IDENTIFICATION AND EVALUATION OF GREEN BUILDING ASSESSMENT INDICATORS FOR MYANMAR

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ABSTRACT

To accommodate its increasing population, the Myanmar government has planned to implement smart city projects in Yangon and Mandalay by 2021 and to build 1 million homes by 2030. However, such projected growth does not coincide with Myanmar's current level of preparedness for sustainable development. Myanmar presently has no standards and specifications for green buildings; it solely relies on the adoption of those from overseas, which may not always be compatible with the unique context of Myanmar. Hence, this study was aimed to identify appropriate green building assessment indicators for Myanmar as an important first step for future rating system development. Nine categories and forty-eight criteria were initially identified by reviewing the widely adopted seven rating systems and investigating existing certified green buildings. The Fuzzy Analytic Hierarchy Process (Fuzzy AHP) was used to determine and rank the importance levels of the identified assessment indicators. Results showed that "energy efficiency" and "water efficiency" are the most crucial categories with weights of 17.48% and 13.95%, respectively. Compared to other rating system standards, "waste and pollution" was distinctively found as an important category for Myanmar. Energy-efficient architectural design was ranked as the highest priority among all criteria. These findings serve as a building block for the future development of a Myanmar green building rating system by revealing assessment categories and criteria that are most relevant to Myanmar's built environment.

KEYWORDS

Construction, Myanmar, green building, assessment indicators, rating systems, Fuzzy Analytic Hierarchy Process

1. INTRODUCTION

Increasing population, urbanization, and the energy crisis draw the attention of the public and society to sustainable development. The implementation and development of the green

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building concept has become a popular trend as a modern construction technique because it is an environmentally friendly building that promotes public welfare (Ding et al., 2018). To define a building's greenness, there is the necessity to measure the building's sustainability aspects and to minimize the building's impact on the environment. Therefore, green building rating system (GBRS) development is crucial for this requirement to assess a building's performance in meeting targeted green building objectives through certification processes. GBRSs are "tools that help to ensure that sustainable buildings, communities, and projects are developed in an integrated manner and that the appropriate experts are involved in the process" and are necessary for the assessment of a building's environmental performance and sustainability throughout building design, construction, and operation (El Yamany et al., 2016).

In Myanmar, there is a lack of standards and policies for green buildings that stakeholders can systematically refer to. As a result, green building demand is very low in Myanmar's construction market, and without much interest from developers and owners for investment. Government organizations and companies have limited numbers of professionals who have experience and expertise in green building construction and environmental sustainability. The largest city in Myanmar, Yangon, has experienced rapid population growth and problems with urbanization and migration. Sustainable and green technology is necessary for foreign and local investors in infrastructure development. Infrastructure and new construction need to be fueled by electricity, yet Myanmar does not have enough supply of energy. Energy demand is a current issue for the government, and clean and cost-efficient energy is a special requirement for society. Besides, environmental protection should be accelerated because of waste and pollution produced by buildings and factories. Environmental sustainability-related research in the building sector of Myanmar is lacking despite several studies having been conducted in other fields such as oil and gas, tourism and hospitality, mining, and urbanization (Shwe et al., 2017a; Ingelmo, 2013; Aung & Shwesin, 2017; Kyi, 2014; Buijtendijk & Tschunkert, 2016). In the area of built environment, Shwe et al. (2017b) has proposed indicators for sustainability assessment of cities and neighborhoods in Myanmar. However, there is still a lack of research identifying indicators for assessing the environmental impact of buildings. For these reasons, developing and implementing rating system indicators is an essential primary phase for green building development in the building sector of Myanmar to integrate sustainability into policymaking decisions.

In general, the previously developed GBRSs play a major part in the implementation of any rating systems adapted to suit a country's local context (Zarghami et al., 2019). In Myanmar, for instance, Singapore's Building and Construction Authority (BCA) Green Mark rating system has been applied for evaluating two non-residential projects, and LEED from the US has recently been introduced. Although such a practice is considered a convenient and effective first step for establishing a standard methodology for green building assessment, especially for developing countries such as Myanmar, a better understanding of the local context relating to the construction industry and various sustainability issues is essential to effectively implement a domestic sustainability assessment method. The existing rating systems developed for certain countries are often not entirely compatible to another country's local context because of variations in environmental issues, economic conditions, social, and cultural aspects (Shad et al., 2017). Due to these considerations, the present study aims to identify and evaluate green building assessment criteria that are most relevant and suitable for Myanmar.

2. LITERATURE REVIEW

2.1 Myanmar and the Need for Sustainable Buildings

For South-East Asian countries, energy, water, and waste remain as the vital measures that affect the environmental sustainability and building assessment rating system. (Shafii, 2008). Myanmar is one of those countries that needs to cultivate its overall sustainability while laying emphasis on other critical development issues. As the country enters the global economy with its rapid growth, resources and environmental degradation is escalating (Raitzer et al., 2015). Myanmar also recognizes that electricity is the core power source for the country's strong economy (The Oil and Gas Planning Department, 2019). The government has set the policies and strategies to meet the power demand by emphasizing renewable energy sources. Although oil and natural gas have been discovered as domestic resources, the energy demand of the country is yet to be fulfilled (Kyaw et al., 2011). Since more commercial buildings, particularly offices and hotels have been constructed, the electricity consumption of the service sector has increased exponentially (The Oil and Gas Planning Department, 2019). Water resources sustainability is also concerning. The estimated amount of water withdrawal from surface water is 91%, and 9% is extracted from ground water which is commonly used for domestic purposes (ADB, 2013). Only less than 5% of total water withdrawal comes from renewable sources (ADB, 2013). Newly constructed high rise buildings in Yangon rely on 30 million gallons of water from tube wells daily because the current water supply of Yangon is insufficient (Lwin & Panuwatwanich, 2020). Moreover, wastewater and solid waste management is an on-going challenge for Myanmar where urbanization and industrialization are accelerating. With population growth and increased waste generation, a well-organized waste management system becomes necessary to promote sustainable development in Myanmar (Raitzer et al., 2015).

The performance of existing buildings in response to changing climate is another aspect to consider. Even though modern buildings have emerged across Myanmar with technological advancement and economic development, the performance of traditional buildings should not be neglected given its dominance in Myanmar's built environment. Previous research highlights the severe effects of climate change, rapid population growth, and deforestation on Myanmar's housing sector (Zune et al., 2020a). The study by Zune et al. (2020b) revealed that modern houses in Myanmar are confronting these challenges; they are not adaptable to extreme heat waves and increased temperature. Another study by Zune et al. (2020a) found that traditional building design is not adequate to achieve thermal comfort in accordance with the predicted climate characteristics. Therefore, building performance for human comfort should be improved to cope with the changing climate.

Although standards and specifications for green buildings have not been developed in Myanmar, some buildings have been certified by foreign GBRSs such as Green Mark (Singapore) and LEED (US). For the non-residential building sector, Sedona Hotel's new portion (Inya Wing, Yangon) and Junction City Yangon have attained Green Mark Gold awards (Lwin & Panuwatwanich, 2020). Likewise, World Bank offices in Yangon have recently achieved LEED Gold certificates and The Embankment office building in Yangon has been registered for LEED certification. For the industrial building sector, Guston Amava Limited in Yangon and Amava Apparel Limited in Pathein city have been certified by LEED Platinum awards (GBIG, 2020).

2.2 Comparative Review of Green Building Rating Systems

A review of existing green building rating systems and comparison of different rating methods are fundamental for new system development. Regarding the implementation of a GBRS, which is also known as Green Building Assessment Tool in some countries, the adopted green building criteria are generally derived from previously developed rating systems. In particular, developing countries would adopt the most suitable criteria considering the likely compatibility with their country's local situations and the expediency of these assessment tools. Moreover, rating systems should be developed based on scientific research, technical requirements, and stakeholders' participation. Shan and Hwang (2018) studied 15 widely recognized green building assessment tools around the world, reviewing their criteria and points-based systems. Their study showed that many tools developed at the beginning of 21st century were derived from the three main tools, namely LEED, BREEAM, and BEAM introduced in the 1990s and further identified seven vital categories from the rating-system comparison with "Energy" as the main category, followed by "Site," "Indoor Environment," "Land and Outdoor Environment," "Material," "Water," and "Innovation." Darus et al. (2009) reviewed the performances of the Green Building Tool from Canada, LEED from the USA, CASBEE from Japan, BREEAM from the UK, HQE from France, Green Mark from Singapore, HK-BEAM from Hong Kong, and VERDE from Spain to determine their suitability for Malaysia. From the study, Green Mark was considered as a comprehensive reference for the development of a sustainable tool in Malaysia, through an analysis of existing office buildings and applying experts' comments. Nevertheless, the authors argue that the relevant criteria from Green Mark need to be adjusted to suit the local conditions of Malaysia.

