Development of a Building Sustainability Assessment Method (BSAM) for Developing Countries in Sub-Saharan Africa

Abstract

The consideration of the regional context in the development of green building rating systems is well established in the previous literature, and this informs the development of a sustainability assessment method for sub-Saharan Africa. Hence, a multi-expert consultation method was carried out in Nigeria which is the largest economy in the region. This was performed via a structured questionnaire survey and interview approaches to identify the key sustainability assessment criteria, assign score-weights to the various criteria, and establish the certification grading system of buildings. The developed Building Sustainability Assessment Method (BSAM) scheme and its weighted criteria were validated using two existing building case studies. The established BSAM scheme was compared to six widely used green building rating systems. The comparative analysis reveals that the score-weights and priorities of the BSAM scheme were remarkably different from the existing rating systems. The study findings also show the increasing focus on the indoor environmental quality and energy criteria by all the rating systems. The developed BSAM scheme, meanwhile, has adequately considered the three main pillars of sustainable development unlike the existing green rating tools. Hence, it is expected for the proposed BSAM scheme to promote greener buildings and enhance sustainable urban development in the region.

Keywords: Assessment method; developing countries; green buildings; rating systems; sustainability; sub-Saharan Africa

1. Introduction

A desktop review of the extant literature conducted by Olawumi and Chan (2018a) and Olawumi and Chan (2017) reveals some salient sustainable development issues in the built environment. The statistics of the construction industry regarding its energy consumption rate stand at 32% of the global consumption rate (IPCC, 2007), its carbon emissions stand at 40% (Johansson et al., 2012), it contributes about 40% of the global solid waste generation (UNEP, 2011); utilizes 12% of the global freshwater and 1/3 of the global material usage (Olawumi and Chan, 2020; Ürge-Vorsatz et al., 2007; WEC, 2013). According to Tam et al. (2019b) and Le et al. (2018), the increase in these carbon emissions is a major contributory factor to global warming as well as the increased energy consumption due to the development of new buildings (Gobbi et al., 2016).

There is an increasing focus and attention on sustainability issues in the built environment, which has led to an increase in the number of certified green buildings nowadays when compared to the advent of the Building Research Establishment Environmental Assessment Method (BREEAM) in the year 1990. Green buildings have been recognized as the flagship of sustainable development in recent years with the increasing responsibility to cater to and balance the social, economic, and environmental sustainability issues (Ando et al., 2005). Green building rating systems (GBRS) have provided an effective means to assess the sustainability performance of various construction projects – be it buildings, civil engineering works, or infrastructure, as well as the integration of sustainable development objectives in such projects (Ali and Al Nsairat, 2009). Currently, there are over 400 registered software tools to assess various aspects of sustainability in buildings (Nguyen and Altan, 2011). More so, there are several green building rating systems such as BREEAM, Leadership in Energy and Environmental Design (LEED), Comprehensive Assessment System for Built Environment Efficiency (CASBEE), Green Star, BEAM Plus, Green Mark, among others, already in place worldwide. These green rating systems are used to address the quality of the building performance throughout its lifecycle as well as the impact of building on its surrounding ecosystem (Illankoon et al., 2017).

Ali and Al Nsairat (2009) argued that the use of these green rating systems in the evaluation of sustainability performance could yield significant benefits that might not be obtainable through the standard practice in the construction industry. A review of four Malaysian green rating tools by Hamid et al. (2014) revealed that these tools place emphasis on environmental sustainability and accordingly recommended the merging of these tools to better handle sustainability issues across the building lifecycle stages. Leading green rating tools such as LEED have similar disadvantages (Ismaeel, 2019; Wu et al., 2016). These figures further highlight the significance of sustainable buildings which are needed to improve the quality of life and health of its occupants, increase productivity, reduce air pollutions and CO_2 emissions, and enhance the efficiency of energy equipment among others.

1.1 Knowledge gaps, research objectives, and contributions to knowledge

However, a review of the extant literature and existing green building rating tools reveals some significant gaps in the existing body of knowledge. For instance, there are currently no available green rating systems that are suited for the local context of developing countries in sub-Saharan Africa. Although, some existing green rating tools such as BREEAM, LEED, and Green Star as discussed in section 4.2 have been attempting to expand their respective rating tools beyond the borders of the originating countries (Banani et al., 2013; Berardi, 2012; Mahmoud et al., 2019). However, none of these existing rating tools have extended their reach and rating tool to suit the local context of countries in the sub-Saharan region. Meanwhile, as argued by Todd and Geissler (1999) and Banani et al. (2013), the regional and local context of GBRS has a significant effect on the importance and priority given to each sustainability criterion in each rating system. A study by Hamid et al. (2014) argued the need to ensure that the national and international green rating tools are tailored to the local context to drive green building forward. Hence, as reported in the extant literature (Alyami and Rezgui, 2012; Xiaoping et al., 2009), these regional variations in the priority of the key sustainable criteria hinder the direct use of the rating tool beyond the country of its origin or the local context to which it was designed for use.

Moreover, these GBRS place more substantial considerations on the environmental sustainability issues with little account (Illankoon et al., 2017; Nguyen and Altan, 2011) or a total neglect of social and economic pillars of sustainable development (Ding et al., 2018; Olawumi and Chan, 2018a, 2018b). Also, the Green Mark rating system does not allocate credit points for the ‘transportation’ criterion (BCA, 2015). Hence, to provide a better evaluation of the ‘greenness’ or sustainability of buildings; Alwisy et al. (2018) and Illankoon et al. (2017) recommended that future development of green rating tools should consider all three sustainability pillars.

Given the above, this study aims to develop a Building Sustainability Assessment Method (BSAM) tool for buildings (both new and existing buildings) to suit the local context of the sub-Saharan region as well as to establish the importance of the key sustainability criteria through their score-weighted category. The proposed BSAM scheme covers the triple pillars of sustainable development and provides profound improvements to the existing green building rating systems. This paper presents the first phase of the development of the BSAM scheme.

The current study will highlights the method and collaborative process of the experts’ consultation and discuss the development of the score-weighting for the key sustainability criteria of the BSAM scheme, the criteria significance as well as the certification grading system, and the validation of the BSAM scheme. Also, the study will illustrates the comparative assessment of the BSAM scheme to six selected green building rating systems.

2. Literature review

This section discusses the various literature review and methodological processes, which informed the development of the BSAM scheme.

2.1 Establishing the key sustainability assessment criteria

Extant literature and existing GBRS were reviewed as illustrated in Table 1 to shows the current trends and the relevant research gaps in these GBRS and the literature. The research gaps in these GBRS and the literature are enormous, however, only those identified in Table 1 are resolved in this study. The review of the literature was carried via a content analysis approach (*see* Downe-Wamboldt, 1992; White and Marsh, 2006) to identify the variables or criteria defined and considered by previous studies as important in the assessment of green buildings' sustainability performance.

Table 1: Review of relevant sources for the development of the BSAM scheme

S/N	Sources	Publication type	Contributions to existing knowledge that supports the current study	Research gaps
1.	**Review of extant literature**			
a.	Factors affecting green building projects (Ahmad et al., 2019; Cooper, 1999; Olawumi and Chan, 2019a)	Journal articles	• Provided some barriers, benefits, and drivers paradigms affecting green buildings. • Provided recommendations for improving the implementation of green buildings.	• Provided only conceptual descriptions of green building paradigms.
b.	Review of some green rating tools based on key sustainability criteria (Ali and Al Nsairat, 2009; Alyami and Rezgui, 2012; Humbert et al., 2007; Illankoon et al., 2017)	Journal articles	• Provided in-depth reviews of the development of some green rating systems – credit points, methodology, data collection. This provided insight into the development of the BSAM scheme. • Description of some key sustainability criteria. These criteria were modified for the development of the BSAM scheme.	• Revealed that there are no suitable green rating tools for the African continent.
c.	Development of green building assessment methods. (Atanda,	Journal	• Developed green building rating systems for some developing	• Little or no emphasis on the social and economic

S/N	Sources	Publication type	Contributions to existing knowledge that supports the current study	Research gaps
	2019; Banani et al., 2013; Gething and Bordass, 2006; Mahmoud et al., 2019)	articles	countries. • Utilize several aggregation techniques in the development of the assessment methods.	sustainability. • No related green rating system suited for the local context of countries in Africa.
d.	Implementation of green rating tools and review of its practices. (AlWaer and Kirk, 2012; Bunz et al., 2006; Chew and Das, 2008; Kaur and Garg, 2019; Sev, 2009)	Journal articles	• Provided in-depth reviews of the development of some green rating systems across North America, Asia, and Europe. • Discussed some key sustainability criteria and shows how the construction industry practices can lead to sustainable development.	• Revealed that there are no suitable green rating tools for the African continent.
e.	Issues with adopting the existing green rating tools (Ding, 2008; Ding et al., 2018; Dwaikat and Ali, 2018; Olawumi and Chan, 2019b)	Journal articles	• Revealed the salient challenges hindering use of the existing green rating tools. • Expatiate on the economic performance of green buildings.	• Revealed the need to bridge the current limitations in the development of new green rating tools.
2.	**Green rating systems**			
a.	**LEED green rating system** i. LEED (v. 4) for Homes Design and Construction (USGBC, 2017) ii. LEED v4 for Interior Design and Construction (USGBC, 2018a) iii. LEED v4 for Building Operations and Maintenance (USGBC, 2018b) iv. LEED v4.1 Operations and Maintenance (USGBC, 2018c) v. LEED v4 for Neigbourhood Development (USGBC, 2018d)	Scheme documentation	• Features a three-level hierarchical structure of sustainability criteria • Use of experts' surveys to determine its credit points • Different schemes for the various building development stage • Greater emphasis on environmental sustainability such as IEQ and Energy, etc. • Relevant schemes for countries in North and South America, and Europe.	• Little or no emphasis on the social and economic sustainability. • No related scheme suited for the local context of countries in Africa.
b.	**BEAM Plus** i. BEAM Plus New Buildings V2.0 (HKGBC, 2018) ii. BEAM Plus Existing Buildings Version 2.0 - Comprehensive Scheme (HKGBC, 2016)	Scheme documentation	• Features a three-level hierarchical structure of sustainability criteria • Involved the participation of experts and industry practitioners in developing the scheme. • Scheme available only for new and existing buildings. • Solely considers environmental sustainability.	• No emphasis on the social and economic sustainability. • Applicable for use solely in Hong Kong

S/N	Sources	Publication type	Contributions to existing knowledge that supports the current study	Research gaps
c.	**BREEAM** i. BREEAM UK New Construction (BRE, 2018) ii. BREEAM In-Use International (BRE, 2016)	Scheme documentation	• Features a three-level hierarchical structure of sustainability criteria • Use of experts' surveys and consultation to determine its credit points • Different schemes for the various building development stage • Greater emphasis on environmental sustainability such as IEQ and Energy, etc • Relevant schemes for the UK and other countries in Europe.	• Little or no emphasis on the social and economic sustainability. • No related scheme suited for the local context of countries in Africa.
d.	**CASBEE** for New Construction (IBEC, 2008, 2004)	Scheme documentation	• Features a two-throng assessment category of quality and load • Divides the building project using a hypothetical internal and external boundary.	• No emphasis on the social and economic sustainability. • Applicable for use solely in Japan • Sole emphasis on a few environmental sustainability criteria.
e.	**Green Mark** i. Green Mark for Residential Buildings (BCA, 2015) ii. Green Mark Certification Standard for New Buildings (BCA, 2010)	Scheme documentation	• Features a three-level hierarchical structure of sustainability criteria • Involvement of more than 130 industry members and academics in the setting of metrics, assessment methods, and performance levels • Different schemes for the various building development stage • Greater emphasis on environmental sustainability.	• No emphasis on the social and economic sustainability. • Applicable for use solely in Singapore • Sole emphasis on a few environmental sustainability criteria.
f.	**IGBC** Green New Buildings Rating System (IGBC, 2014)	Scheme documentation	• Features a three-level hierarchical structure of sustainability criteria • Involvement of more than 1,923 industry experts in its development. • Sole emphasis on environmental sustainability.	• No emphasis on the social and economic sustainability. • Applicable for use only in the Indian context.
3.	**Green building technical notes**			
a.	Environmental design guide (CIBSE, 2007)	Technical note	• Provided some data values, equations, and reference tables,	• Focused on environmental sustainability aspects.

