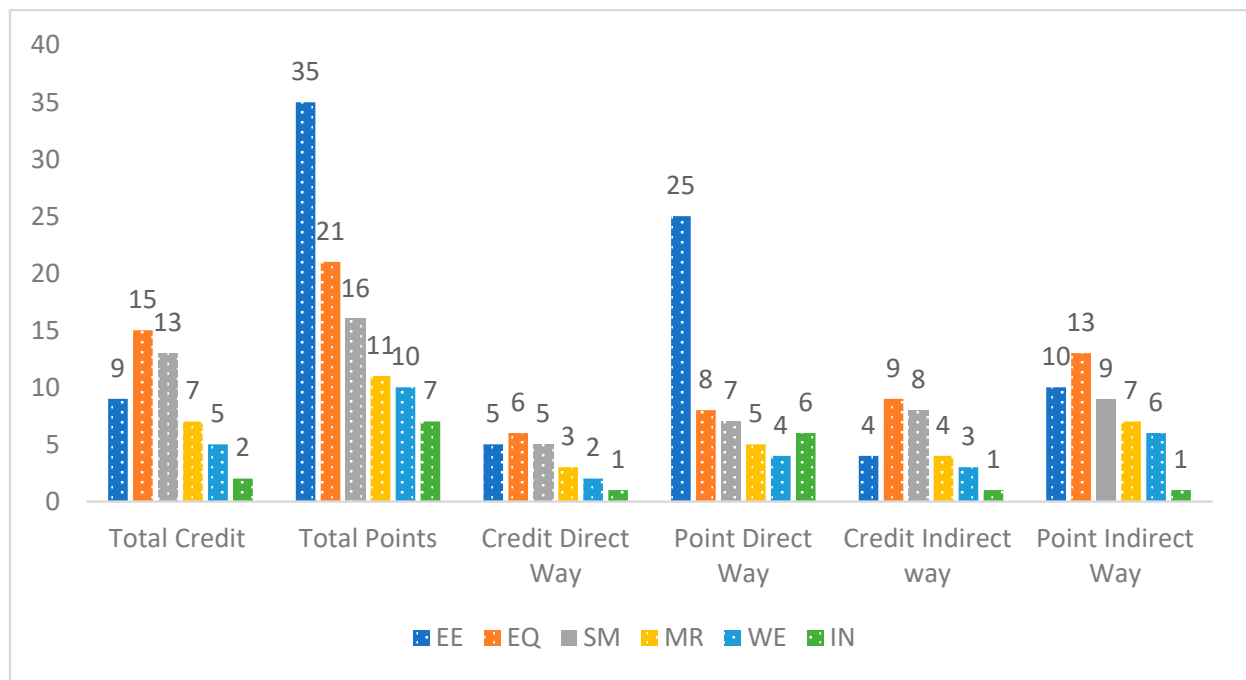
Figure 3. BIM Application Analysis Method.

The BIM application method can directly assess five credits by using authoring tools to assess two credits. Tools with EE of 25, of the total 35 points, can assess three credits. This means that BIM can assess five credits during DA by using two of the BIM preconstruction uses. The remaining four credits require additional information for the GBI process in the CVA stage using the BIM postconstruction uses. Figure 4 shows the BIM application's ability to assist the GBI criteria in the design (DA) and operation (CVA) stages in the GBI process.
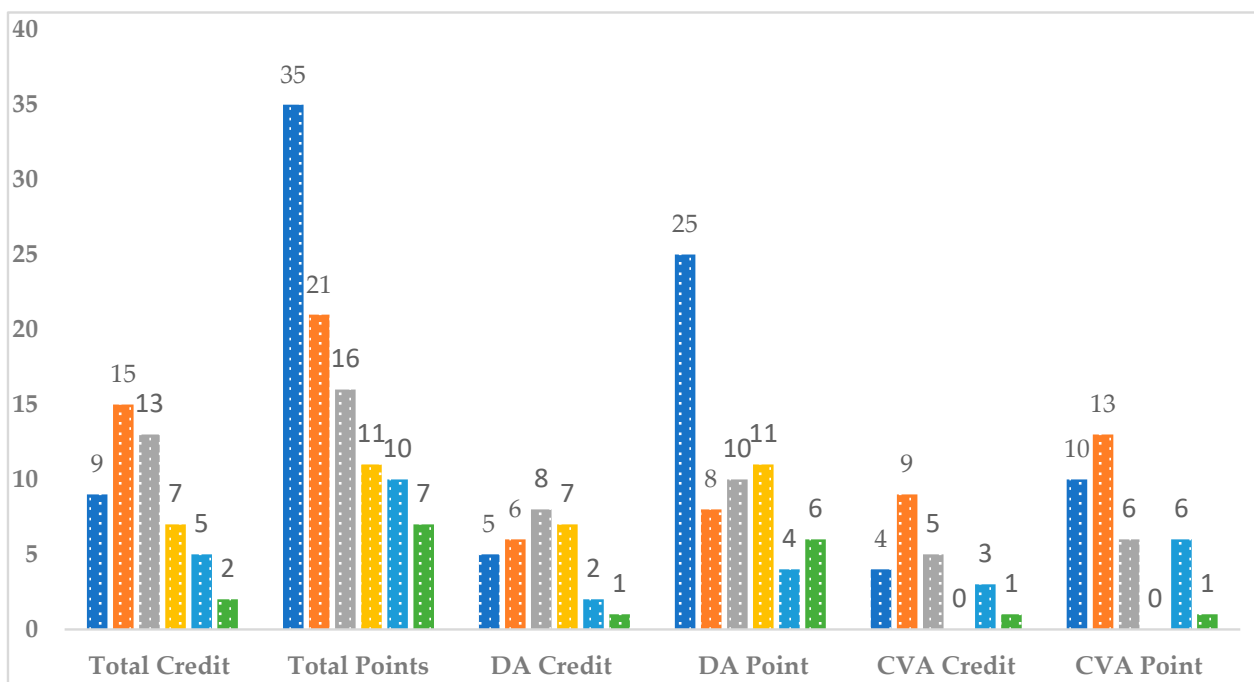
Figure 4. BIM Application in the GBI Process.