Nguyen and Altan (2011) compared five green building assessment tools namely BREEAM, LEED, GREEN STAR, HK-BEAM, and CASBEE in order to find the best tool by considering the related issues of these rating systems such as "popularity and influence, availability, methodology, applicability, data collection process, accuracy and verification, user-friendliness, development, and result presentation." The final scores were calculated depending on the based points that the authors defined for each of these issues. The results revealed that BREEAM and LEED have the highest scores followed by CASBEE, GREEN STAR, and HK-BEAM. Doan et al. (2017) analyzed CASBEE, BREEAM, LEED, and Green Star NZ to investigate the systematic green building rating systems development. The results showed that BREEAM was considered as a robust assessment tool. However, there is currently no rating system that could assess all sustainability aspects of a project. BREEAM, LEED, and CASBEE have been employed since the end of the 2000s whereas Green Star NZ is in an early stage. The study pointed out that Indoor Environmental Quality, Energy, and Material are the common categories across the selected rating systems. Among the various versions of an assessment tool, the new construction version mainly focuses on environmental concerns whereas social aspect is highlighted in the neighborhood development version, which includes the concepts of urbanism, smart growth, and green building altogether. Illankoon et al. (2017) established a criteria baseline rooted in the related literature and eight assessment tools to develop a future green building rating tool and to evaluate the existing tools. The research analysis was based on a quantitative approach; normalized values of allocated scores of credit criteria were calculated for further comparison. The authors compared seven criteria namely (1) Site, (2) Energy, (3) Water, (4) Indoor Environment Quality (IEQ), (5) Material, (6) Waste and pollution, and (7) Management. Among them, energy was identified as the most important category followed by indoor environmental quality and water criteria. The findings revealed that other economic and social related criteria should be designed for the future purpose of rating system development.

Previous studies explored the international rating systems and presented their capability and common criteria. Assessment categories and criteria of the existing rating systems should be compared and synthesized to extract key items for the future rating system development, since many assessment methods have been developed with differences and similarities existing among them. Therefore, as presented later in Section 4, this study conducted the critical evaluation of globally recognized seven rating systems namely LEED, BREEAM, Green Star, Three Star, Green Mark, HQE, and TREES in order to identify the potential indicators that could be further examined and considered with respect to the factors that are indigenous to Myanmar.

2.3 Adoption of Green Building Rating Systems

Existing green buildings can be investigated as case studies to scrutinize the applicability of rating systems regarding regional circumstances. El Yamany et al. (2016) recommended LEED from the U.S. Green Building Council (USGBC) as a thriving sustainable tool that can enhance the sustainability of Egyptian buildings and assess building performance. They examined a longitudinal study of three LEED-certified buildings by investigating the suitability of LEED criteria for local use in Egypt. Moussa and Farag (2017) investigated the LEED rating system for New Construction (Version 9), and examined its applicability in the Middle East. They compared the scores of 25 projects from five countries, based on score sheets from the U.S. Green Building Council. Their research showed that there are some variations in the categories and criteria comparison of these projects, according to regional differences. For instance, the "Sustainable Site" category is reasonable for all countries except Oman, and "Energy and Atmosphere" is a well-performing category for the Kingdom of Saudi Arabia. Israel and the UAE experienced complications in the "Water Efficiency" category. In addition, the study extracted the achievable criteria, as well as pointing out the most attractive criteria (i.e. the criteria that attract developers to implement in the project) of all categories in the comparison. The identification of benefits and hindrances of each assessment category and criterion is necessary for the implementation of a green building assessment tool. A study of indoor environmental quality credits in green buildings in India by Vohra and Mital (2016) demonstrated how to overcome the barriers to achieving the criteria for buildings to be certified as green. It also suggested how to make the criteria more easily achievable by the stakeholders' experience and ranking method. Their study used six buildings certified by the LEED India rating system (i.e. LEED modified for Indian context) as case studies, to classify the catalysts and hindrances of each credit under the Indoor Environmental Quality (IEQ) category. For the IEQ criteria of buildings in India, "productivity, occupant comfort and wellbeing, and improved indoor air quality" are beneficial features, and the difficulties faced to attain these criteria are "high implementation cost of technology, amendment in the design of the building, and obstruction to coordinate with the MEP, architect, and project manager."

Some research also considers the local professionals' perceptions for GBRS adoption. Khaemba and Mutsune (2014) found that 26 green building attributes, grouped under 5 categories, including "Sustainable Sites," "Water Efficiency," "Energy and Atmosphere," "Materials and Resources," and "Indoor Environmental Quality," are the best measures for adoption in Kenya and further having their level of importance defined by using descriptive statistical tools. In a study to establish the SABA green building rating system in Jordan by Ali and Al Nsairat (2009), international rating systems, including LEED, CASBEE, BREEAM, GB Tool, and others were studied to identify assessment measures that are suited for Jordan. Seven main categories, 42 indicators, and 157 parameters were ranked by their proper imperative, according to the awareness and familiarity of stakeholders, and the environmental situations in Jordan. Regarding the ranking results from respondents utilizing the analytic hierarchy process (AHP) method, seven categories from the SABA rating system are arranged as follows: Water Efficiency, Energy Efficiency, Indoor Environment Quality, Site, Material, Cost and Economics, and Pollution, with each category consisting of related indicators with nested parameters. Banani et al. (2016) addressed the debate on the capability of the rating systems outside of the original country. They compared the five assessment tools such as BREEAM, LEED, Green Star, CASBEE, and Estidama for launching the domestic sustainable criteria framework for non-residential buildings in Saudi Arabia. Perceptions of local experts and Analytic Hierarchy Process (AHP) were employed for analysis. Nine categories and 36 criteria were identified: Water Efficiency, Energy Efficiency, Indoor Air Quality, Materials Selection, Effective Management, Land and Waste, Whole-Life Cost, Quality of Service, and Cultural Aspects. The results revealed that water and energy categories account for 51% of the total assessment indicators' weight, in which water is more dominant than energy according to the contexts of Saudi Arabia. Bhatt and Macwan (2012) attempted to find the global weights of sustainable building indicators for India's regional variation in economics, environment, society, and culture. They prioritized these indicators by the AHP method according to the decisions of a group of consultants from various areas of India, and found that Renewable Energy, Optimum Energy Performance, Water-Use Reduction, Reduced Wastewater Generation, and Energy Accountability turned out as major criteria.

Although green building rating systems have been developed and studied globally, the understanding of this topic in Myanmar is sufficiently lacking, which is significantly limiting the sustainable building development in the country. Shwe et al. (2017b) discussed the sustainability assessment framework for Myanmar by incorporating the usefulness of selected developed assessment tools, and sustainability ideologies and realistic aspects from case studies. Based on the adaptive measures, suitable indicators for neighborhood and city level were identified for local use in Myanmar. Shwe et al. (2018) also assessed three existing projects in three different cities in Myanmar using LEED, BREEAM, and CASBEE for neighborhood development. Three sustainability aspects of the effectiveness of these tools were investigated for developing countries. The research showed that these tools are not suitable for the projects which were designed for three regions in Myanmar. From the study, it was concluded that developing countries require the development of their own relevant tools, considering a country's locality. For Myanmar, rules and regulations for sustainable development are necessary for long term development. Bearing in mind that a proposed building sustainability assessment tool should be appropriate for the local contexts of Myanmar, this study adopted and modified the assessment indicators from the integration of seven existing rating systems and investigation of existing Green Mark certified buildings in Myanmar, and employed Fuzzy Analytic Hierarchy Process (Fuzzy AHP) to determine the weightings of the proposed indicators. The following sections further elaborate on the methodology used in this study.

3. METHODOLOGY

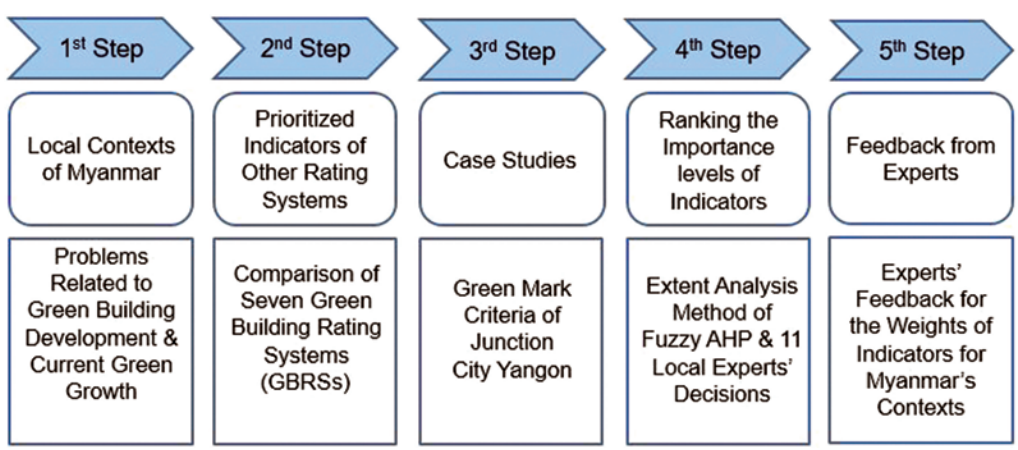
3.1 Research Design

In this research, the case study and Fuzzy Analytic Hierarchy Process (Fuzzy AHP) methods were adopted as the main tool for the selection and analysis of green building assessment indicators (i.e. categories and criteria) for Myanmar. Five stages were implemented as the research design framework. Problems related to green building development, an overview of current green growth and green buildings in Myanmar were identified from the literature review as the first step. The second step is the comparison of seven GBRSs to identify and select common indicators among all the reviewed systems. As the third step, three existing buildings in the Junction City Yangon project in Myanmar, which have been certified for the Green Mark Gold award, were selected as a case study. Suitable categories and criteria for Myanmar were identified from the comparison and case study including the interview with three sustainable building professionals to refine the selected criteria. The fourth step is the pairwise comparison of categories and criteria utilizing the Fuzzy AHP technique based on the input from 11 local experts. The extent analysis method in Fuzzy AHP was applied to rank the importance levels of the categories and criteria. The weights of the indicators were summarized, and the discussion on the relevance of the prioritized indicators in the context of Myanmar presented. As the final stage, the feedback from the experts was requested by sending the weighting results. The research design can be summarized in Figure 1.