S/N	Sources	Publication type	Contributions to existing knowledge that supports the current study	Research gaps
			which were used in the evaluation of some environmental sustainability criteria for the BSAM scheme.	
b.	GSA Lighting (GSA, 2019)	Technical note	• Provided some data tables which were referenced in some IEQ criterion in the development of the BSAM scheme.	• Focused only on an environmental sustainability criterion.
c.	Energy and Use of Energy: Calculation and Application of OTTV and U-value (HKIA, 2012)	Technical note	• Provided some equations, and reference tables which were used in the evaluation of some energy criterion for the BSAM scheme.	• Focused only on an environmental sustainability criterion.
d.	Green Mark i. Handbook on Energy Conservation in Buildings and Building Services (BCA, 1986) ii. Guidelines on Envelope Thermal Transfer Value for Buildings (BCA, 2004)	Technical note	• Provided some data values, equations, and reference tables, which were used in the evaluation of some energy criterion for the BSAM scheme.	• Focused only on an environmental sustainability criterion.

More so, as shown in Table 1, a review of existing and leading green rating systems was conducted, such as BREEAM, LEED, BEAM Plus, CASBEE, Green Mark, Green Star, IGBC among others. These rating systems were sourced from their publicly available repository.

The four steps of the review process highlighted above informed the identification of the three levels of the sustainability criteria. The levels of classification of the sustainability criteria of the BSAM scheme is based on the format of other well-established rating systems such as LEED, BREEAM, etc. which utilized similar system. Hence, the sustainability criteria consist of eight (8) key sustainability indicators – which are the level 1 criteria. For the sustainability attributes (level 2 criteria) – which are the subsets of their respective indicators, there are thirty-two (32) attributes; and lastly, for the sustainability sub-attributes – which are the sub-sets of their attributes, there are 136 sub-attributes. Most green rating systems whether designed for country-wide use (Ali and Al Nsairat, 2009; Ameen and Mourshed, 2019; Berardi, 2012; Escolar et al., 2019; Mahmoud et al., 2019) or regions (BCA, 2015;

USGBC, 2018b, 2018c) only evaluate the existing buildings. However, the BSAM scheme proposed in this study is designed to assess the “greenness” and sustainability performance of both new and existing buildings, a similar model is used by the BREEAM system (BRE, 2018, 2016). Designing the BSAM scheme to cater for both new and existing buildings will ensure the sustainability potential of building projects in developing countries which can be forecasted in the early stages of the building project development.

2.2 Review of the selected existing green building rating systems

This section provides an overview and justifications for the selection of the six existing GBRS used for comparative assessment along with the proposed BSAM scheme. The primary criteria for selecting these GBRS is that they are developed by members of the World Green Building Council (WGBC). According to the WGBC directory, there are 66 green building council members of three membership levels – established (38), emerging (10), and prospective (18) (WGBC, 2019). The “established” level members are defined as one with “*a fully developed and operational organization that is running impactful green building programs of work*” (WGBC, 2019). These green building councils are all independent, non-profit organizations with interest in the sustainability of the built environment and advance green building in their own countries. The six green rating tools selected for comparative evaluation in this paper are developed and implemented by established green building council members based on the WGBC classification.

The second criteria in selecting these GBRS are identifying the number of building projects that have received green certification based on these rating tools. The six green rating systems and the number of certified green projects include BREEAM (>560,000) LEED (>90,000), Green Mark (>3000), IGBC (>1800), Green Star (>1500), and BEAM Plus (>467). Apart from these listed rating tools, CASBEE, with over 14,000 certified green projects, was excluded in the comparative analysis because this rating tool does not allocate credit points to each of its sustainability criteria but instead uses the Building Environment Efficiency score to rate projects (Illankoon et al., 2017). Although there are several green rating tools (Bernardi et al., 2017; Nguyen and Altan, 2011), most of them are not members of the WGBC and are not widely used.

Among these GBRS, three tools, namely – BEAM Plus, IGBC, Green Mark, are country-specific systems, while BREEAM, LEED, Green Star have been adopted and their criteria have been modified for more than one country (see Table 2). It is noted that BREEAM and LEED are the most widely used worldwide (Banani et al., 2013; Illankoon et al., 2017; Nguyen and Altan, 2011) and widely accepted. Hence, the six GBRS were reviewed in this paper and explained in Table 2.

Table 2: BSAM scheme and the six selected existing green building rating systems

GB rating systems	Year	Region	Countries
LEED	1998	North America	United States of America, Canada
		South America	Argentina, Brazil, Chile, Peru
		Europe	Germany, Turkey, Spain, Poland, Sweden, Italy
		Asia	mainland China, Korea Republic, India, Jordan, Chinese Taipei, United Arab Emirates
BEAM Plus	1996	Asia	Hong Kong
BREEAM	1990	Europe	United Kingdom, Croatia, Germany, Netherlands, Poland, Spain, Sweden, Turkey, Norway, Switzerland, Austria, Luxembourg
		Asia	
IGBC	2001	Asia	India
Green Mark	2005	Asia	Singapore
Green Star	2003	Oceania	Australia, New Zealand
		Africa	South Africa
BSAM scheme (*current study*)	2019	Africa	Target countries – *sub-Saharan African countries*

Source: The data was sourced from the respective websites of the six GBRS.
Note: BEAM Plus – Building Environmental Assessment Method (Hong Kong); IGBC – Indian Green Building Council Rating (India); GB – Green Building

More so, most of the six selected green rating systems have different schemes available for the certification of different buildings types. For instance, BREEAM has five main schemes available, namely: (1) Communities (2) Infrastructure (3) New construction (4) In-Use (5) Refurbishment and (6) Fit-out.

3. Research methods and data collection

This section further discusses the research method and data collection approaches for the study.

The methodological approach employed for the development of the proposed BSAM scheme are shown in Figure 1. Firstly, a comprehensive desktop review of relevant guidelines and technical notes on green building practices was undertaken, as well as a holistic review of the existing green rating systems through peer reviewed journal articles and web pages using a content analysis approach (step A). These reviews formed the basis of the identification and establishing the key sustainability criteria (indicators, attributes, and sub-attributes) of the BSAM scheme (step B).

Using a similar approach adopted by the established green building councils for the development of existing green rating systems such as LEED, BREEAM, etc., the current study utilized experts' consultations and surveys to provide a quantitative measure suitable for the determination of credit points (score-weighting) and significance for the key sustainability criteria (step C). Hence, a set of questionnaire survey forms were distributed to the invited green building experts. The data collated from experts surveys and consultation helps in establishing the ranking of the key BSAM scheme criteria based on the allocated credit points (steps B and C).

More so, these preceding steps help to deduce the overall sustainability ranking of the benchmark building project (which helps to ascertain such building sustainability performance); and to establish the certification system of the BSAM scheme (step D and E). Lastly, towards justifying the contributions of the BSAM scheme to address the particular context of the sub-Saharan region – it was validated using two building projects situated within the region (step F). Meanwhile, to show the precedence of the BSAM scheme over the existing green rating tools – a comparative assessment of selected green rating systems with the BSAM scheme was undertaken via comparing the score-weight distributions of the key criteria of the respective green building rating systems (step G).

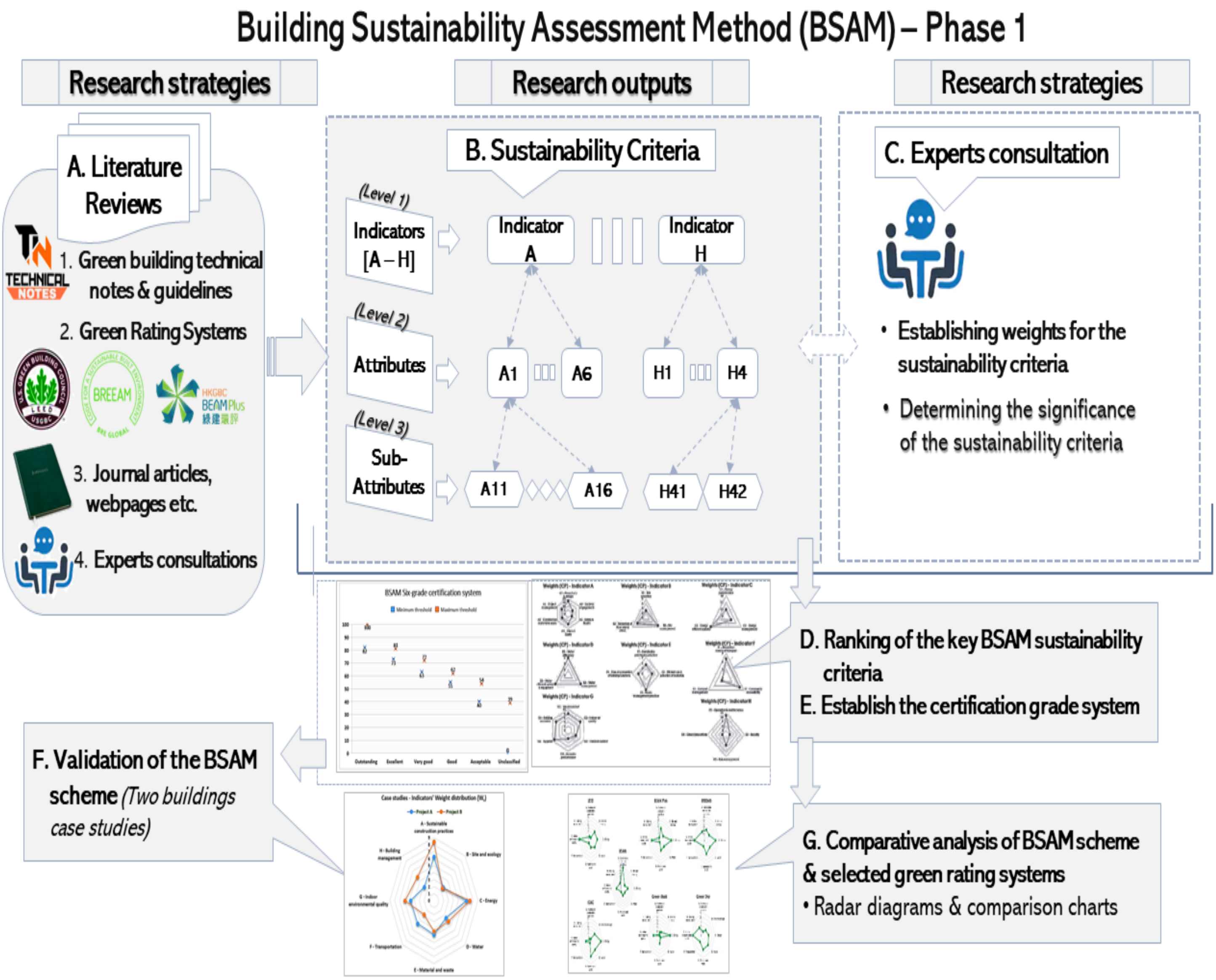

Figure 1: Methodological approach to BSAM scheme development

Note: Step A → Step B; there is a continuous loop between Step C and Step B until Step B is established; Step B → Step D and Step E. Step E → Step F and Step G. "→" = "leads to"

3.1 BSAM scheme: Its documentation and experts' consultations

The eight key sustainability indicators which are criteria to the sustainability performance of buildings and identified through the four stages of the review process include – 'sustainable construction practices', 'site and ecology', 'energy', 'water', 'material and waste', 'transportation', 'indoor environmental quality', and 'building management.' As mentioned, these sustainability indicators consist of sub-sets called attributes as illustrated in Figure 2, which are evaluated in the determination of the sustainability performance of buildings. The attributes also contain sub-sets called sub-attributes – which are numerous (136) and open to future improvement. A complete structure and components of the proposed BSAM scheme are given in Appendix A. The sustainability indicator "*sustainable construction practices*" is only assessed for new buildings and excluded in the sustainability assessment for existing building projects. Also, there are some subsets (sub-attributes) of the sustainability attributes which will not be evaluated for either new or existing buildings (Olawumi and Chan, 2019c). Readers can check the full documentation of the BSAM scheme for more details on which of the sub-attributes evaluate for new buildings and those that solely evaluate existing buildings.