The second criteria in the GBI rating (EQ) are indoor environmental quality with 15 credits of the total 21 points. BIM can directly assess six credits, which can achieve eight points in the design assessment. The remaining nine credits of the total thirteen points can be assessed in CVA using the BIM postconstruction uses. The third GBI criteria are sustainable site management and planning (SM) and are allocated 13 credits of the total 16 points. Five credits can be directly assessed using BIM authoring tools, which can achieve seven points in DA. However, three credits can be assessed by providing information for the model, giving three points during DA. Five credits require additional information using BIM postconstruction use to digitise these credits in the CVA stage. Site utilisation is one of the BIM construction uses and can be applied to assess the materials and resources (MR) criteria in DA. MR has seven credits, but only three credits can be assessed directly using BIM through authoring tools, giving 5 of the 11 points. The remaining four credits with six points can be assessed by providing further information for the design stage model. BIM application can be directly assessed and can give 4 of the total 10 points and 2 credits by using the authoring and analysis tools for WE. The remaining three credits of the total six points can be assessed in the CVA stage using the postconstruction uses of BIM. The last category of the GBI criteria is innovation, and it has two credits of the total seven points. BIM can directly assess one credit in DA, which can give six points. The remaining credit with one point can be assessed by providing documentation in the CVA stage. In general, the BIM application is able to directly or indirectly assess GBI credits for the six GBI categories in different GBI assessment processes. Figure 5 shows the percentages of the capability of BIM to assess BIM credits and points in DA.
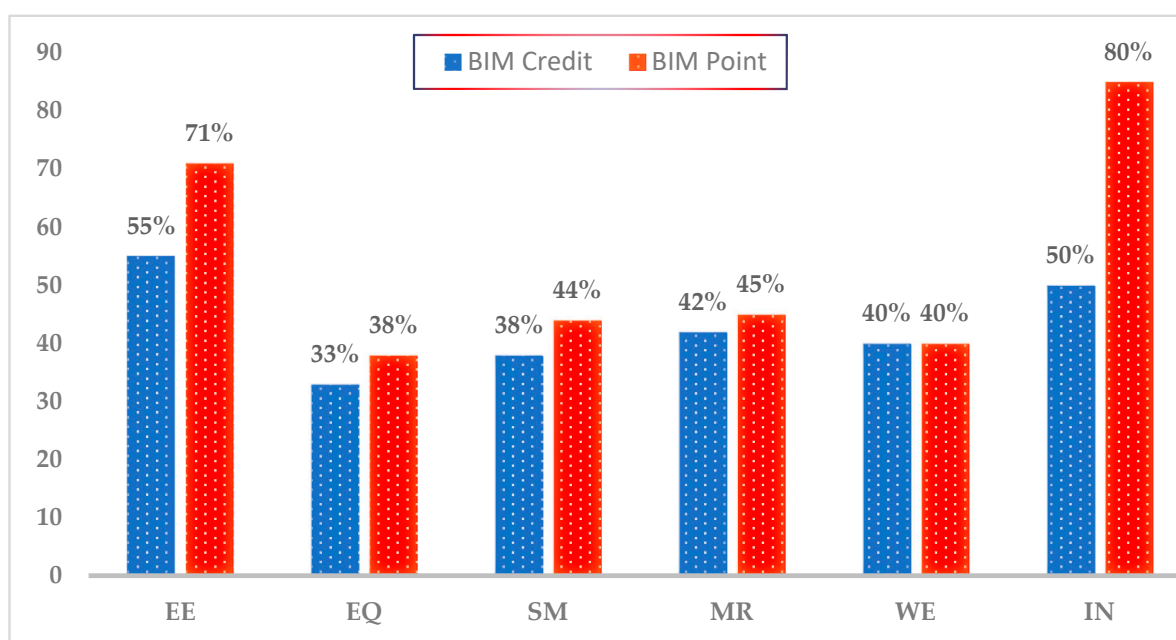
Figure 5. BIM–GBI Assessment in DA.