3.2 Data Collection and Analysis

First, engineering drawings, Green Mark score sheets, and other required documents of three case study buildings in the Junction City Yangon project were collected as case studies. Environmentally Sustainable Design (ESD) consultants, architects, and mechanical and electrical engineers involved in the design, construction, and certification processes of these buildings were interviewed. From the case study results, and comparison of seven GBRSs, suitable categories and criteria were identified, and those selected indicators were modified with the input from three sustainable building professionals. Second, the finalized assessment items were converted into an assessment form for the pairwise comparison as part of the Fuzzy AHP technique, which was sent to 36 professionals in Myanmar to compare the importance levels of

FIGURE 1. Research Design.



categories and criteria. These professionals include those from the Junction City Project, experts from Myanmar Green Building Society, professors from academic fields, and engineers from government organizations who worked for the country's environmental regulators.

The Fuzzy AHP assessment form, cover letter, and research information were distributed by both email and in-person to the experts. Among the invited 36 professionals, 17 responses were received. Six responses were removed due to incomplete and inconsistent assessment. Hence, 11 responses were included for the analysis. The Fuzzy AHP calculation was then carried out using the fuzzy mathematical model with calculation performed in a computer spreadsheet. Among the different approaches of the Fuzzy AHP assessment, this research applied Chang's (1996) extent analysis method. In Chang's method, vagueness related to pairwise comparison results was modeled by triangular fuzzy numbers. Estimations of the vectors of weights under each criterion were obtained by the calculation procedures which are entered into spreadsheet software. Finally, five experts who were members of Myanmar's Green Building Society were requested to comment and provide feedback on the priority ranking of the assessment indicators.

3.3 Application of Fuzzy Analytic Hierarchy Process

Thomas L. Saaty's conventional Analytic Hierarchy Process (AHP) method (Saaty, 2008) is popular for solving multi-criteria decision-making problems. The main purpose of the AHP is to rank the criteria and sub-criteria by their importance levels through the pairwise comparison matrix and hierarchical structure. However, AHP has some disadvantages: there is a lack of interval judgment between comparison scales, and it does not consider uncertainty in the assessment model (Zarghami et al., 2019; Gopal & Thakkar, 2015). Human preference and judgment are vague and imprecise, and AHP cannot handle incomplete data and uncertain judgments of the decision-makers. To deal with these uncertainties, fuzzy logic is incorporated into the conventional AHP, by using triangular fuzzy numbers with a pairwise comparison scale to determine the weights of criteria. Fuzzy AHP is utilized to transform linguistic assessments into fuzzy numbers for the building of comparison matrices to calculate the weights based on the conventional AHP (Durán & Aguilo, 2008). Kordi and Brandit (2012) indicated that even though AHP may already be developed as fuzzy process, researchers realize that there are a number of reasons to fuzzify it further. One reason is the necessity for greater flexibilities in decision making process to rank the importance level of criteria over each other. Decision makers are more flexible to show their preferences by various degrees of fuzzification and uncertainty of fuzzy ratios. Another reason is that fuzzy method can perform the interval judgment which does not exist in conventional AHP instead of combining the different judgments of different decision makers (Gopal & Thakkar, 2015; Kordi & Brandit, 2012). Fuzzy AHP has been commonly applied in research related to sustainability issues (Zarghami et al., 2019). Therefore, the Fuzzy AHP is considered suitable to perform multi-criteria decision-making problems related to individual judgments, particularly in sustainability assessment. Fuzzy triangular numbers have been widely adopted because of the linearity of the fuzzy triangular membership function and the straightforward calculations (Calabrese et al., 2016). Among Fuzzy AHP methods, the extent analysis method presented by Chang (1996) is well-known and widely used in the research studies (Uğurlu, 2015). In the extent analysis method, each criterion is considered as important (at the same time) and extension analysis is observed. The weight vectors for each element under a certain criterion of a hierarchical structure of the green building rating system were attained by the extent analysis method for the synthetic extent value and the comparison of fuzzy numbers (Chang, 1996). In this study, the calculation procedure of fuzzy AHP was performed in a Microsoft Excel spreadsheet to find the relative importance weights of green building categories and criteria for Myanmar.

4. COMPARISON OF SEVEN GREEN BUILDING RATING SYSTEMS

Seven widely adopted green building assessment tools (LEED, BREEAM, Green Star, Three Star, Green Mark, HQE, and TREES) were compared for the selection of green features adaptable for the context of Myanmar. In the comparison of seven GBRSs categories as shown in Table 1, although some categories appear to be omitted in some rating systems, they are in fact manifested in criteria under other related categories. Common categories of all seven rating systems are "Energy," "Indoor Environmental Quality," "Water," "Materials," and "Sustainable Site." Almost all rating systems evaluated in this study consider "Management," "Transportation," "Innovation," "Waste," and "Pollution." "Regional Priority" is the innovative assessment item of LEED and "Maintenance" and "Work Site" are originated from HQE. "Climatic Responsive Design" and "Environmental Protection" are derived from Green Mark NRB/2015 and NRB/4.1. The common categories and other relevant categories included in the studied seven rating systems are proposed for the Myanmar context. Table 2 presents the

TABLE 1. Categories Comparison of Seven GBRSs.

Categories	LEED	BREEAM	GM NRB/2015	GM NRB/4.1	Green Star	Three Star	HQE	TREES
Energy	√	√	√	√	√	√	√	√
Indoor Environmental Quality	√	√	√	√	√	√	√	√
Water	√	√	√	√	√	√	√	√
Materials	√	√	√	√	√	√	√	√
Sustainable Sites	√	√	√	√	√	√	√	√
Management	X	√	√	√	√	√	X	√
Transportation	√	√	√	√	√	X	X	X
Innovation	√	√	√	√	√	X	X	√
Waste	X	√	√	√	X	X	√	√
Pollution	X	√	X	X	√	X	X	X
Regional Priority	√	X	X	X	X	X	X	X
Climatic Responsive Design	X	X	√	X	X	X	X	X
Environmental Protection	X	X	X	√	X	X	X	X
Maintenance	X	X	X	X	X	X	√	X
Work Site	X	X	X	X	X	X	√	X

TABLE 2. Category Grouping of the Criteria across the Seven GBRSs.

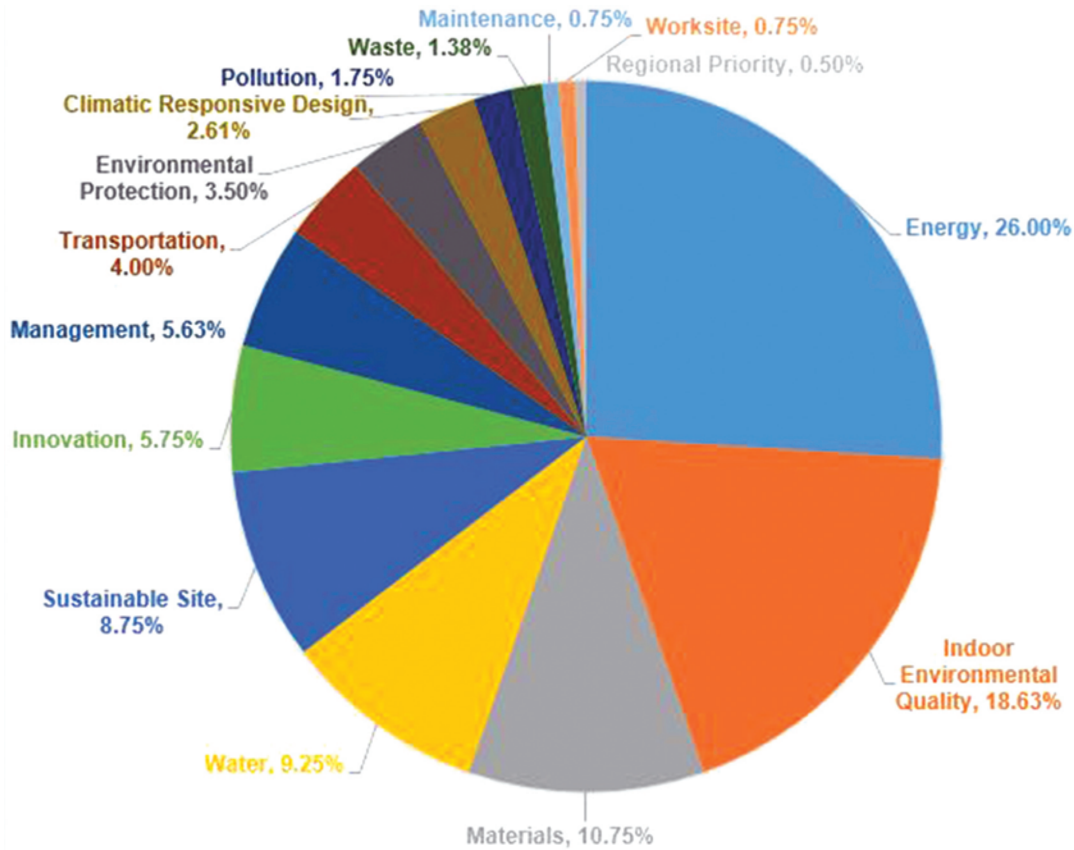
Categories	Criteria	LEED	BREEAM	GM NRB/2015	GM NRB/4.1	Green Star	Three Star	HQE	TREES
Management	Accredited Professional	√	X	√	√	√	√	X	X
	Integrative Design Process	X	√	√	X	X	X	X	X
	Sustainable Building Practices	X	√	√	√	√	√	X	√
	Life Cycle Cost	X	√	X	X	X	√	X	X
	Commissioning	X	√	X	X	√	X	X	X
	Promoting Green Building	X	X	X	X	X	X	X	√
Energy Efficiency	HVAC System	√	√	√	√	√	√	√	√
	Lighting (External & Internal)	√	√	√	√	√	√	√	√
	Ventilation	√	√	√	√	√	√	√	√
	Energy Efficient Features	X	X	X	√	X	X	X	√
	Building Envelope	√	√	√	√	√	√	√	√
	Energy Monitoring	√	√	X	X	X	X	X	X
	Carbon Reduction	√	√	X	X	X	X	√	X
	Hot Water Heating Efficiency	X	X	X	X	X	√	√	X
	Energy Efficient Architectural Design	√	√	√	√	√	√	√	√
	Energy Efficient Lifts and Escalators	X	√	X	√	X	X	X	X
	Energy in Car Park	X	√	√	X	X	X	X	X
	Renewable Energy	√	√	√	√	√	√	√	√
	Energy Performance and saving	√	√	√	X	√	X	X	√
Water Efficiency	Water Efficient Fittings	√	√	√	√	√	√	√	√
	Wastewater Treatment	√	√	√	√	X	√	X	X
	Outdoor Irrigation	√	√	√	√	√	√	X	X
	Leak Detection	√	√	√	√	X	X	X	√
	Water Metering	√	√	√	√	X	√	X	√
	Rain Water Collection	√	√	√	X	√	X	√	√
	Cooling Tower Water Treatment	√	X	√	√	X	X	X	X
Materials & Resources	Life Cycle Impacts	√	√	√	X	√	√	√	√