Indicators	(A) Sustainable Construction Practices	(B) Site and Ecology	(C) Energy	(D) Water	(E) Material and Waste	(F) Transportation	(G) Indoor Environmental Quality (IEQ)	(H) Building Management
Attributes	Project Site & Design	Site Selection	Energy Performance	Water Efficiency	Sustainable Purchasing Practice	Alternative Means of Transport	Visual Comfort	Operation & Maintenance
	Societal Engagement	Site Management	Energy Management	Water Management	Efficient Use & Selection of Materials	Community Accessibility	Indoor Air Quality	Security
	Safety & Health	Reduction of Heat Island Effect	Energy Efficient Systems & Equipment	Water Efficient Systems & Equipment	Waste Management Practice	Transport Management	Thermal comfort	Risk Management
	Ethics & Equity				Ease of Conversion of Building Functions		Acoustic Performance	Green Innovations
	Construction Material & Waste						Hygiene	
	Project Management						Building Amenities	

Figure 2: Key sustainability indicators (A-H) and their associated attributes

For the evaluation of the sustainability criteria in building projects, it is recommended that the assessment be carried out by an independent third-party assessor.

3.2 Data collection and experts' demographics

Country-wide experts' consultations were undertaken in seven major cities in Nigeria via structured questionnaire surveys for six months which featured the engagement of 189 experts in the built environment towards the development of the BSAM scheme. In some instances, discussions and interviews were held with some experts who require clarification on the identified sustainability criteria. It is worthy of note that other well-established green building rating systems utilized surveys and interviews in developing the credit points for their rating systems. The participating experts were selected via a purposive sampling technique and snowball sampling.

As shown in Table 3, the experts were requested to supply their personal details such as – their professions, years of experience in the construction industry, and whether the experts or their organizations have been involved in making sustainability decisions (minor/major) in a building project. The questionnaire survey form is not the regular Likert scale-type survey form but provides spaces for the experts to input numerical values for the credit points, grading system levels, …, etc.

Table 3: The experts' demographics of the survey

Description	Frequency	Percentage (%)
Major profession or occupation		
Architects	35	18.5
Civil Engineers	31	16.4
Project Managers	25	13.2
Quantity Surveyors	42	22.2
Structural Engineers	7	3.7
Building Services Engineers	18	9.5
Estate Surveyors	17	9.0
Urban Planners	7	3.7
Mechanical and Electrical Engineers	4	2.1
Land Surveyors	3	1.6
Total	**189**	**100.0**
Years of working experience in the built environment		
< 5 years	38	20.1
5-10 years	53	28.0
11-15 years	33	17.5
16-20 years	40	21.2
> 20 years	25	13.2
Total	**189**	**100.0**
Experts' organizations involved in sustainability decisions?		
Yes	173	91.5
No	11	5.8
Not sure	5	2.6
Total	**189**	**100.0**

The analysis of the invited experts, revealed the ten varied sets of key experts and stakeholders in the built environment who participated in the development of the BSAM scheme. Ali and Al Nsairat (2009) recommended that multi-stakeholders should be involved in developing green rating tools which was accomplished in this research. More so, ninety-eight experts who represented more than 50% of the total number of participating experts have more than 11 years of working experience in the built environment. Also, it is worthy of note that more than 91% of the experts have been involved in making sustainability-related decisions in either current or previous building projects.

Meanwhile, comparing the statistics of experts' demographics of the current study with previous studies where authors have developed native green rating systems for a country – such as (i) Ali and Al Nsairat (2009) only employed four sets of stakeholders where invited namely academicians, project managers, field and design engineers; of which a total of 60 experts participated. (ii) For Mahmoud et al. (2019), only five sets of stakeholders participated namely civil engineers, mechanical and electrical engineers, sustainability experts, facility managers, and architects, of which 20 experts participated. (iii) Also, in Ahmad and Thaheem (2017), the study involved a higher proportion of its respondents from the academics, with a little percentage from the design and construction consultancy.

In total, 120 respondents participated in the study presented by Ahmad and Thaheem (2017). It can be concluded that the invited experts for this current study are well experienced (regarding their years of working experience and involvement in sustainability implementation in the built environment). Hence, this lend credence to the analyzed data. More so, the inputs of the key stakeholders in the built environment are well represented in the development of the BSAM scheme. The larger number of the participating experts for this study, when compared to the previous studies, validate the adequacy of the sample size.

4. Results and discussion

4.1 BSAM Scheme: Analysis of its key sustainability assessment criteria and case study validation

This section presents the analysis of the data collected via the multi-expert consultations. The results in this section, while fulfilling one of the primary objectives of the study, also focus on the suitability of the BSAM scheme in practice within the built environment – especially in developing countries. Hence, this section includes the validation of the proposed BSAM scheme using a case study analysis involving two-building projects, a residential building and a commercial building.

4.1.1 Key sustainability assessment criteria: score-weight determination and distribution

The determination of the credit points (score-weights) for each of the sustainability sub-attributes was undertaken in consultation with industry experts in the built environment across seven states in Nigeria. The invited experts were asked to assign credit point scores to each of the sustainability sub-attributes. The invited construction industry experts were provided information as regards the importance of the credit point that is to be allocated to each sub-attribute and provided a guide based on the earlier four-stage review process. The ratio of the mean average of the credit scores of the sustainability criteria to the nearest unit is presented in Appendix A, and Figure 3 shows the score-weight distribution for each sustainability indicator (A – H) in terms of the weightings of their sustainability attributes.

The summation of the credit points of the respective sub-attributes gives its total credit point for its attribute. Equation (i) is used to establish the score-weight (credit point) of each indicator and it is based on the mean score metric, which divides a set of values by the number of values in that set. The mean score metric was also employed in other well-established rating systems such as LEED, BREEAM, etc. The set of values are the numerical values inputted by the invited experts within the spaces provided in front of each sustainability criteria.

$$W_z = Weight\ (credit\ point) = \frac{\sum CP_a}{N} \qquad eqn\ (i)$$

Where $\sum CP_a$= summation of the credit points of the attributes of sustainability indicator (W_z)

N = the number of attributes for the sustainability indicator ($_z$)

W_z= score-weight [credit points (CP)] of the sustainability indicator ($_z$)

For example, the W_z (F) for sustainability indicator F is 5.333 CP (see Appendix A) which is a resultant of the average of its three attributes (F1= 7; F2= 7; F3= 2 *credit points*). Appendix A reveals that sustainability indicators "*sustainability construction practices*," "*energy*," "*indoor environmental quality*," and "*building management*" (A=11.5 CP; C= 10.67 CP; G= 7.0 CP; and H= 6.5 CP, respectively) are rated critical to the sustainability performance of the project based on the score-weight (W_z) of the attributes.

The score-weights of the sustainability criteria are vital to establishing the ranking of each sustainability assessment indicator and the overall sustainability rating of buildings.

4.1.2 Determination of the significance of the sustainability sub-attributes

This section discusses and presents the results of the importance of each sustainability sub-attribute based on their classification as either "*required*," "*optional*," or "*negligible*." The classification of the sub-attributes is basically for the comparison or ranking of building projects; and not to exclude the assessment of the sustainability sub-attribute when evaluating a building project's sustainability performance, especially if the sub-attribute is marked "*optional*." However, if a sub-attribute is marked "negligible," it will be excluded in project ranking or comparison. The industry experts invited to participate in the development of the BSAM were also asked to classify the 136 sustainability sub-attributes and rate the level of significance of the sub-attributes in respect of each sustainability attributes using a three-point scale ("*required*," "*optional*," and "*negligible*").

The "classification by percentage score" adopted by Olatunji et al. (2017) was modified for use in this study. The classifications are as follows: (1) if ≥65% of the experts rated the sub-attribute as "required," or less than 40% of the experts rated the sub-attribute as "optional," it was classified as a *required sub-attribute*. (2) if less than 65% of the experts rated the sub-attribute as "required" and between 40 and 65% of the experts rated it as "optional," the sub-attribute was classified as *optional*; and (3) if less than 50% of the experts ranked the sub-attribute as required, and less than 40% rated it optional, the sub-attribute was classified as *negligible.*

Based on these classification criteria, Appendix B presents the classification of the significance of each sustainability sub-attribute; seventy-three (73) sub-attributes were classified as *required*, while 63 sub-attributes were classified as an *optional attribute*. No sub-attribute was classified as negligible. Column "*inference*" in Appendix B shows the resultant significance of each sub-attribute based on the classification criteria.

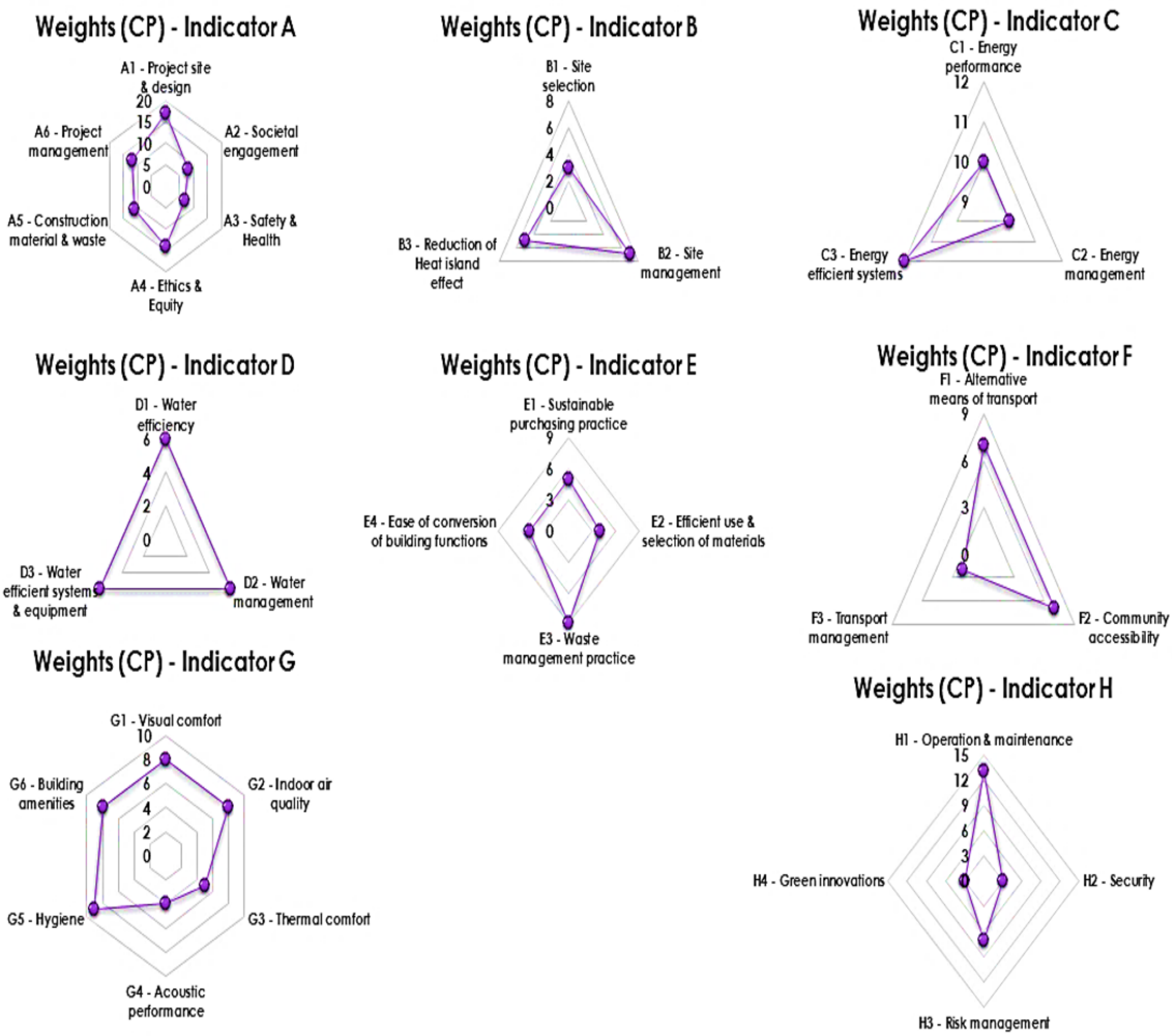

Figure 3: Score-weight distribution for each of the key sustainability assessment criteria

4.1.3 Establishing the ratio of each sustainability indicator

As shown in Figure 4, sustainability indicators A, C, and G were regarded by the experts as the sustainability criteria that should be given the highest priority in the evaluation of a building sustainability performance compared to the other five criteria.