The GBI non-residential new construction criteria have 51 credits with a total of 100 points. In contrast, BIM application can achieve 22 credits of GBI criteria, which means that this approach can be digitally and directly assessed using BIM tools. Fourteen of the twenty-two credits can be assessed using authoring tools such as the Revit Autodesk software. Eight credits should be assessed using analysis tools, such as the IES software recommended by GBI. The remaining 29 credits of the GBI criteria can be assessed indirectly by providing additional information, such as documentation, calculation, testing, and adding new BIM tool parameters. BIM application can achieve 26 credits during DA, and 25 credits can be assessed during CVA assessment using BIM uses in different development construction stages. Of the 25 uses of BIM, only 16 are significant for the GBI

assessment process. This finding is the basis for the focus group interviews on BIM uses in the preconstruction stage for 20 credits. BIM use for construction has nine credits, and postconstruction uses can achieve 22 credits. BIM can help the design team achieve 55% of points in DA, which is Level 4 GBI certification with the certified rating. The remaining 45 % can be achieved by digital CVA assessment, which is appropriate for comparing GBI assessment with other tools, as shown in Figure 6.
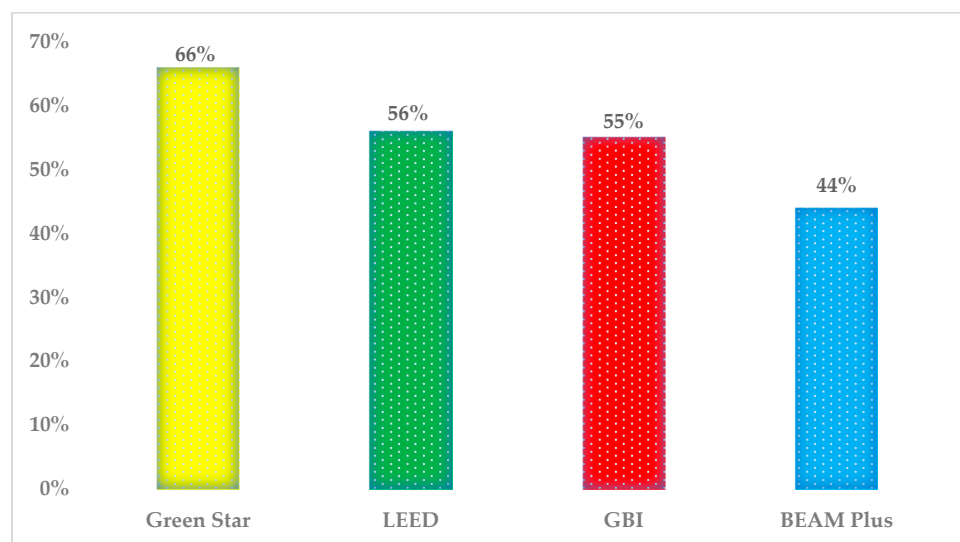
Figure 6. BIM assessment in the Green Building Tools.

4. Conclusions

The BIM application analysis with GBI assessment certification allowed the professional's team to analyse each GBI criteria credit with the certification process. This has given an understanding of the potential of using BIM with an interoperable automation approach in the GBI certification process. For the professionals involved in a project, the intended method has defined and assessed each GBI credit by BIM tools associated with a specific parameter in GBI process stages (BIM direct and indirect credit). BIM tools can digitalise and calculate GBI criteria in the early design stages, which allows the design team to produce better designs for sustainability based on the GBI assessment criteria and obtain better achievement during the construction and operation stages. BIM can define the GBI credit, which requires information exchange and additional documentation during the construction and operation stages for digitalisation in each of the 51 GBI credits. The BIM-based-GBI assessment method has provided a new role for the BIM tools, such as Revit functions, to prepare certification and documentation for GBI credits. By applying Revit capabilities along with the fully integrated and interoperable BIM protocol in GBI criteria, all the intended tasks can be achieved, such as 4D constructability, 5D cost estimating, maintenance scheduling, asset management, space management, lighting analysis, site utilisation, and MEP analysis. However, there is a need to verify further the potential of GBI based on a real case study and compare the results produced by the assessment application with the actual GBI submission. Further study is needed to assess how BIM tools and analysis can facilitate the analysis of potential GBI credits. In addition, the application procedures can be standardised and automatically processed by using Revit API functions to set up the corresponding programming. Overall, the BIM–GBI assessment method facilitates the function of BIM tools in the green building assessment and optimises the use of existing resources (i.e., Revit) by saving time preparing a certification submission for GBI in Malaysia.

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Abbreviations

BIM—Building Information Modelling; GBI—Green Building Index; LCA—life cycle assessment; LEED—Leadership in Energy and Environmental Design; BEAM—Building Environmental Assessment Method; EE—Energy Efficiency; SM—Sustainable Site Management and Planning; EQ—Indoor Environmental Quality; WE—Water Efficiency; MR—Materials and Resources; IN—Innovation in Design; DA—Design Assessment; CVA—Completion and Verification Assessment; FM—Facility Management.

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