	Use of Recycled Materials	√	√	√	√	X	√	√	√
	Sustainable Products	√	√	√	√	√	√	√	√
	Concrete Usage Index (CUI)			√	√	X	X	X	X
	Material Sources	√	√	X	X	√	X	X	X
	Local Materials	X	X	X	X	X	√	X	√
	Reuse Materials	X	X	X	X	X	√	X	√
	Material Ingredients	√	X	X	X	X	X	X	X
	Insulation	X	√	X	X	X	X	X	X
	Material Efficiency	X	√	X	X	X	X	X	X
	Offsite Mixed Concrete Supplies	X	X	X	X	X	√	X	X
Indoor Environmental Quality	Indoor Air Quality (Strategies, Management, Assessment)	√	√	√	√	√	√	√	√
	Low Emitting Materials	√	X	√	√	X	X	X	√
	Visual Comfort	√	√	√	√	√	√	√	√
	Acoustic Performance	√	√	√	√	√	√	√	X
	Thermal Comfort	√	√	√	√	√	√	√	√
	Safety and Security	X	√	X	X	X	X	X	X
	Smart Building Operation	X	X	√	X	X	X	X	X
	Olfactory Comfort, Spaces and Water Quality	X	X	X	X	X	X	√	X
	Accessibility—Disabled Persons, Elderly, Young	X	X	X	X	X	√	X	X
	Exterior Shading	X	X	X	X	X	√	X	X
Sustainable Sites	Site Selection	√	√	X	X	√	√	X	√
	Protection of Site Ecology	X	√	X	X	√	X	X	X
	Site Assessment	√	X	√	X	X	X	√	X
	Heat Island Reduction	√	X	√	√	√	√	X	√
	Open Space	√	X	X	X	X	X	√	√
	Brown Field	√	X	X	X	√	√	X	X
	Sensitive Land Protection	√	X	X	X	√	X	X	X
	Underground Development	X	X	X	X	X	√	X	X
	Protecting Habitats	√	√	X	X	X	X	X	X

TABLE 2. Category Grouping of the Criteria across the Seven GBRSs.

Categories	Criteria	LEED	BREEAM	GM NRB/2015	GM NRB/4.1	Green Star	Three Star	HQE	TREES
Transportation	Access by Public Transport	√	√	X	√	√	X	X	√
	Bicycle Facilities	√	√	√	√	√	X	X	√
	Reduce Car Parking Spaces	√	√	√	X	√	X	X	X
	Developed Land	X	√	X	X	√	X	X	X
	Low Emission Vehicles	√	X	√	√	√	X	X	√
	Promote bicycle usage	X	X	√	X	X	X	X	X
	Cover Walkway Facilities	X	X	X	√	X	X	X	X
Waste	Construction Waste Management	√	√	√	X	√	√	√	√
	Operational Waste Management	X	√	√	X	√	X	√	X
Pollution	Refrigerant Impact	√	√	X	√	√	X	√	√
	Light Pollution	X	√	X	X	√	X	√	X
	Noise Pollution	X	√	X	X	X	X	√	X
	Stormwater	√	√	X	√	√	X	X	X
	NOx Emission	X	√	X	X	X	X	X	X

FIGURE 2. Average Point Percentages of the Seven GBRSs' Categories.



grouping of the main criteria across all seven of the GBRSs into the proposed categories for Myanmar. It is worth noting that there are differences in the allocation of points for the categories in these rating systems since each of them was developed in accordance with the local circumstances of a specific country. In order to understand the overall emphasis that these GBRSs place on each category, the percentage proportion of these allocated points were calculated and averaged. These average point percentages of all categories in Table 1 are summarized in Figure 2. It can be seen from the figure that "Energy" is the most imperative category with 26% allocated points whereas "Indoor Environmental Quality" has been placed as the second most important category with 18.63%. "Materials" is in the third position with 10.75% followed by "Water" (9.25%), "Sustainable Site" (8.75%), "Innovation" (5.75%), "Management" (5.63%), and "Transportation" (4%). "Pollution" (1.75%) and "Waste" (1.38%) are the relatively least important categories.

5. APPLICABLE CRITERIA FROM THE CASE STUDY (JUNCTION CITY YANGON)

In the development of any domestic GBRS, the local situation such as environmental, social, climate, cultural, and economic aspects have been commonly considered. In addition, involvement of stakeholders, technical observation, and scientific research should be included for the development of local standards and codes. Likewise, the assessment of building performance should be carried out for investigating the local sustainability issues and main objectives (El Yamany et al., 2016). Thus, to achieve the objectives of this study, the Junction City Yangon project in Myanmar, which is certified by Singapore's BCA Green Mark, was studied to examine the applicability of overseas GBRS with regards to green technologies and standards, applicable criteria, and challenges in the context of Myanmar.

With an estimated developed area of 260,000 square meters, the Junction City Yangon is a world-class mixed-use project comprising a Grade-A office tower, retail and entertainment complex, and a five-star luxury hotel. This project is unique for its landmark of sustainability among buildings in Myanmar. This project resulted in a 15–29% energy consumption reduction based on Singapore's baseline standards (Joshua & Taylor 2017). The case studies were conducted with the three buildings in the Junction City Yangon project: Office Tower, Retail Mall, and Hotel Tower buildings by interviewing the professionals who were involved in the project during the implementation period. From the results, BCA Green Mark for New Non-Residential Building Version NRB/4.1 was considered an appropriate tool to be employed in

TABLE 3. Applicable Green Mark Criteria from Case Studies.

Categories	Easily Achieved Criteria	Challenging Criteria
Part 1—Energy Efficiency	• NRB 1-2 Air Conditioning System • NRB 1-6 Artificial Lighting • NRB 1-7 Ventilation in Car parks • NRB 1-8 Ventilation in Common Areas • NRB 1-9 Lifts & Escalators	• NRB 1-1 Thermal Performance of Building Envelope—EETV • NRB 1-3 Building Envelope—Design/Thermal Parameters • NRB 1-4 Natural Ventilation/ Mechanical Ventilation (not targeted) • NRB 1-5 Day lighting (not targeted) • NRB 1-10 Energy Efficient Features • NRB 1-11 Renewable Energy
Part 2—Water Efficiency	• NRB 2-1 Water Efficient Fittings • NRB 2-2 Water Usage and Leak Detection	• NRB 2-3 Irrigation System and Landscaping
Part 3—Environmental Protection	• NRB 3-5 Green Transport • NRB 3-6 Refrigerants	• NRB 3-1 Sustainable Construction • NRB 3-2 Sustainable Products • NRB 3-3 Greenery Provision • NRB 3-4 Environmental Management Practice • NRB 3-7 Stormwater Management (not targeted)
Part 4—Indoor Environmental Quality	• NRB 4-1 Thermal Comfort • NRB 4-2 Noise Level • NRB 4-5 High Frequency Ballasts	• NRB 4-3 Indoor Air Pollutants • NRB 4-4 Indoor Air Quality Management
Part 5—Other Green Features	• NRB 5-1 Green Features & Innovations	

Myanmar. As proposed assessment indicators were required to be compatible with the local conditions of the country, the criteria implemented in the project were analyzed to identify which of them can be adopted for Myanmar. Five categories of Green Mark NRB/V4.1 could be certified in the Junction City Yangon project. Green Mark NRB/V4.1 allocates almost 50% of the total points to the "Energy Efficiency" category. Among all assessment criteria under the five categories, those under "Water Efficiency" and "Indoor Environmental Quality" were less demanding and feasible for the implementation, despite some challenges regarding the regional situations such as the country's economic condition, lack of public awareness and demand for green building, and absence of the government's support. Some criteria were not targeted by the project team while others were only applicable depending on project size, area, and location. For the criteria under "Green Features and Innovations" category, only the social development activities could be accomplished while advanced technology invention was a great challenge for Myanmar. The easily achieved criteria and challenging criteria according to the interview results are summarized in Table 3. Among them, adaptable criteria were selected for the development of the framework for Myanmar GBRS based on experts' suggestions.