Further, the percentage contribution (ratio, S_r) of each sustainability indicator (A – H) to the overall sustainability performance of a building project is evaluated using equation (ii) and as shown in Figure 4. The overall sustainability status (S_p) of the building project is deduced by calculating the score-weights between the $\sum W$ of the benchmark and the proposed case using equation (iii). The benchmark case – is a building project demonstrating the optimum sustainability performance – that has achieved the maximum score-weight (credit point) for the sustainability criteria. The proposed case is the building project under observation or being assessed.

$$S_r = \frac{W_z}{\sum W_z} X\,100 \qquad eqn\,(ii)$$

Where $\sum W_z$ = summation of the score-weights of the sustainability indicator ($_z$)

W_z= score-weight [credit point] of the sustainability indicator ($_z$)

S_r = Percentage contribution of each sustainability indicator

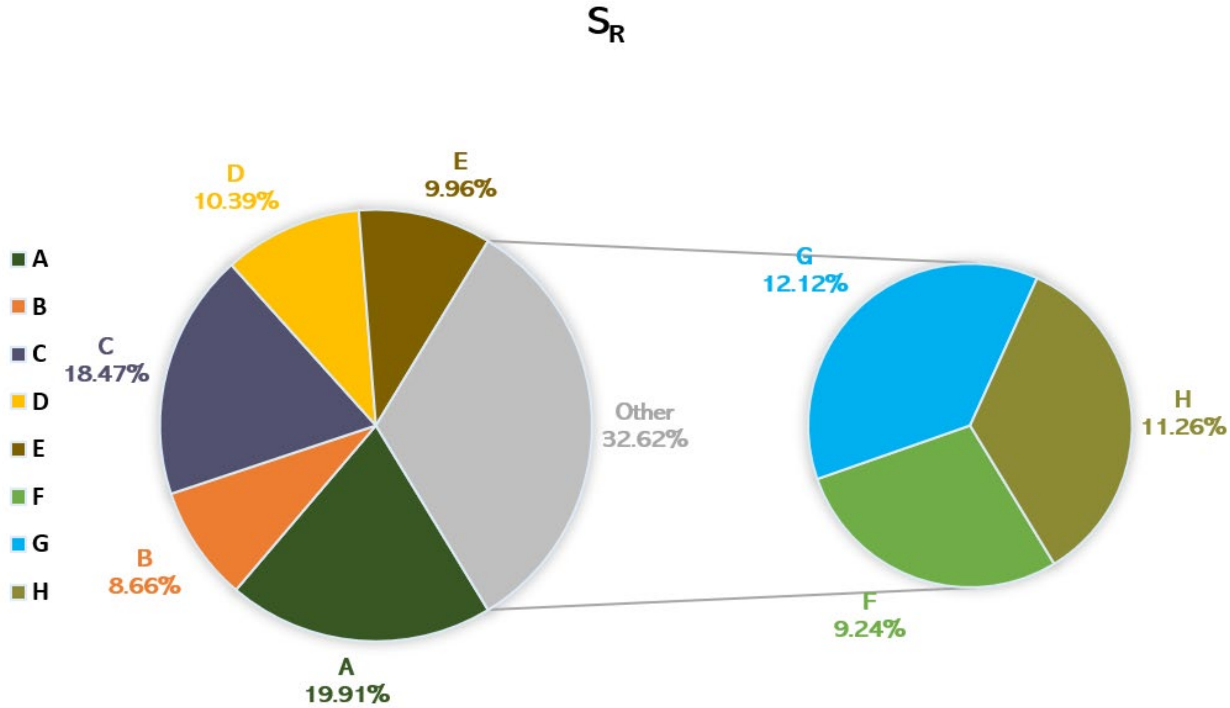

Figure 4: Percentage contribution of each of the key sustainability assessment criteria

Note: A – 'Sustainable construction practices'; B – 'Site & Ecology'; C- 'Energy'; D – 'Water'; E – 'Material & waste'; F – 'Transportation'; G – 'Indoor environmental quality' (IEQ); H – 'Building management.'

$$S_p = \frac{\sum W_s}{\sum W_i} X\,100 - - - eqn\,(iii)$$

Where $\sum W_s$ = summation of the score-weights of the sustainability indicator (proposed case)

$\sum W_i$ = summation of the score-weights of the sustainability indicator (benchmark case)

S_p = The overall sustainability performance (in percentage, %)

4.1.4 The BSAM certification grading system

The grading system for the BSAM scheme was derived by soliciting from the invited experts to input two numerical values (minimum and maximum thresholds) in the questionnaire survey form for the six identified performance levels (outstanding, excellent, very good, good, acceptable, and unclassified) of the BSAM scheme. The six performance levels have been earlier identified by the authors based on a similar approach adopted by the other green rating systems such as LEED, Green Star, BEAM Plus, BREEAM, etc. The experts were asked to provide the two numerical values (thresholds) which must be within the range of 0 and 100. The mean value of these thresholds for the individual performance level was calculated as shown in Figure 5.

Hence, to calculate the certification grade level for a green building, the result of the evaluation of equation (iii) which assesses the overall sustainability performance (S_p) of the building project is used. The BSAM certification grade system is based on the performance level on which the resultant S_p, falls. The BSAM certification grade system is a scale from 0 to 100, which represents the six performance levels. Therefore, based on the thresholds of the six performance level of the BSAM scheme (see Figure 5), a green building project must have a S_p value of 40 ("*acceptable*" grade) before it can be green certified under the proposed BSAM scheme. The highest performance level for the BSAM tool is the "*outstanding*" grade level, which is from 82 – 100%.

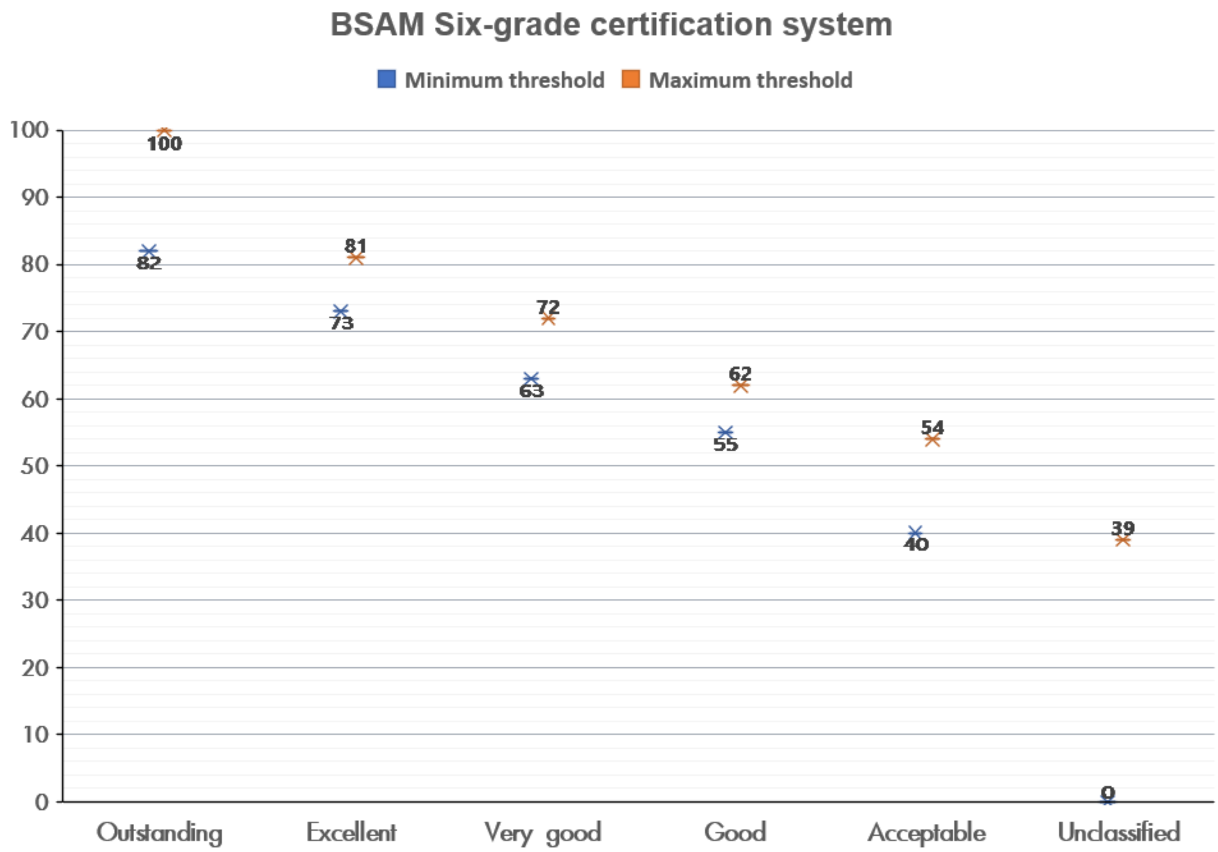

Figure 5: BSAM Six-grade certification system

4.1.5 Case study validation for the BSAM scheme

Two case study of projects were used to validate the suitability, adequacy, reliability, and appropriateness of the BSAM scheme in practice within the built environment – especially in developing countries of sub-Saharan Africa. These include a residential building and a commercial building. These two case studies share similar tropical climate classification with varying rainy and dry seasons. The first case study is a residential building (a duplex) project (Project A) located within the south-eastern part of Nigeria. It is classified as a "new building" based on BRE (2018) classification as the building is still less than one year of occupancy. The second case study is a commercial building project (Project B) located within the south-western part of Nigeria – which featured three laboratories and other offices at the ground floor and include two meeting halls, a conference room among other offices at the first floor – and can also be classified as a "new building."

The two case studies (projects A and B) were assessed using the BSAM scheme documentation (Olawumi and Chan, 2019c) and sustainability criteria weights, and the results are shown in Appendix C and Table 4. The result revealed in Appendix C shows the weighting average at the sustainability attributes and indicators levels (Table 4) because results at these levels help understand where the building projects perform well and where it is inadequate. However, it must be noted that the two case study projects were assessed based on their score-weights at the sub-attributes level – which is the building block of the BSAM scheme. A radar diagram shown in Figure 6 maps the standing of the case study building projects (projects A & B) in terms of their sustainability indicators' weightings (W_s).

The analysis of the weightings (W_s) for the sustainability indicators for the case studies – projects A and B (Table 4) reveals that project A outperforms project B in three sustainability criteria. These are criteria B, E, and F with weighting values of 2.67, 4.88, and 4.67, respectively. Also, project B outperforms project A in five sustainability criteria, which are A, C, D, G, and H with weighing values of 8.42, 7.33, 4.17, 5.92, and 4.75, respectively.

Hence, to improve the projects' sustainability performance of projects; the clients, designers, and other key stakeholders need to critically assess the projects' credit points (score-weights) at the sustainability attribute levelas shown in Appendix C. This will help to evaluate where the building is performing well and where there is a need to improve the overall sustainability performance. The overall sustainability performance (S_p) of the case study projects is also presented in Table 4. Project A has a 62.6% overall sustainability performance when its score-weights ($\sum W$) is normalized with the benchmark case, while project B has a better overall sustainability performance status of 69.11%. Based on the BSAM scheme grade certification system, project A can be classified as a "*good*" rated green building and project B as a "*very good*" rated green building.

Table 4: Weighting average for the sustainability indicators and the overall sustainability performance (S_p) values for the case study projects

Sustainability Indicators	Maximum Weight (W) [*benchmark case*]			Project A			Project B		
	$\sum CP_i$	W_i	S_r (%)	$\sum CP_s$	W_s	S_r (%)	$\sum CP_s$	W_s	S_r (%)
A	69	11.50	19.91	37.5	6.25	17.28	50.5	8.42	20.89
B	15	5.00	8.66	8	2.67	7.37	7.5	2.50	6.20
C	32	10.67	18.47	20	6.67	18.43	22	7.33	18.20
D	18	6.00	10.39	10.5	3.50	9.68	12.5	4.17	10.34
E	23	5.75	9.96	19.5	4.88	13.48	17.5	4.38	10.86
F	16	5.33	9.24	14	4.67	12.90	8.5	2.83	7.03
G	42	7.00	12.12	28.75	4.79	13.25	35.5	5.92	14.68
H	26	6.50	11.26	11	2.75	7.60	19	4.75	11.79
Total (∑)		**57.75**	100.00		**36.17**	100.00		**40.29**	100.00
S_p			**100%**			**62.63%**			**69.77%**

Note *$\sum CP_{i,s}$ = total of each sustainability indicator' attribute weights; S_p = The overall sustainability performance (in percentage, %); $W_{i,s}$=* score-*weight of the indicator; S_r = Percentage contribution of each indicator. A – 'Sustainable construction practices'; B – 'Site & Ecology';*

C- 'Energy'; D – 'Water'; E – 'Material & waste'; F – 'Transportation'; G – 'Indoor environmental quality' (IEQ); H – 'Building management.'

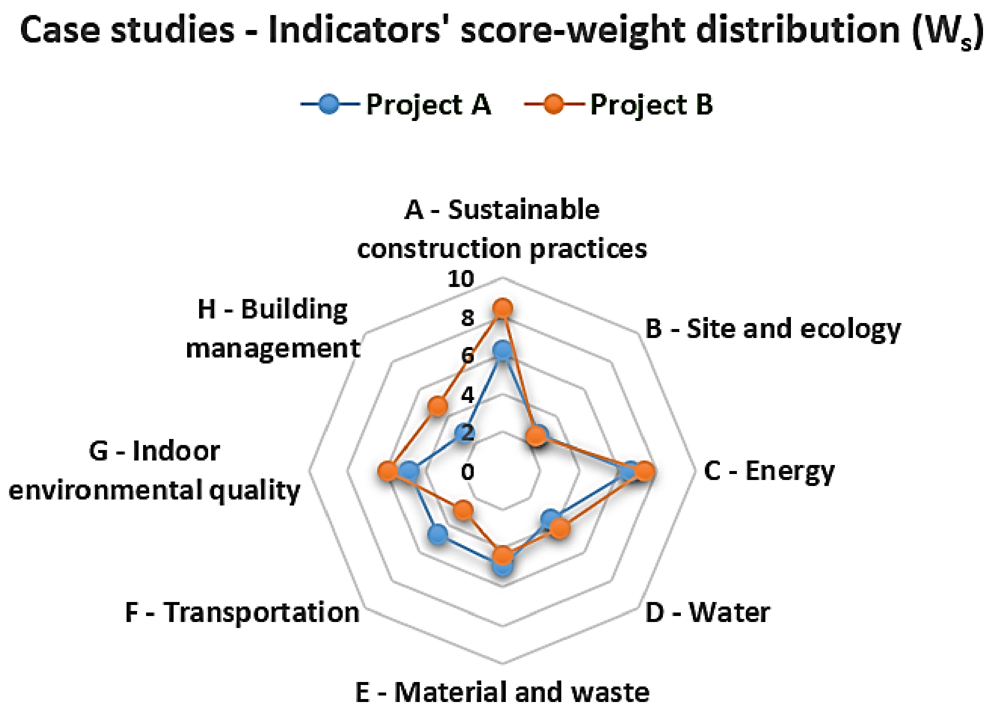

Figure 6: Comparison of the score-weight distribution of the two case study projects (A & B) in terms of their sustainability indicators

The results and analysis presented in this section offer key stakeholders and decision-makers a convenient and efficient means and methods for assessing the sustainability performance of a building project. The breakdown of the analysis into the sustainability attributes and indicators levels also help in understanding how the green building project functions at each sustainability assessment criteria level and assist in pinpointing where it fails to perform adequately.

4.2 Comparison of the proposed BSAM scheme with the six selected existing green building rating systems

This section compares the BSAM scheme with six well established GBRS. This paper focuses on the 'new construction' schemes and latest versions of the six selected green rating tools for uniformity purpose (Illankoon et al., 2017). The different sustainability criteria and the scheme of the six selected GBRS used in this study are identified in Table 5.

Table 2: Distribution of the credit points for key sustainability assessment criteria of BSAM scheme and the six selected green building rating tools

LEED v4. (Design & Construction - 101 credit points)	**BEAM Plus v2.0** (New Building - 133 credit points)	**BREEAM 2018** (New Construction - 149 credit points)	**IGBC v3.0** (New Buildings - 100 credit points)
Integrative process (2)	Integrated design and construction management (25)	Management (21)	Sustainable architecture and design (5)
Location and transportation (15)	Sustainable sites (20)	Health and wellbeing (20)	Site selection and planning (14)
Sustainable sites (7)	Materials and waste (14)	Energy (31)	Water conservation (18)
Water efficiency (12)	Energy use (31)	Transport (12)	Energy efficiency (28)
Energy and atmosphere (29)	Water use (12)	Water (9)	Building materials and resources (16)
Indoor environmental quality (16)	Health and wellbeing (21)	Materials (14)	Indoor environmental quality (12)
Innovation (5)		Waste (11)	Innovation and development (7)
Regional Priority (4)		Land use and ecology (13)	
		Pollution (12)	
		Innovation (10)	
Green Mark v5.0 (Residential building - 140 credit points)	**Green Star v1.2** (Design & As-built - 100 credit points)	**BSAM v1.0** (New Buildings - 241 credit points)	
Climatic responsive design (30)	Management (14)	Sustainable construction practices (69)	
Building energy performance (30)	Indoor environmental quality (17)	Site and ecology (15)	
Resource stewardship (30)	Energy (22)	Energy (32)	
Smart and healthy building (30)	Water (12)	Water (18)	
Advanced green efforts (20)	Materials (14)	Material and waste (23)	
	Land use and ecology (6)	Transportation (16)	
	Emissions (5)	Indoor environmental quality (42)	
	Innovations (10)	Building management (26)	

4.2.1 Allocating credit points to the key sustainability assessment criteria

The proposed BSAM scheme and the six selected GBRS identified in the previous section have different sustainability criteria (Table 5). Specific sustainability criteria are identical in some of the rating tools such as 'energy' and "IEQ"; IEQ is addressed in BREEAM and BEAM Plus as "health and wellbeing" (Table 5). Sustainable sites (or land use), materials, and waste are another set of sustainability criteria addressed directly in most of the green rating tools (BRE, 2018; GBCA, 2017; HKGBC, 2018; IGBC, 2014; USGBC, 2017); except in Green Mark where 'waste' and 'materials' are addressed under the "resource stewardship" criterion while the sustainable sites are termed 'tropicality' under the "climatic responsive design" criteria of the Green Mark (BCA, 2015). Also, all the selected GBRS has the 'innovation' criterion embedded as a key criterion or as a sub-level of other criteria; and it is intended to reward innovative techniques employed in the projects. In BEAM Plus, the 'innovation and additions' criterion is addressed as a bonus criterion (BRE, 2018).

More so, the seven green building rating tools have differing sustainability criteria (see Table 5) and to provide a common basis to compare these rating tools – this study adopts the eight key sustainability criteria of the BSAM scheme to allow uniformity in the comparative assessment of the seven rating tools. Furthermore, in the review of the selected rating tools, it was observed that for instance – in Green Mark®, some sub-levels of the sustainability criteria such as 'sustainable construction practices,' 'transportation,' 'site and ecology,' and ‘water’ identified in BSAM was evaluated under the ‘climatic responsive design’ criterion in Green Mark rating tool (BCA, 2015).

In LEED®, ‘non-toxic pest control’ was identified in ‘sustainable sites’ criterion but was attributed under ‘IEQ’ criterion in the BSAM scheme as the credit point helps to provide a better IEQ; also, ‘regional priority’ criterion in LEED (USGBC, 2017) was attributed under ‘site and ecology’ in the BSAM scheme as it includes credit points that have an impact on site and designs. Similar re-arrangement of the credit points of the sustainability criteria of the selected green rating tools was undertaken to conform with the structure of the eight BSAM scheme sustainability criteria. As a result, the credit points of the criteria for the six selected green rating tools, were separately attributed based on the BSAM criteria (Table 6).

Based on these normalized credit points, radar diagrams (Figure 7) and a comparison chart (Figure 8) were developed to further compare the key sustainability criteria and the seven green rating tools.

Table 3: Allocation of the credit points for the eight key sustainability assessment criteria (A - H) for each of the green building rating tools

Sustainability criteria		**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**Total**
LEED	CP	2	14	17	15	11	7	30	5	101
	%	1.98	13.86	16.83	14.85	10.89	6.93	29.70	4.95	100.00
BEAM-Plus	CP	18	9	31	13	15	4	27	6	123
	%	14.63	7.32	25.20	10.57	12.20	3.25	21.95	4.88	100.00
BREEAM	CP	16	11	27	14	20	12	35	18	153
	%	10.46	7.19	17.65	9.15	13.07	7.84	22.88	11.76	100.00
IGBC	CP	3	14	27	16	20	3	13	4	100
	%	3.00	14.00	27.00	16.00	20.00	3.00	13.00	4.00	100.00
Green Mark	CP	8	12	55	8	22	0	33	2	140
	%	5.71	8.57	39.29	5.71	15.71	0.00	23.57	1.43	100.00
Green Star	CP	4	8	12	15	16	10	23	12	100
	%	4.00	8.00	12.00	15.00	16.00	10.00	23.00	12.00	100.00
BSAM Scheme (*current study*)	CP	69	15	32	18	23	16	42	26	241
	%	28.63	6.22	13.28	7.47	9.54	6.64	17.43	10.79	100.00

Note: A – ‘Sustainable construction practices’; B – ‘Site & Ecology’; C- ‘Energy’; D – ‘Water’; E – ‘Material & waste’; F – ‘Transportation’; G – ‘Indoor environmental quality’ (IEQ); H – ‘Building management.’ CP – Credit points; % - the percentage of each criterion of the total score of the scheme.

4.2.2 Similarities in the radar diagrams for the green building rating tools in comparison to the BSAM scheme

As illustrated in Figure 7, LEED and BEAM Plus have a similar pattern in the structure of their diagram based on the credit point allocation among the key sustainability criteria except for the ‘sustainable construction practices’ criterion which was considered in a greater context in BEAM Plus. Also, the pattern of the BREEAM and Green Star radar diagrams is quite similar except for the ‘sustainable construction practices’ criterion, which was considered in a little more detail in BREEAM. These findings are akin to the normative literature (Fowler and Rauch, 2006; Illankoon et al., 2017), which reported that Green Star was developed based on the BREEAM scheme. The BEAM Plus which was also developed based on the BREEAM system also share similar pattern except for the less evaluation of the ‘building management’ in the former.