6. SELECTION OF CATEGORIES AND CRITERIA FOR MYANMAR GREEN BUILDING RATING SYSTEM

Based on the GBRSs comparison and the case studies, categories and related criteria were selected upon the consultation with local experts. A framework of the assessment indicators for Myanmar covering 9 categories and 48 criteria was established by building the three hierarchical levels consisting of goal, categories, and criteria according to the Fuzzy AHP concept. The first level—"goal" was defined as green building rating system. The second level—proposed localized "categories" are management, energy efficiency, water efficiency, material and resources, indoor environmental quality, sustainable site, transportation, waste and pollution, and innovation. The third level—"criteria" were compiled by integrating the assessment criteria from seven rating systems and case studies in such a way that some irrelevant criteria were removed, some were added, and some were recommended for Myanmar. The consolidated criteria were then improved according to the suggestions of the professionals. Figure 3 illustrates the framework of the proposed Myanmar's GBRS categories and criteria. Each of the framework category is explained below.

6.1 Management

Five criteria were recognized under the "management" category. The criterion related to sustainable building practices is shared by most of the rating systems reviewed in this study. One expert suggested that the integrated design process criterion that can be effortlessly implemented for certification assessment. Myanmar is in need of well-experienced professionals for green building. Experts agreed that accredited professional is able to deliver awareness about sustainability standards among local professionals by providing the training and participating in the project implementation and assessment process. Regarding the three pillars of sustainability, the role of economic sustainability should be involved in the GBRS framework. The initial cost exists as an immense challenge in the green construction of Myanmar. The life cycle cost is proven essential because it considers the financial scope (cost-effectiveness) during the design stage and the long-term benefits of good building performance. It can also attract the stakeholders to invest in green buildings as a way to minimize life cycle costs as compared with the traditional buildings.

6.2 Energy Efficiency

Energy efficiency category involves eight criteria. In nearly all rating systems analyzed in this study, passive building design, HVAC system, and lighting were recognized as typical criteria under energy efficiency. Provision of energy efficient transportation which involves lifts and escalators in the building was an easily achieved criterion in the case study. Since Myanmar needs a large production of electricity for further development, it was suggested that renewable energy production onsite is an effective criterion in the effort to generate sustainable energy. Experts believed that renewable energy will be popular in the future, although it is currently considered an expensive way of energy generation.

6.3 Water Efficiency

In the water efficiency category, water usage monitoring by installing sub-meters, water-efficient fixtures, onsite rainwater collection, and reusing the recycled wastewater on-site are the traditional criteria allowed under all rating systems studied. Municipal water supply is limited, and groundwater is extracted for daily demands in Myanmar. Rainwater harvesting onsite is recommended as a sustainable and cost-effective water collection system to prevent water resource depletion. Although installation, maintenance, and operation costs are high for storage of rainwater, rainwater collection can reduce the amount of water bills, and the initial cost can be easily recovered in the long term (Rahman et al., 2014). Lastly, cooling tower water treatment system to conserve water quality of cooling tower for preventing causes of health problems was achievable in Junction City Yangon as one criterion of the Green Mark.

6.4 Material and Resources

Reused and recycled materials are the general criteria for material efficiency which is presented in all systems. The Green Mark criteria, including calculation of concrete usage index, choosing proper refrigerants, and utilizing sustainable products were adopted because of their applicability in Myanmar, according to the case study results. Promoting the use of country's traditional construction materials, frequently known as local materials criterion is relevant to green construction in Myanmar where most of the products are imported from foreign countries. It also raises the demand for local products as a part of economic sustainability.

6.5 Indoor Environmental Quality

Indoor environmental quality category is dominant in all seven rating systems, highlighting the pollution, ventilation, lighting, sound, and heating and cooling related criteria for the occupants' comfort. Moreover, the assessment of ventilation system in installation, design, and operation phases is found under all rating systems. Experts agreed that proper selection of materials that avoids the contamination of building for occupants' health, is suitable for Myanmar. This criterion does not need much effort and technology for implementation.

6.6 Sustainable Site

Most of the criteria under the sustainable site category revolve around site selection, protection of land, greenery, and habitats. Although BREEAM and Green Star emphasize site ecology, it was removed in the case of Myanmar because of the limited number of environmentalists who have expertise in ecology, and the lack of standards for environmental impact assessment in Myanmar. Sensitive lands protection criterion is sensible for Myanmar rating system. This is because it can help to overcome the current challenges in Myanmar as green area is significantly low, and green landscape and playground have been rapidly replaced by infrastructures.

6.7 Transportation

All rating systems studied in this research include "public transport accessibility" criterion. In addition, BREEAM and Green Star offer "proximity to amenities" criterion which means that the project is sited near the urban facilities and featured buildings of the city to reduce the vehicle travel distance. "Bicycle facilities" criterion is presented in all reviewed rating systems. However, bicycles are not normally used in Yangon as bicycle lanes and safe spaces are not specified for urban lanes. Thus, "promoting bicycle usage," which is unique criterion under Green Mark 2015, is simply recommended for the rating system in Myanmar, instead of "bicycle facilities" criterion (supporting charging stations and parking facilities for bicycles). Low-emission vehicles are generally an unaffordable technology in Myanmar.

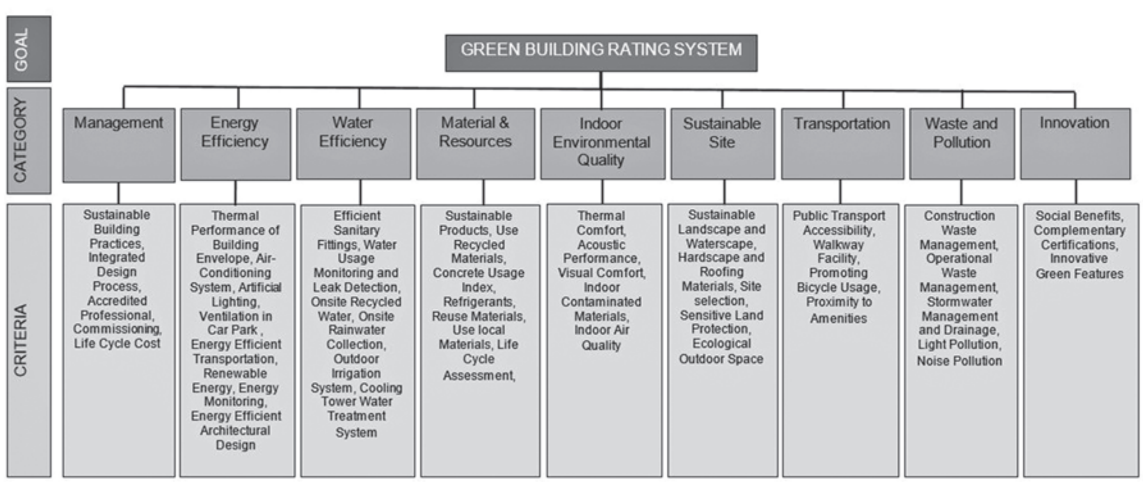
6.8 Waste and Pollution

Waste management during the construction and operation stages was grouped into this category. By providing effective waste management system in the building sector, mass construction waste destined to landfill sites can be significantly reduced in Myanmar where sanitary landfill or waste segregation systems are vulnerable. Stormwater management and drainage is a unique criterion for the urban landscape and pollution reduction. Experts agreed that external lighting for urban night view and noise level for surroundings are important issues and must be addressed.

6.9 Innovation Category

All rating systems offered this category as a mark of honor to the project team that attempts to meet the objectives of green building with exceptional performance by inventing technology. Social benefits and complementary certifications criteria under innovation category of Green Mark 2015 are adopted beyond environmental concerns. Junction City Yangon project

FIGURE 3. Proposed Myanmar's GBRS Framework.



implemented most of the criteria associated with Corporate Social Responsibility (CSR) activities to certify green features and innovations category of Green Mark NRB/4.1.

7. FUZZY AHP RESULTS AND DISCUSSION

7.1 Categories Weights

For the development of an assessment tool, a weighting system of the established indicators is necessary (Ali & Al Nsairat, 2009). In this research, the weights of the categories and criteria were determined through the Fuzzy AHP technique utilizing the pairwise comparison input from 11 experts in Myanmar. The majority of the invited experts are from Myanmar Green Building Society, and some are participants of the Junction City Yangon project and academicians.

As shown in Figure 4, energy efficiency leads the group in Myanmar's build environment context with the assigned weight of 17.48%, followed by water efficiency (13.95%) indoor environmental quality (13.23%), management (13.13%), and waste and pollution (12.95%). The last four categories are sustainable site (10.59%), material and resources (9.76%), transportation (8.67%), and innovation (0.23%). The weighting results of the categories are in line with the current problems in Myanmar such as the energy crisis, insufficient water supply, and unsystematic waste management.

7.2 Criteria Weights

In addition to the calculation of categories' weights, criteria are also rated by their importance levels. The localized priority weights of the criteria of each category are presented in Figures 5–13.