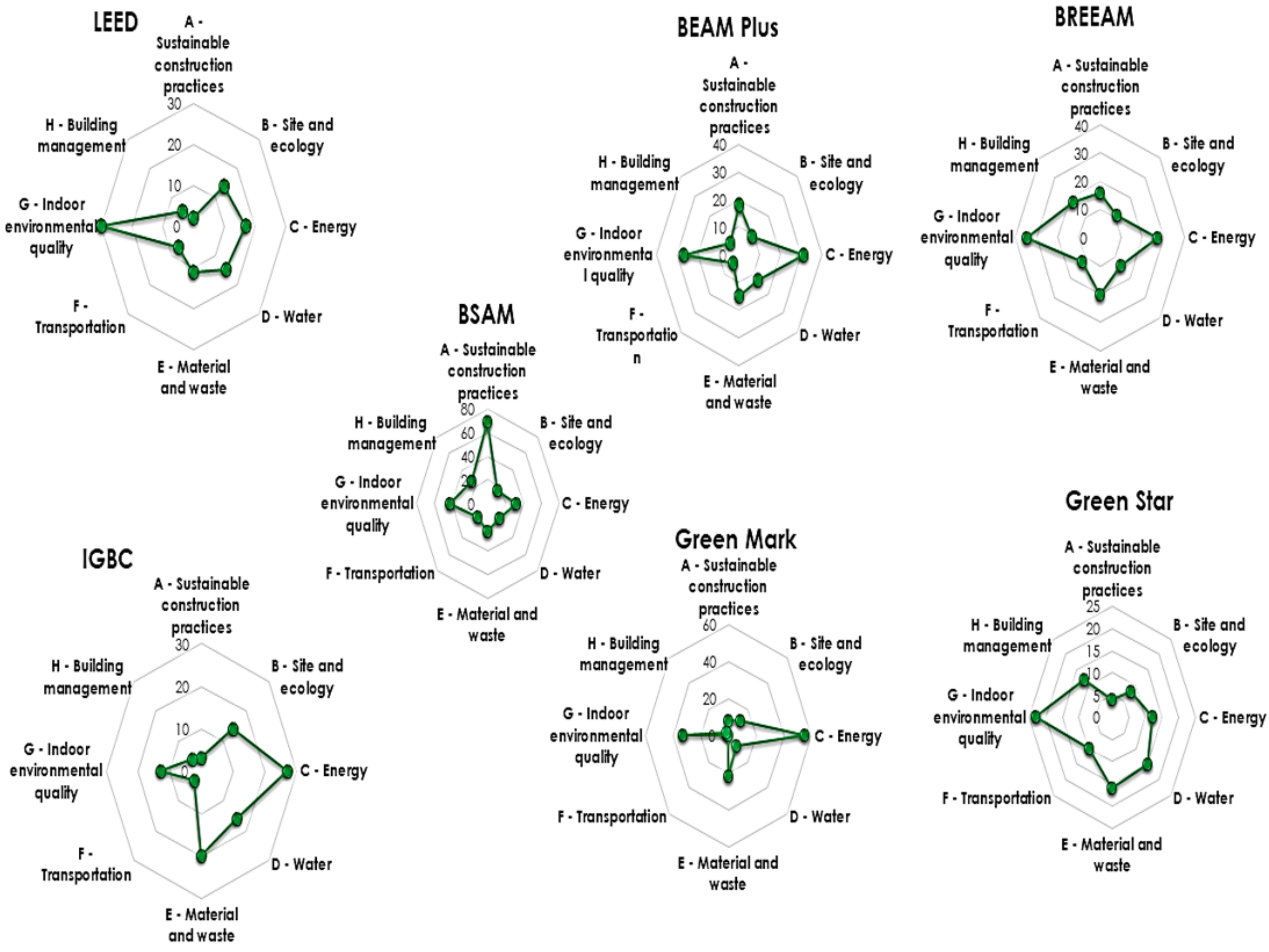

Figure 7: Radar diagrams for the green building rating tools based on the credit points of their key sustainability assessment criteria

Also, the pattern of the IGBC and BREEAM system radar diagrams is similar except for the better consideration for the ‘building management’ and ‘sustainable construction practices’ criteria in BREEAM. The pattern of the BSAM scheme however is somewhat similar to most of the other selected green rating tools (except Green Mark), though the massive consideration of the ‘sustainable construction practices’ criterion in the BSAM scheme is an exception. The ‘sustainable construction practices’ criterion is a massive improvement on the existing GBRS to suit the local context of the developing countries with the sub-Saharan region of Africa.

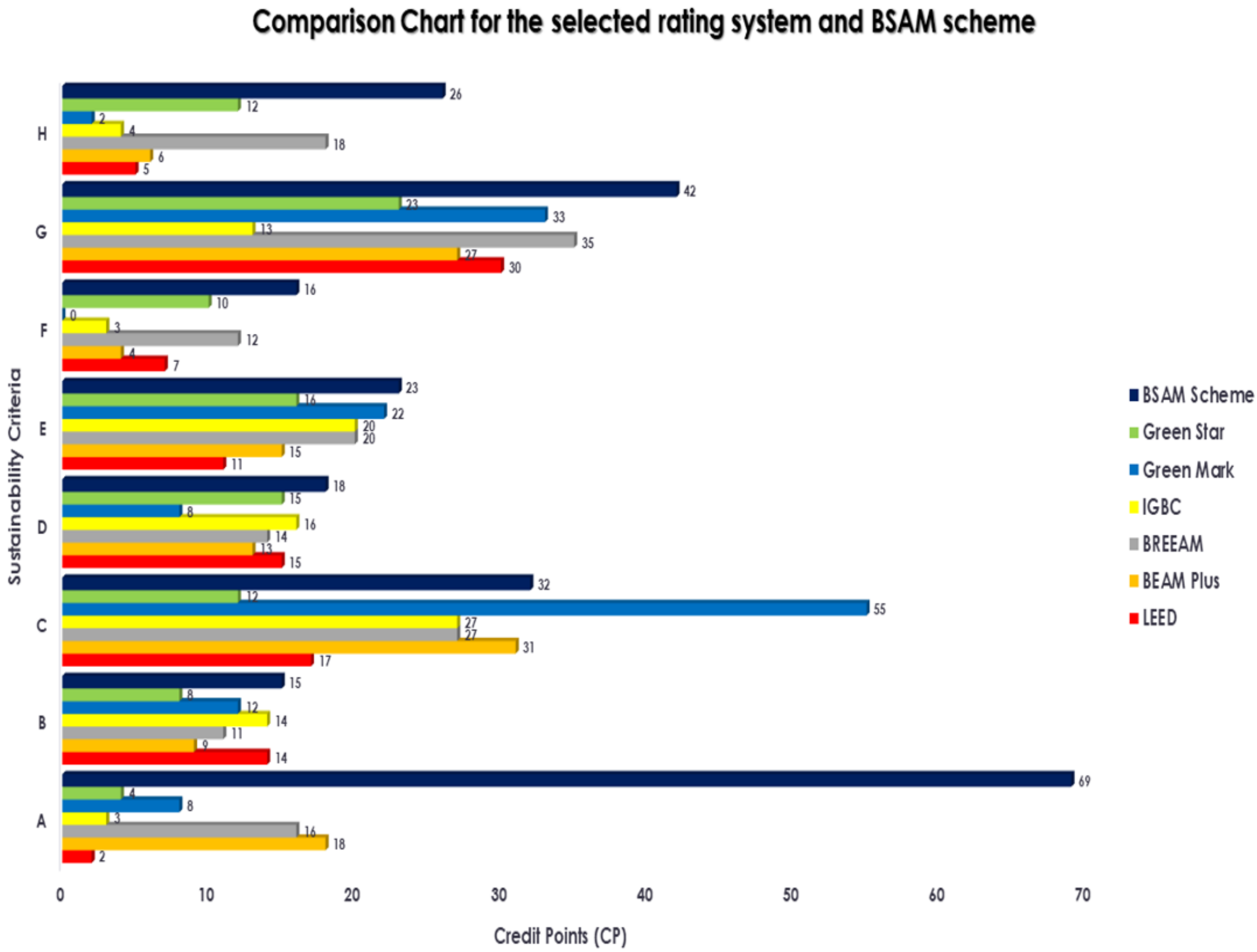

Figure 8: Comparison chart for the green building rating tools based on the credit points of their key sustainability assessment criteria

Note: A – 'Sustainable construction practices'; B – 'Site & Ecology'; C- 'Energy'; D – 'Water'; E – 'Material & waste'; F – 'Transportation'; G – 'Indoor environmental quality' (IEQ); H – 'Building management.'

4.2.3 Differences in the radar diagrams for the green building rating tools in comparison with the BSAM scheme

An evaluation of the comparison of the selected green building rating tools shows that the 'IEQ' criterion has the highest consideration in most of the rating tools except for BEAM Plus and the proposed BSAM scheme, where it receives a little lesser attention (Figures 7 and 8). The normalized credit points for the 'IEQ' for the rating tools range from 13% to 29.7%. The 'IEQ' criterion is given the highest priority in LEED, with about 29.7% of the total credit points, followed closely by BREEAM (22.88%). In the BSAM scheme, the 'IEQ' criterion is given the second priority behind the ‘sustainable construction practices’ criterion. Illankoon et al. (2017) reported that there is an increased concern about occupant satisfaction in buildings that IEQ denotes due to the prevalence of ‘sick building’ syndrome. However, a survey by El Asmar et al. (2014) reveals a weak link between the intended performance of the building as regards IEQ at the design stage and its actual performance during occupancy. Berardi (2012) identified IEQ as an essential criterion in the assessment of green buildings.

Next in line is the ‘energy’ criterion, which is given second priority, except in BEAM Plus, IGBC, and the Green Mark, where it receives the highest consideration. Also, the normalized credit points for the ‘IEQ’ for the rating tools range from 12% to 39.29% of the total score. The ‘energy’ criterion receives 39.29% of the overall credit point in Green Mark when compared to the 16.83% in LEED. A review of the Green Mark rating system shows that the ‘energy’ criterion is distributed across three out of the five credit criteria in Green Mark® with each criteria receiving a very high credit allocation (BCA, 2015). This finding corresponds with one of the main objectives of Green Mark to achieve “increased energy effectiveness,”; which explains the higher percentage weighting of the ‘energy’ criterion in Green Mark compared to the other rating tools (BCA, 2015). The ‘energy’ criterion is rated as a third priority within the BSAM scheme after the ‘sustainable construction practices’ and ‘IEQ’ criteria. Berardi (2012) and Kamaruzzaman et al. (2016) reported that the ‘IEQ’ and ‘Energy’ criteria are the salient sustainability criteria in all green building rating tools which correlate with the findings reported in this paper.

Nevertheless, an analysis of 490 buildings from the green building council database by Berardi (2012) revealed that the ‘energy’ criterion is the most difficult to achieve. In line with one of the main objectives of Green Mark to “increased energy effectiveness,”; which explains its higher percentage weighting compared to the other rating tools. Kamaruzzaman et al. (2016) reported that the ‘IEQ’ and ‘Energy’ criteria are the salient sustainability criteria in all green building rating tools which correlate with the findings reported in this paper.

The ‘material and waste’ criterion also receives some consideration by all the rating tools with its normalized credit points ranging from 9.54% to 20% of the total score. The ‘material and waste’ criterion received its highest priority in the IGBC scheme, followed closely by the Green Star. Zhang et al. (2017) stressed that there is a need for an increased focus on the recycling of building materials and waste to promote a sustainable material performance, as well as encourage the use of local materials. The Australian Bureau of Statistics (2012) also reported that the building construction works contribute about 26% of total waste in the ecosystem; hence, it is important to evaluate this criterion in buildings to ensure an optimal sustainable performance. Each of the rating tools gives the ‘water’ criterion some focus on the radar diagram except for the Green Mark system, where it receives the lowest credit point of 5.71% of the total score. It gets the highest score in the IGBC scheme with a normalized credit point of 16%. Berardi (2012) revealed that the 'water' criterion has the highest percentage of fulfillment in most certified green buildings.

Meanwhile, among the selected green building rating system, only the BSAM scheme considers 'water conservation' as a priority criterion. Cheng et al. (2016), in an analysis of buildings in Taiwan, reported that green buildings achieved 60% water savings than non-green buildings. Alwisy et al. (2018) stressed that the use of water-efficient equipment could help buildings achieve significant reductions in water usage. Also, per Tam et al. (2019a) who stated that the use of sustainable water facilities rather than the conventional ones can help improve water efficiency.

The 'material and waste' criterion also receives some consideration by all the green rating tools with its normalized credit points ranging from 9.54% to 20% of the total score. The 'material and waste' criterion received its highest priority in the IGBC scheme, followed closely by the Green Star. For the 'transportation' criterion, the Green Mark system gave no priority or credit point unlike other the 'transportation' criterion, and it also gave less than 2% of its total score to the 'building management' criterion.

4.2.4 Precedence of the BSAM scheme over the existing green building rating tools

This section highlights and discuss certain key sustainability criteria that are not identified in the six GBRS but which were identified in the extant literature. It is noteworthy that these key sustainability criteria were considered in developing the BSAM scheme. Also, the BSAM scheme embeds virtually all the criteria in the six selected green rating tools, but the inclusion of these key criteria in the BSAM scheme is based on their importance within the local context of developing countries in sub-Saharan Africa.

Olawumi and Chan (2018a), Olawumi and Chan (2019c) and ISO 15392 reported that for a building project to be regarded as a green building, it needs to fulfill the triple-bottom pillar of sustainability – that is, must be environmentally, socially, and economically sustainable. However, with reference to the findings of the review of the six selected green rating tools and as reported in the extant literature (*see* Ali and Al Nsairat, 2009; Illankoon et al., 2017; Sev, 2009), these existing green building rating tools consider only the factors pertaining to the minimization of environmental impacts of buildings while ignoring the key social and economic criteria in the evaluation of buildings. Illankoon et al. (2017) and Gibberd (2005) further stressed the need for the future development of green rating tools especially in developing countries to address this shortcoming in the existing GBRS.

Shari (2011) identified some key social sustainability criteria such as education and awareness, local people and employment, and inclusiveness of opportunities which were not considered by the selected green rating tools. Also, Liu et al. (2013) highlighted 'stakeholder relation' as another social criterion that should be considered by green rating tools, but which are not currently included in the existing rating tools. All these social sustainability criteria were given significant consideration in the newly developed BSAM scheme under the 'sustainable construction practices' criterion. Social sustainability criteria identified under the BSAM scheme include 'engagement of local firms', 'local employment opportunities', 'public participation', 'compliance with social standards', 'education and skills development' among many other key social sustainability attributes. Berardi (2012) argued further that the neglect of social sustainability criteria in existing rating systems makes these green rating system incomplete as it contradicts a key pillar of the sustainable development dimension.

For the economic sustainability criteria, the extant literature (Ali and Al Nsairat, 2009; Liu et al., 2013; Wei et al., 2011) has discussed extensively the need for an increase in the consideration of economic criteria in the development of building projects which are currently lacking in the existing green building rating systems. The proposed BSAM scheme considered economic criteria such as 'enhanced local economy,' 'reuse of construction materials,' among others. Zhang et al. (2017) reiterated the need to link the economic and environmental criteria of green buildings to allow for harmony in its assessment. Another key sustainability indicator (cultural aspect) identified in the literature (Banani et al., 2013; Salehudin et al., 2012; Shari, 2011) is the 'protection of cultural heritage' which is not provided in most green rating tools except in BEAM Plus. The criterion is catered for in the proposed BSAM scheme as 'integration of cultural heritage in design.'

More so, the 'management' criterion is given less consideration in the existing green rating tools; even though this sustainability criterion has been much discussed in the literature (Illankoon et al., 2017; Sev, 2009). In the BSAM scheme, the 'management' criterion is given due consideration to about 11% of the total credit point, which gave the criterion the fourth priority among the eight key sustainability criteria identified in BSAM. Also, as regards the 'materials and waste' criterion, none of the existing green rating tools consider this key criterion for assessment at the construction stage of the green building development. Another key sustainability criteria unavailable in the existing GBRS but given consideration in the proposed BSAM scheme are the 'safety and health' and 'ethics and equity' criteria. Also, as regards the 'materials' criterion, the existing GBRS focus on the material type (category) while the BSAM scheme focuses both on the former as well as the materials were locally sourced.

Meanwhile, Ali and Al Nsairat (2009) reported that developing countries are typically conscious of the economic and social pillars of sustainable development than the environmental construct. Hence, this study addressed the imbalance by developing a holistic GBRS towards achieving the sustainable development goals.

5. Conclusions

Green building rating systems provide a means to create and monitor the development of sustainable buildings and infrastructure. The relevance of the development of the proposed BSAM scheme lies in addressing the shortcomings of the existing green building rating systems and providing a holistic green rating tool suitable to the local context of developing countries in sub-Saharan Africa. The research established the key sustainability criteria of the proposed BSAM scheme based on a four-step review process discussed in the study's methodological approach. A review of the extant literature using the content analysis approach identified the need for green building rating systems to focus on the three pillars of sustainability. The eight key sustainability criteria were identified for inclusion in the BSAM scheme. The full documentation of the BSAM scheme is provided as a supplementary data and multi-expert consultations helped in determining the credit weighting of each of the BSAM sustainability criteria.

The sustainability assessment criteria weights and the significance of each sustainability sub-attributes were also established based on the analysis of the data collected via the experts' consultations. The criteria-based ranking of the BSAM scheme is generated by aggregating the credit points of its sustainability attributes and sub-attributes. Also, the percentage of the total score-weights for each sustainability criterion and the certification grading system scales – outstanding, excellent, very good, good, acceptable, and unclassified, which are measured on the scale of 0-100% was established. Forty percent is the minimum threshold before a building can receive green certification under the BSAM scheme. Two case studies of building projects (residential and commercial buildings) were employed to validate the suitability, practicality, and appropriateness of the BSAM scheme in practice within the built environment.

Furthermore, to validate and demonstrate the improvement of the proposed BSAM scheme over the existing green building rating systems, a comparative analysis of the BSAM scheme with six selected common green rating tools – LEED, BEAM Plus, BREEAM, IGBC, Green Mark, and Green Star – was carried out in this study. An analysis of the existing green rating tools reveals a different set of sustainability criteria and to allow for uniformity of comparison of the green rating tools in this paper; the credit points of these rating tools were re-assigned based on the eight key sustainability criteria of the BSAM scheme. Based on the comparison of these green rating tools, the following conclusions were derived – (1) The existing green building rating tools place more emphasis on the environmental aspect of sustainability and overlooked the social and economic parameters; while the BSAM scheme gave a steady consideration to the three aspects of sustainability; thereby providing a better holistic evaluation of green buildings. (2) The BSAM scheme embeds virtually all the key sustainability criteria required for the assessment of green buildings based on the local context, while some green rating tools fail to cater for some of the key sustainability criteria adequately.

More so, (3) There are some similarities in the credit points allocation among the green rating tools, as shown in the patterns of their radar diagrams while there are differences. (4) The BSAM scheme, BREEAM, and Green Star shows a more balanced consideration in the allocation of credit points for the key sustainability criteria. (5) The 'management' and 'sustainable construction practices' criteria were given higher priority in the BSAM scheme when compared to the other selected green rating tools; although, these criteria are of vital to the sustainability performance of buildings. (6) All the green building rating tools place more significant consideration to the 'IEQ' and 'energy' criteria, although the 'energy' criterion was found to be the most difficult to achieve while the 'water' criterion is the easiest to achieve.

As evidenced by the findings in this paper, the BSAM scheme encompasses the necessary key sustainability criteria as well as an improvement of the existing green rating tools. Limitations to the proposed BSAM scheme, includes that the scheme like the other green rating tools, fails to address the complex relationships among the key sustainability criteria. Also, another limitation of the study is the use of aggregation of points which limits the expressions of the key sustainability criteria. These two shortcomings will be addressed in the next phase of the development of the BSAM scheme.

In summary, the following are the significant contributions of the study. (1) The proposed BSAM scheme includes effective guidelines towards evaluating green buildings as well as the documentary evidences to be assessed and verified to ascertain the fulfillment of the key sustainability criteria. (2) It also covers the maintenance and improvement of the sustainability performance of the buildings throughout their lifecycles. (3) Implementing the proposed BSAM scheme can promote greener buildings and sustainable urban development and guide the design team as well as the construction team to employ greener technologies. (4) It also fulfills the need for a technical scheme through the experience-based ranking of the key sustainability criteria.

It is recommended that countries using the existing green rating systems such as LEED, BREEAM, BEAM Plus, etc. which emphasizes the environmental sustainability are implored to examine the social and economic sustainability criteria in the BSAM scheme updating their respective GBRS. Also, stakeholders in the built environment are encouraged to adopt and test the proposed BSAM scheme in evaluating their building projects to accelerate the implementation of this green rating tool. Future research can focus on expanding the scope of the key sustainability criteria and adding more variables at each sub-level – attributes and sub-attributes.

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Supplementary Data

The composition and full documentation for the BSAM scheme, as developed in the course of this research, is publicly available via a repository – https://doi.org/10.17632/jvjm5h8md3.1 (Olawumi and Chan, 2019c) and as an e-supplement to this paper.

References

Ahmad, T., Aibinu, A.A., Stephan, A., 2019. Managing green building development – A review of current state of research and future directions. Build. Environ. 155, 83–104. https://doi.org/10.1016/j.buildenv.2019.03.034

Ahmad, T., Thaheem, M.J., 2017. Developing a residential building-related social sustainability assessment framework and its implications for BIM. Sustain. Cities Soc. 28, 1–15. https://doi.org/10.1016/j.scs.2016.08.002

Ali, H.H., Al Nsairat, S.F., 2009. Developing a green building assessment tool for developing countries - Case of Jordan. Build. Environ. 44, 1053–1064. https://doi.org/10.1016/j.buildenv.2008.07.015

AlWaer, Kirk, 2012. Building sustainability assessment methods. Proc. Inst. Civ. Eng. - Eng. Sustain. 165, 241–253. https://doi.org/10.1680/ensu.10.00058

Alwisy, A., BuHamdan, S., Gül, M., 2018. Criteria-based ranking of green building design factors according to leading rating systems. Energy Build. 178, 347–359. https://doi.org/10.1016/j.enbuild.2018.08.043

Alyami, S.H., Rezgui, Y., 2012. Sustainable building assessment tool development approach. Sustain. Cities Soc. 5, 52–62. https://doi.org/10.1016/j.scs.2012.05.004

Ameen, R.F.M., Mourshed, M., 2019. Urban sustainability assessment framework development: The ranking and weighting of sustainability indicators using analytic hierarchy process. Sustain. Cities Soc. 44, 356–366. https://doi.org/10.1016/j.scs.2018.10.020

Ando, S., Arima, T., Bogaki, K., Hasegawa, H., Hoyano, A., Ikaga, T., 2005. Architecture for a sustainable future. Tokyo.

Atanda, J.O., 2019. Developing a social sustainability assessment framework. Sustain. Cities Soc. 44, 237–252. https://doi.org/10.1016/j.scs.2018.09.023

Australian Bureau of Statistics, 2012. Land Management Practices in the Great Barrier Reef Catchment Area, in: Year Book 2012 [1301.0]. Canberra.

Banani, R., Vahdati, M., Elmualim, A., 2013. Demonstrating the importance of criteria and sub-criteria in building assessment methods. WIT Trans. Ecol. Environ. 173, 443–454. https://doi.org/10.2495/SDP130371

BCA, 2015. Green Mark for Residential Buildings: including Hawker Centers, Healthcare Facilities, Laboratory Buildings and Schools. Building and Construction Authority, Singapore.

BCA, 2010. The BCA Green Mark Certification Standard for New Buildings. Building and Construction Authority, Singapore.

BCA, 2004. Guidelines on Envelope Thermal Transfer Value for Buildings. Building and Construction Authority, Singapore.

BCA, 1986. Handbook on Energy Conservation in Buildings and Building Services. Building and Construction Authority, Singapore.

Berardi, U., 2012. Sustainability Assessment in the Construction Sector: Rating Systems and Rated Buildings. Sustain. Dev. 20, 411–424. https://doi.org/10.1002/sd.532

Bernardi, E., Carlucci, S., Cornaro, C., Bohne, R.A., 2017. An analysis of the most adopted rating systems for assessing the environmental impact of buildings. Sustainability 9, 1–27. https://doi.org/10.3390/su9071226

BRE, 2018. BREEAM UK New Construction (Non-domestic Buildings). BRE Global Ltd, Hertfordshire.

BRE, 2016. BREEAM In-Use International (Technical Manual), 2nd ed. BRE Global Ltd, Hertfordshire.

Bunz, K.R., Henze, G.P., Tiller, D.K., 2006. Survey of Sustainable Building Design Practices in North America, Europe, and Asia. J. Archit. Eng. 12, 33–62. https://doi.org/10.1061/(asce)1076-0431(2006)12:1(33)

Cheng, C.L., Peng, J.J., Ho, M.C., Liao, W.J., Chern, S.J., 2016. Evaluation of water efficiency in green building in Taiwan. Water (Switzerland) 8, 236. https://doi.org/10.3390/w8060236

Chew, M.Y.L., Das, S., 2008. Building Grading Systems: A Review of the State- of-the-Art. Archit. Sci. Rev. 51, 3–13. https://doi.org/10.3763/asre.2008.5102

CIBSE, 2007. Environmental design-CIBSE Guide A, 2nd ed. Chartered Institution of Building Services Engineers, Norwich.