- *Energy Efficiency:* For the criteria of the energy efficiency category, the energy-efficient architectural design is the crucial criterion among other criteria with the 38.40% weight. The thermal performance of the building envelope is second with the weight of 22.77%. The total weight of these two important criteria accounts for more than half of the total weight of the energy category. The air-conditioning system and renewable energy reach nearly the same rating with 9.25% and 8.68%, respectively.
- *Water Efficiency:* The intents of key criteria of the water efficiency category are to collect the rainwater onsite (23.75%) and to provide water-efficient fixtures in the building (21.23%). Water usage monitoring and leakage detection is the third most vital criterion with the weight of 17.60%.
- *Indoor Environmental Quality:* Indoor air quality (34.01%) is the first in the indoor environmental quality category, followed by thermal comfort (28.37%), and indoor contaminated materials (25.71%). As the least important criteria, visual comfort and acoustic performance are weighted as 7.48% and 4.42%, respectively.
- *Management:* The criteria of the Management category are arranged as an integrated design process (27.03%), sustainable building practices (25.30%), accredited professionals (23.14%), commission (14.03%), and life cycle cost (10.49%).
- *Waste and Pollution:* For the waste and pollution category, experts agreed that stormwater management and drainage is the most essential criterion (41.08%), which is almost half of the total weight. In addition, "the operational waste management" and "construction waste management" criteria are considered as sensible measures with the weight of 28.10% and 25.51%, respectively.

- *Sustainable Site:* Sensitive land protection (30.18%) and hardscape and roofing materials (11.14%) are positioned as the most and least vital criteria in a sustainable site category. Ecological outdoor space stands at second rank with the weight of 23.09% followed by sustainable landscape and waterscape (18.93%) and site selection (16.66%).
- *Material and Resources:* The top three criteria of the material and resources category are sustainable products (16.44%), concrete usage index (15.93%), and refrigerants (15.74%), followed by the remaining four criteria with similar weight values, ranging from 12.43% to 13.37%.
- *Transportation:* Experts considered the selection of project sites which have access to public transportation as relatively high with the 42.7% weight as compared with other criteria. Promoting bicycle usage (10.59%) is defined as the least vital measure.
- *Innovation:* In the innovation category, experts indicated that the social benefits criterion is the most beneficial one with the weight of 46.32%. In addition, innovative green features criterion is rated as the second ranking (38.12%) and complementary certification is ranked as the least important criterion (15.56%).

After indicating the local priority weights of the criteria, the global weight was determined by multiplying the local priority weight of each criterion by the weight of the corresponding category, as presented in Table 4. The purpose of the global weight is for overall ranking of the

FIGURE 4. Weight of Categories.

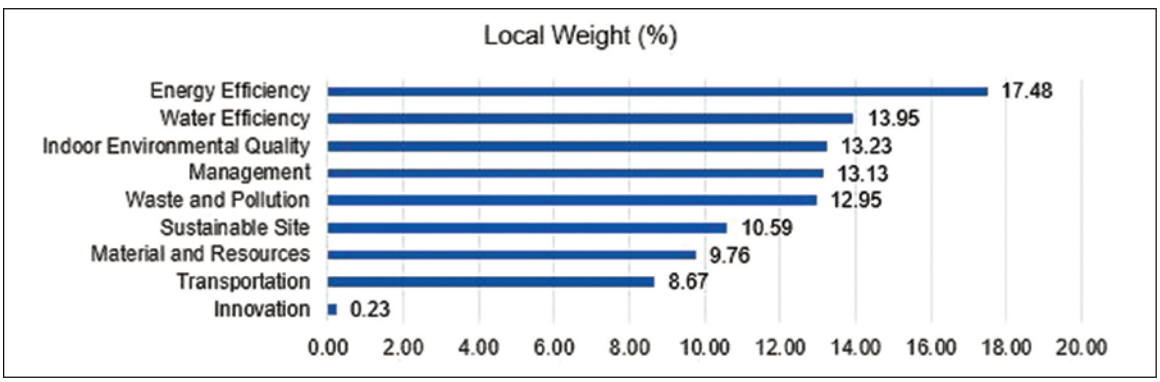


FIGURE 5. Criteria Weights: Energy Efficiency Category.

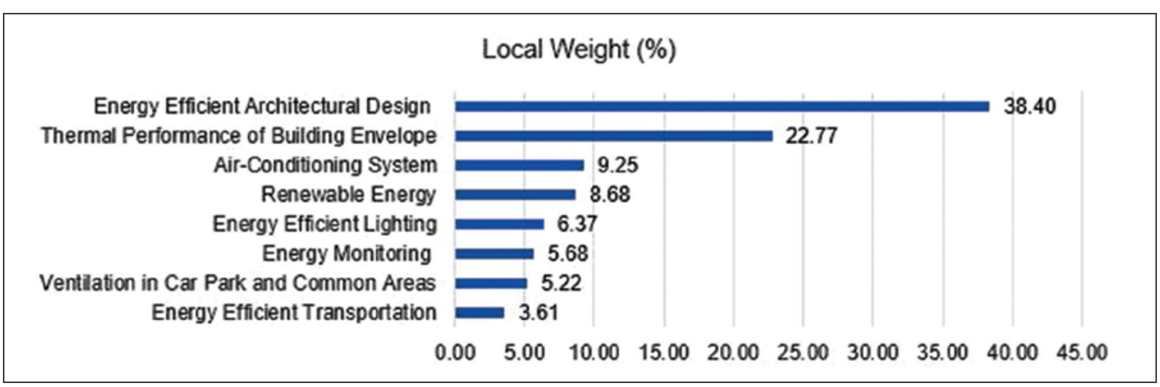


FIGURE 6. Criteria Weights: Water Efficiency Category.

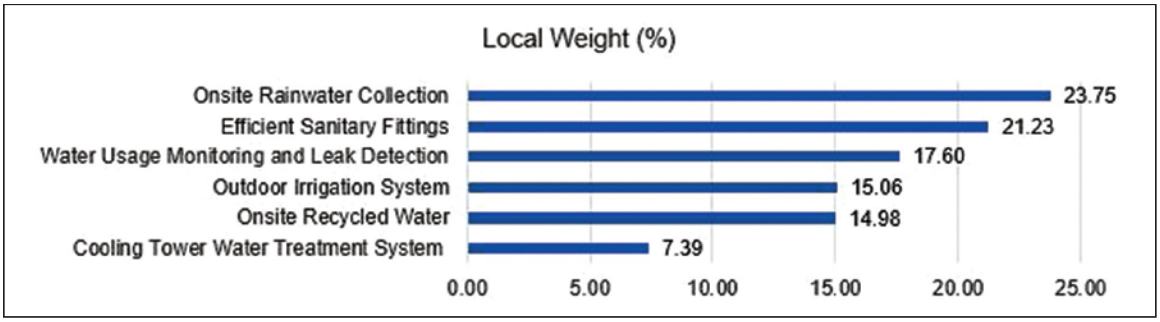


FIGURE 7. Criteria Weights: Indoor Environmental Quality Category.

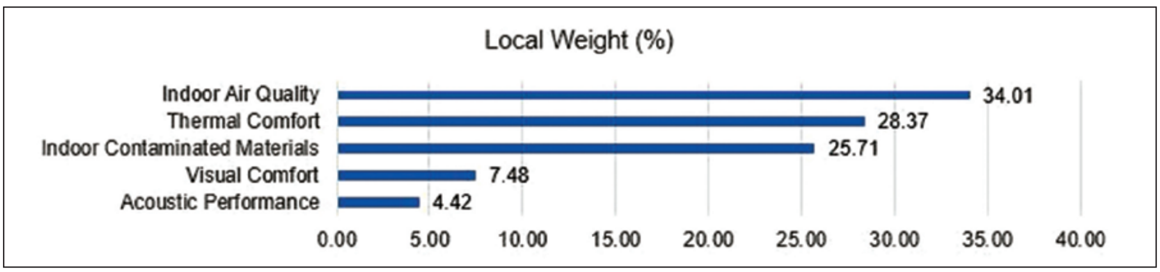


FIGURE 8. Criteria Weights: Management Category.

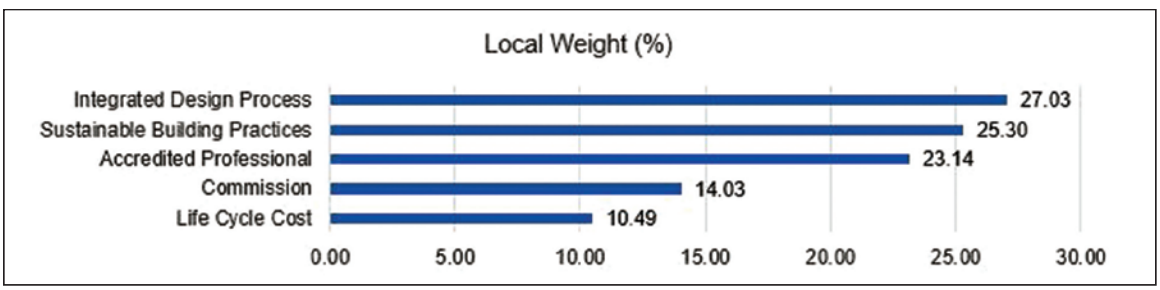


FIGURE 9. Criteria Weights: Waste and Pollution Category.

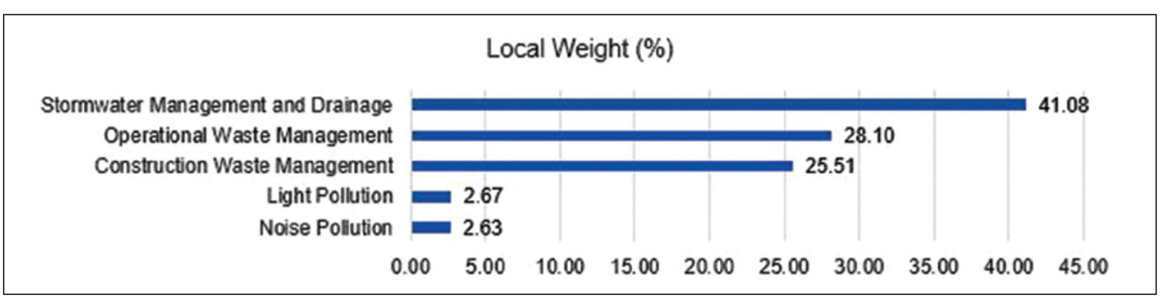


FIGURE 10. Criteria Weights: Sustainable Site Category.