Cooper, I., 1999. Which focus for building assessment methods - Environmental performance or sustainability? Build. Res. Inf. 27, 321–331. https://doi.org/10.1080/096132199369435

Ding, G.K.C., 2008. Sustainable construction-The role of environmental assessment tools. J. Environ. Manage. 86, 451–464. https://doi.org/10.1016/j.jenvman.2006.12.025

Ding, Z., Fan, Z., Tam, V.W.Y., Bian, Y., Li, S., Illankoon, I.M.C.S., Moon, S., 2018. Green building evaluation system implementation. Build. Environ. 133, 32–40.

https://doi.org/10.1016/j.buildenv.2018.02.012

Downe-Wamboldt, B., 1992. Content analysis: Method, applications, and issues. Health Care Women Int. 13, 313–321. https://doi.org/10.1080/07399339209516006

Dwaikat, L.N., Ali, K.N., 2018. The economic benefits of a green building – Evidence from Malaysia. J. Build. Eng. 18, 448–453. https://doi.org/10.1016/j.jobe.2018.04.017

El Asmar, M., Chokor, A., Srour, I., 2014. Occupant satisfaction with indoor environmental quality: A study of the LEED-certified buildings on the Arizona State University campus, in: ICSI 2014: Creating Infrastructure for a Sustainable World. International Conference on Sustainable Infrastructure (ICSI), November 6-8, California, pp. 1063–1070. https://doi.org/10.1061/9780784478745.100

Escolar, S., Villanueva, F.J., Santofimia, M.J., Villa, D., Toro, X. del, López, J.C., 2019. A Multiple-Attribute Decision Making-based approach for smart city rankings design. Technol. Forecast. Soc. Change 142, 42–55. https://doi.org/10.1016/j.techfore.2018.07.024

Fowler, K.M., Rauch, E.M., 2006. Sustainable Building Rating Systems Summary (No. PNNL-15858), Pacific Northwest National Lab.(PNNL). PNNL, Richland, WA (United States). https://doi.org/PNNL-15858

GBCA, 2017. Green Star – Design & As Built v1.2 : Building design and construction, Green Building Council Australia. Australia.

Gething, B., Bordass, B., 2006. Rapid assessment checklist for sustainable buildings. Build. Res. Inf. 34, 416–426. https://doi.org/10.1080/09613210600764455

Gibberd, J., 2005. Assessing sustainable buildings in developing countries – the sustainable building assessment tool (SBAT) and the sustainable building lifecycle (SBL)., in: The 2005 World Sustainable Building Conference, Tokyo. September, Tokyo, pp. 1605–1612.

Gobbi, S., Puglisi, V., Ciaramella, A., 2016. A Rating System for Integrating Building Performance Tools in Developing Countries. Energy Procedia 96, 333–344. https://doi.org/10.1016/j.egypro.2016.09.156

GSA, 2019. Lighting - GSA [WWW Document]. U.S. Gen. Serv. Adm. URL http://bit.ly/2M9aOx5 (accessed 5.7.19).

Hamid, Z.A., Zain, M.Z.M., Hung, F.C., Noor, M.S.M., Roslan, A.F., Kilau, N.M., Ali, M.C., 2014. Towards a national green building rating system for Malaysia. Malaysian Constr. Res. J. 14, 1–16.

HKGBC, 2018. BEAM Plus New Buildings V2.0, 2.0 (Beta). ed. Hong Kong Green Building Council, Hong Kong.

HKGBC, 2016. BEAM Plus Existing Buildings Version 2.0 - Comprehensive Scheme, 2.0. ed. Hong Kong Green Building Council, Hong Kong.

HKIA, 2012. Energy and Use of Energy: Calculation and Application of OTTV and U-value. Hong Kong Institute of Architects, Hong Kong.

Humbert, S., Abeck, H., Bali, N., Horvath, A., 2007. Leadership in Energy and Environmental Design (LEED)- A critical evaluation by LCA and recommendations for improvement. Int. J. Life Cycle Assess. 12, 46–57. https://doi.org/10.11436/mssj.15.250

IBEC, 2008. CASBEE for New Construction: Comprehensive Assessment System for Building Environmental Efficiency Technical Manual. Institute for Building Environment and Energy Conservation, Japan.

IBEC, 2004. CASBEE for New Construction. Institute for Building Environment and Energy Conservation, Japan.

IGBC, 2014. IGBC Green New Buildings Rating Sytem - Abridged Reference Guide, Indian Green Building Council.

Illankoon, I.M.C.S., Tam, V.W.Y., Le, K.N., Shen, L., 2017. Key credit criteria among international green building rating tools. J. Clean. Prod. 164, 209–220. https://doi.org/10.1016/j.jclepro.2017.06.206

IPCC, 2007. Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

Ismaeel, W.S.E., 2019. Drawing the operating mechanisms of green building rating systems. J. Clean. Prod. 213, 599–609. https://doi.org/10.1016/j.jclepro.2018.12.115

Johansson, T.B., Patwardhan, A.P., Nakićenović, N., Gomez-Echeverri, L. (Eds.), 2012. Global Energy Assessment, Global Energy Assessment - Toward a Sustainable Future. Cambridge University Press, Cambridge, UK.

Kamaruzzaman, S.N., Lou, E.C.W., Zainon, N., Mohamed Zaid, N.S., Wong, P.F., 2016. Environmental assessment schemes for non-domestic building refurbishment in the Malaysian context. Ecol. Indic. https://doi.org/10.1016/j.ecolind.2016.04.031

Kaur, H., Garg, P., 2019. Urban sustainability assessment tools: A review. J. Clean. Prod. 210, 146–158. https://doi.org/10.1016/j.jclepro.2018.11.009

Le, K.N., Tam, V.W., Tran, C.N., Wang, J., Goggins, B., 2018. Life-cycle greenhouse gas emission analyses for Green Star's concrete credits in Australia. IEEE Trans. Eng. Manag. 66, 286–298. https://doi.org/10.1109/TEM.2018.2832094

Liu, J., Ding, G.K.C., Samali, B., 2013. Building Sustainable Score (BSS)—A Hybrid Process Approach for Sustainable Building Assessment in China. J. Power Energy Eng. 1, 58–62. https://doi.org/10.4236/jpee.2013.15009

Mahmoud, S., Zayed, T., Fahmy, M., 2019. Development of sustainability assessment tool for existing buildings. Sustain. Cities Soc. 44, 99–119. https://doi.org/10.1016/j.scs.2018.09.024

Nguyen, B.K., Altan, H., 2011. Comparative review of five sustainable rating systems. Procedia Eng. 21, 376–386. https://doi.org/10.1016/j.proeng.2011.11.2029

Olatunji, S.O., Olawumi, T.O., Aje, I.O., 2017. Rethinking Partnering among Quantity-Surveying Firms in Nigeria. J. Constr. Eng. Manag. 143, 1–12. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001394

Olawumi, T.O., Chan, D.W.M., 2020. Concomitant Impediments to the implementation of Smart Sustainable Practices in the Built Environment. Sustain. Prod. Consum. 21, 239–251. https://doi.org/10.1016/j.spc.2019.09.001

Olawumi, T.O., Chan, D.W.M., 2019a. An empirical survey of the perceived benefits of executing BIM and sustainability practices in the built environment. Constr. Innov. Information, Process. Manag. 19, 321–342. https://doi.org/10.1108/CI-08-2018-0065

Olawumi, T.O., Chan, D.W.M., 2019b. Critical Success Factors of Implementing Building Information Modelling (BIM) and Sustainability Practices in Construction Projects: A Delphi Survey. Sustain. Dev. 27, 587–602. https://doi.org/10.1002/sd.1925

Olawumi, T.O., Chan, D.W.M., 2019c. Building Sustainability Assessment Method (BSAM) - for Countries in sub-Saharan region. Mendeley Data 1. https://doi.org/10.17632/jvjm5h8md3.1

Olawumi, T.O., Chan, D.W.M., 2018a. A Scientometric Review of Global Research on Sustainability and Sustainable Development. J. Clean. Prod. 183, 231–250.

https://doi.org/10.1016/j.jclepro.2018.02.162

Olawumi, T.O., Chan, D.W.M., 2018b. Identifying and prioritizing the benefits of integrating BIM and sustainability practices in construction projects: A Delphi survey of international experts. Sustain. Cities Soc. 40, 16–27. https://doi.org/10.1016/j.scs.2018.03.033

Olawumi, T.O., Chan, D.W.M., 2017. Geospatial Map of the Global Research on Sustainability and Sustainable Development: Generating and converting KML files to Map. Mendeley Data 1. https://doi.org/10.17632/sv23pvr252.1

Salehudin, M.S., Prasad, D.K., Osmond, P.W., Khamis, M.T., 2012. Sustainable Resort Development: Malaysian Case Studies, in: 2nd International Conference on Tourism Management and Tourism Related Issues. European Institute for Advanced Studies in Management (EIASM), September 20-21. Nice, France.

Sev, A., 2009. How can the construction industry contribute to sustainable development? A conceptual framework. Sustain. Dev. 17, 161–173. https://doi.org/10.1002/sd.373

Shari, Z., 2011. Development of a Sustainability Assessment Framework for Malaysian Office Buildings Using a Mixed-methods Approach. PhD Dissertation. University of Adelaide, Adelaide, Australia.

Tam, V.W., Kim, K., Brohier, A., 2019a. Life-cycle analysis by using the alternative sustainable water innovations in residential dwellings. Int. J. Constr. Manag. 1–13. https://doi.org/10.1080/15623599.2019.1603564

Tam, V.W., Le, K.N., Tran, C.N., Illankoon, I.C.S., 2019b. A review on international ecological legislation on energy consumption: greenhouse gas emission management. Int. J. Constr. Manag. 1–12. https://doi.org/10.1080/15623599.2019.1576259

Todd, J.A., Geissler, S., 1999. Regional and cultural issues in environmental performance assessment for buildings. Build. Res. Inf. 27, 247–256. https://doi.org/10.1080/096132199369363

UNEP, 2011. Towards a green economy: Pathways to sustainable development and poverty eradication. United Nations Environment Programme, Nairobi, Kenya.

Ürge-Vorsatz, D., Harvey, L.D.D., Mirasgedis, S., Levine, M.D., 2007. Mitigating CO2 emissions from energy use in the world's buildings. Build. Res. Inf. 35, 379–398. https://doi.org/10.1080/09613210701325883

USGBC, 2018a. LEED v4 for Interior Design and Construction, 4th ed. U.S. Green Building Council, Washington D.C.

USGBC, 2018b. LEED v4 for Building Operations and Maintenance, 4th ed. U.S. Green Building Council, Washington D.C.

USGBC, 2018c. LEED v4.1 Operations and Maintenance, 4.1. ed. U.S. Green Building Council, Washington D.C.

USGBC, 2018d. LEED v4 for Neigbourhood Development, 4th ed. U.S. Green Building Council, Washington D.C.

USGBC, 2017. LEED v4 for Homes Design and Construction, 4th ed. U.S. Green Building Council, Washington D.C.

WEC, 2013. World Energy Resources: 2013 survey, World Energy Council. World Energy Council, London, UK.

Wei, B., Zhang, B., Luo, W., 2011. Research on Assessment Method of Green Buildings in China, in: ASME 2010 4th International Conference on Energy Sustainability. American Society of Mechanical Engineers, May 17–22. Phoenix, Arizona, USA, pp. 65–73. https://doi.org/10.1115/es2010-90349

WGBC, 2019. Green Building Councils [WWW Document]. World Green Build. Counc. London. URL https://www.worldgbc.org/our-green-building-councils (accessed 8.10.19).

White, M., Marsh, E., 2006. Content analysis: A flexible methodology. Libr. Trends 55, 22–45. https://doi.org/10.1353/lib.2006.0053

Wu, P., Mao, C., Wang, J., Song, Y., Wang, X., 2016. A decade review of the credits obtained by LEED v2.2 certified green building projects. Build. Environ. https://doi.org/10.1016/j.buildenv.2016.03.026

Xiaoping, M., Huimin, L., Qiming, L., 2009. A Comparison Study of Mainstream Sustainable/green building rating tools in the world, in: 2009 International Conference on Management and Service Science. IEEE, 20-22 September, Wuhan, China, pp. 1–5. https://doi.org/10.1109/ICMSS.2009.5303546

Zhang, Y., Wang, J., Hu, F., Wang, Y., 2017. Comparison of evaluation standards for green building in China, Britain, United States. Renew. Sustain. Energy Rev. 262–271. https://doi.org/10.1016/j.rser.2016.09.139