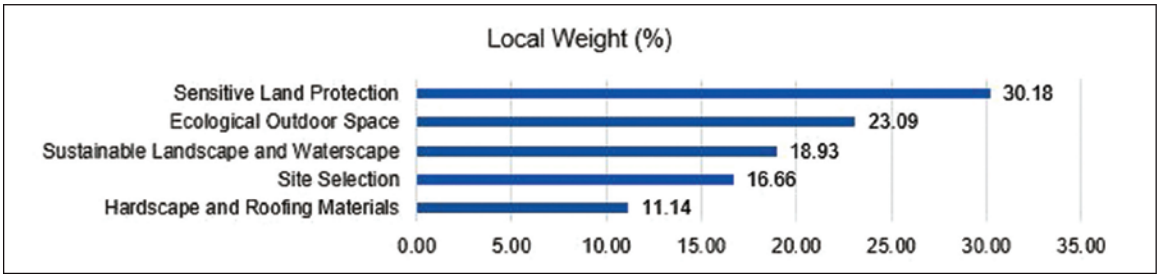


FIGURE 11. Criteria Weights: Material and Resources Category.

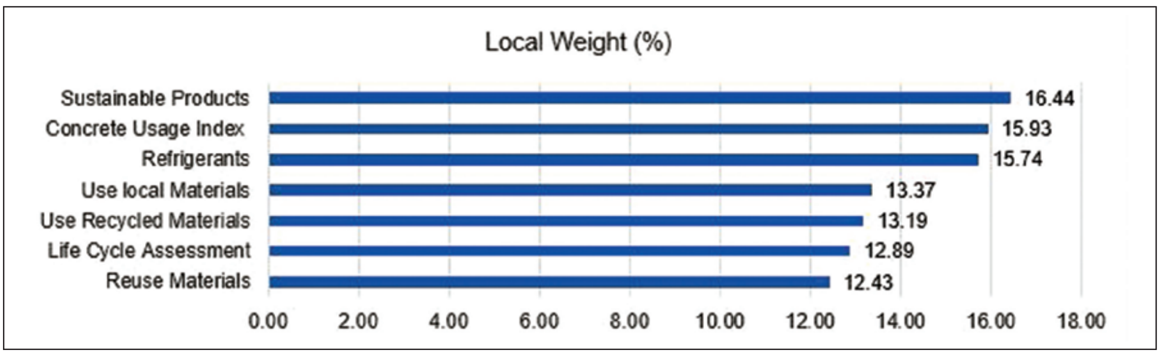


FIGURE 12. Criteria Weights: Transportation Category.

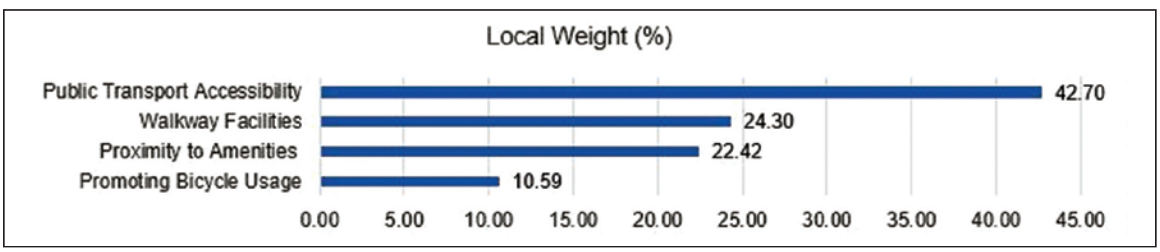


FIGURE 13. Criteria Weights: Innovation Category.

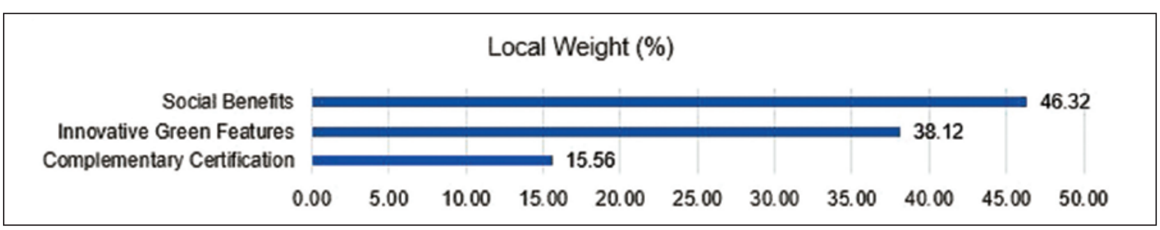


TABLE 4. Rankings of Categories and Criteria for Myanmar's Rating System.

Categories	Weight (%)	Criteria	Local Weight (%)	Global Weight (%)	Ranking
Energy Efficiency	17.48	Energy-Efficient Architectural Design	38.40	6.71	1
		Thermal Performance of Building Envelope	22.77	3.98	4
		Air-Conditioning System	9.25	1.62	25
		Renewable Energy	8.68	1.52	29
		Energy-Efficient Lighting	6.37	1.11	36
		Energy Monitoring	5.68	0.99	38
		Ventilation in Car Park and Common Areas	5.22	0.91	41
		Energy-Efficient Transportation	3.61	0.63	42
Water Efficiency	13.95	Onsite Rainwater Collection	23.75	3.31	11
		Efficient Sanitary Fittings	21.23	2.96	15
		Water Usage Monitoring and Leak Detection	17.60	2.45	16
		Outdoor Irrigation System	15.06	2.10	19
		Onsite Recycled Water	14.98	2.09	20
		Cooling Tower Water Treatment System	7.39	1.03	37
Indoor Environmental Quality	13.23	Indoor Air Quality	34.01	4.50	3
		Thermal Comfort	28.37	3.75	5
		Indoor Contaminated Materials	25.71	3.40	9
		Visual Comfort	7.48	0.99	39
		Acoustic Performance	4.42	0.59	43
Management	13.13	Integrated Design Process	27.03	3.55	8
		Sustainable Building Practices	25.30	3.32	10
		Accredited Professional	23.14	3.04	14
		Commission	14.03	1.84	23
		Life Cycle Cost	10.49	1.38	30

TABLE 4. (Continued)

Categories	Weight (%)	Criteria	Local Weight (%)	Global Weight (%)	Ranking
Waste and Pollution	12.95	Stormwater Management and Drainage	41.08	5.32	2
		Operational Waste Management	28.10	3.64	7
		Construction Waste Management	25.51	3.31	12
		Light Pollution	2.67	0.35	44
		Noise Pollution	2.63	0.34	45
Sustainable Site	10.59	Sensitive Land Protection	30.18	3.20	13
		Ecological Outdoor Space	23.09	2.45	17
		Sustainable Landscape and Waterscape	18.93	2.01	21
		Site Selection	16.66	1.77	24
		Hardscape and Roofing Materials	11.14	1.18	35
Material and Resources	9.76	Sustainable Products	16.44	1.60	26
		Concrete Usage Index	15.93	1.55	27
		Refrigerants	15.74	1.54	28
		Use local Materials	13.37	1.30	31
		Use Recycled Materials	13.19	1.29	32
		Life Cycle Assessment	12.89	1.26	33
		Reuse Materials	12.43	1.21	34
Transportation	8.67	Public Transport Accessibility	42.70	3.70	6
		Walkway Facilities	24.30	2.11	18
		Proximity to Amenities	22.42	1.94	22
		Promoting Bicycle Usage	10.59	0.92	40
Innovation	0.23	Social Benefits	46.32	0.11	46
		Innovative Green Features	38.12	0.09	47
		Complementary Certification	15.56	0.04	48
Σ	**100.0**			**100.00**	

criteria and scoring of the certification level. According to global priority weight measures, the top five criteria of the rating system for Myanmar were energy-efficient architectural design (6.71%, ranking 1st) from the energy category, stormwater management and drainage (5.32%, ranking 2nd) from the waste and pollution category, indoor air quality (4.50%, ranking 3rd) from the indoor environmental quality category, thermal performance of building envelope (3.98%, ranking 4) form the energy efficiency category, and thermal comfort (3.75%, ranking 5th) from the indoor environmental quality category.

7.3 Adaptability of Proposed Indicators for Myanmar's Built Environment

Overall, the "Energy Efficiency" category was rated most highly by the majority of participants in this study, as well as in the rating systems comparison. The importance levels of "Water Efficiency," "Indoor Environmental Quality," and "Management" were ranked as second, third, and fourth by experts for Myanmar's context, while the seven rating systems comparison provided Indoor Environmental Quality as the second most important category, Material and Resources as the third, and Water Efficiency as the fourth, as illustrated in Figure 2.

"Waste and Pollution" was distinctively found as an important category for Myanmar although other rating systems did not define it as an important category. The weighting results of the indicators were sent to five professionals who participated in the pairwise comparison assessment for their feedback regarding the applicability of proposed assessment indicators for Myanmar's built environment. Feedback from respondents showed that the proposed categories and criteria (indicators) are inclusive, supportive, and appropriate for Myanmar. One suggested that "Site Selection" and "Roofing and Hardscape Materials" criteria under "Sustainable Site" category should have higher priorities than current rankings because these criteria could be easily implemented for projects in Myanmar. Moreover, they recognize the applicability of energy-efficient lighting which is more appropriate than renewable energy for Myanmar's built environment. The reason is that energy-efficient lighting (artificial lighting) has been widely used whereas renewable energy is still early and costly to produce in Myanmar at this time. Thus, the "Energy-Efficient Lighting" criterion should be assigned more points from the views of the experts. Since the categories and criteria have several weight values in terms of their importance levels within Myanmar's contexts according to the perceptions of respondents, the effects of those on the environment of Myanmar is discussed underneath. Four categories (Energy Efficiency, Water Efficiency, Indoor Environmental Quality, and Waste and Pollution) which are mostly relevant to the existing situations of Myanmar and adaptability of 5 criteria with the highest rankings (Energy-Efficient Architectural Design, Stormwater Management and Drainage, Indoor Air Quality, Thermal Performance of Building Envelope, and Thermal Comfort) as presented in Table 4 are discussed below.

7.3.1 Energy Efficiency

It is not surprising that the "Energy Efficient" category is highly recommended among other categories because sufficient energy generation for future infrastructure development is the priority of Myanmar government. Myanmar had the lowest rate of electricity production globally with 160 kWh per capita consumption in 2014 and rose to 263 kWh in 2015/2016 which is only one-tenth of UK's consumption. According to National Electrification Plan (NEP) by the World Bank and United Nations, energy generation in Myanmar is targeted as 50% by 2020, 75% by 2025 and 100% by 2030 including renewable energy as a one-fifth share of the total production (Lwin & Panuwatwanich, 2020). Environmentalists urge the government to consider renewable energy and other alternatives, as sustainable energy solutions for climate change crisis (U.S.Embassies, 2019). In recognition of natural geographic and climatic characteristics of Myanmar, the potential for renewable energy, especially for solar and wind is relatively high across all regions. Due to these opportunities and current demand of energy supply, energy efficiency has gained the priority as a solution for emission reduction in energy use and production of energy from renewable sources. For the criteria under the "Energy Efficiency" category, the experts were aware of "Energy-Efficient Architectural Design" and "Thermal Performance of Building Envelope" as crucial criteria for building sustainability in Myanmar. Experts believed that a high-quality building design with proper natural lighting, ventilation, heating, cooling, and spaces are fundamental rather than electrical and mechanical systems. "Energy-Efficient Architectural Design" was ranked as the topmost key criterion among all proposed criteria. This is due to the importance of passive design for energy efficiency in Myanmar, which is rich in traditional and aesthetic architecture for a comfortable building environment. It is important to note that building design that is adapted to the local environment and provides human comfort is not only the modern design strategy, but also the old strategy that has been together with us for a long time (Almansuri et al., 2015). Zune et al. (2020a) exhibited that the passive design strategies for traditional buildings in Myanmar need upgrading with innovative solutions so to be consistent with the future climate variations. Moreover, the building envelope should be integrated into the building design. The material selection is important for the heat transfer inside the building, and changing the internal and external climate conditions of the building (Almansuri et al., 2015). Lee and Tiong (2007) highlighted that if passive building envelope design features such as glazing, color, insulation, and solar shading devices are installed simultaneously, the annual energy requirement for cooling purpose of the whole building can be saved by 31.4%. This can also minimize the peak cooling load with 36.8% savings. Therefore, the thermal performance of building envelope (Ranking 4th), which is another important factor of energy efficiency category that needs to be considered in Myanmar's rating system.

7.3.2 Water efficiency

Water efficiency was a key assessment category after energy due to the country's deficient water safeguarding and unsystematic water supply system. The conservation of water resources requires the nationwide development in Myanmar. Yangon City Development Committee is unable to supply sufficient water to the whole Yangon City. Thus, residents rely on an unsustainable form of water (groundwater) as an alternative source. Newly constructed high-rise buildings in Yangon rely on groundwater; 30 million gallons of water are extracted from tube wells every day. The extensive usage of groundwater can harm the stability of buildings and some projects built on soft soil experience risky conditions of settlement in some townships of Yangon. Therefore, integrating water efficient technology in building design is a solution for the sustainability of upcoming new projects and water resource protection in Myanmar.

7.3.3 Indoor Environmental Quality

Indoor Environmental Quality (IEQ) which addresses indoor air quality, thermal, visual, and acoustic comfort, and health of residents, was given priority as a next critical concern after energy efficiency and water efficiency categories in Myanmar's assessment indicators framework. Urban areas of developing countries suffer from problems related to air pollution. Likewise, Myanmar has been encountering problems associated with polluted air, especially in Yangon which is the most populous and urbanized city. Regarding the assessment of outdoor and indoor air quality of Yangon, the study by Aung et al. (2019) indicated that contribution of pollutants that contaminate outdoor air quality is from the vehicles running on the roads; Yangon has experienced greater traffic volume now than before. Interior characteristics of the buildings cause the indoor air quality changes, and gases that have an impact on occupants' health were detected in the indoor air of the areas studied. Moreover, inadequate ventilation and infiltration from outdoor sources made the poor indoor air quality (Aung et al., 2019). Although indoor air quality management and control systems are not common in the projects in Myanmar, "Indoor Air Quality" was recognized as a crucial criterion of the IEQ category, ranking 3rd among all criteria. Indoor air quality has a significant impact on modern life around the globe and direct effects on human comfort, health, and productivity. On average, most people spend 90% of their time inside of buildings where pollution levels are two to five times (sometimes 100 times) higher than the outside. As a result of this, indoor air quality is an important factor that decides the functionality of buildings, and a key item of a green building assessment tool (Vohra & Mital, 2016). Another important criterion under IEQ category as compared to other criteria was thermal comfort. The objective of the buildings is to protect the occupants from the outdoor climate. Thermal performance of building in Myanmar is vulnerable to the increased temperatures and changes in precipitation posed by the alteration in global or regional climate patterns. In consideration of the global climate crisis and local climatic conditions, Myanmar's housing sector needs improvements to achieve acceptable thermal performance (Zune et al., 2020a). Therefore, experts highlighted thermal comfort inside of buildings as an important criterion (ranking 5) and basic requirement of green building performance.

7.3.4 Waste and Pollution

The "Waste and Pollution" category was also a vital measure in the assessment scheme for Myanmar despite being given the smallest percentage points (as compared with the other categories) in the seven reviewed GBRSs (Figure 2). Waste management and climate change are serious matters that Myanmar is currently facing. The main challenges for waste management systems are a lack of awareness for the 3Rs practices (Reduce, Reuse, and Recycle), technology and infrastructure weaknesses, and counterproductive environmental rules and regulations. Globally, Myanmar's environmental management practices and regulations are the least developed (U.S.Embassies, 2019). Fifty percent of waste in landfill sites of Yangon comes from buildings and households. In addition to waste management, uncontrolled water run-off causes the watercourse pollution and flooding. Thus, management of stormwater and building discharges is an essential consideration (Kamaruzzaman et al., 2019). Reaching the goals of building sustainability cannot be implemented by only building performance assessment as building operations connect with infrastructures and several networks. Basic infrastructure requirements such as sewage, drains, and transportation systems in developing countries are inadequate (Alyami et al., 2013). These are similar crucial issues in most cities of Myanmar. Therefore, "Stormwater Management and drainage" under "waste and pollution" category was rated as the second most important criterion. Providing perforated landscaping is recommended as a simple and effective way to recharge the groundwater, instead of water flowing into drains.

As mentioned previously, although Myanmar possess large renewable energy sources, the production of energy has not been able to meet the demand. Similarly, though water resources are abundant, ground water is being extracted excessively and surface water has been polluted by discharges from drains without proper treatment. As a result, experts emphasized the categories which are closely related to current situations of Myanmar as the primary issues for the sustainable building development. Despite the fact that the role of management is not as obvious as other abovementioned problems, experts pointed out that effective management method should be applied for the large numbers of projects with occurring delay of construction processes and cost overruns.

8. CONCLUSION

A GBRS is an assessment framework that provides specifications related to the social and economic aspects rather than focusing only on the impacts of buildings on the environment. More new rating systems have been developed by the adoption of the existing rating systems. Despite similarities among the criteria of the rating systems, they have different levels of importance that are based on the circumstances of a country. This research mainly centers on the local context while the criteria from selected existing systems are integrated. As an outcome of this research, the most suitable assessment indicators along with their relative weights can be identified for the development of a rating system for Myanmar.

A rating system framework consists of assessment indicators, points allocation, and certification levels. Basically, there are two types of scoring systems for certification: point-based system and weight-based system. This research follows a weight-based approach, and results could be the foundation for the accomplishment of local or national assessment tools in developing countries such as Myanmar. It could help to implement guidelines for a government to develop, evaluate, and update the sustainability standards and policies in its country. Skillful and knowledgeable professionals who are working for GBRS implementation could be further involved in determining the credits or points distribution. Future research may employ the Delphi methodology, such as panel or group discussions with experts for establishing subthemes of assessment items and identifying the certification levels for green building awards. It is recommended that a range of sustainability assessment tools from developing countries be investigated further and a wider survey including large numbers of professionals be added in future studies. An important outcome of this study is a set of general assessment indicators for Myanmar's context focusing on the non-residential sector. It would be beneficial that the climate context of different regions be considered for the identification of assessment indicators in further research.

This study should be interpreted with some reservation due to certain limitations. There is a constraint for the number of experts participating in the pairwise comparison assessment because there are limited professionals who have expertise in this field in Myanmar. Moreover, there have been challenges in the data collection process because the main developers and consultants who participated in the case study buildings are from Singapore (i.e., not local). Contact with overseas consultants is one of the research limitations, and interviews had been carried out with only local professionals. In addition, only one project could be conducted as a case study due to the small number of certified green buildings in Myanmar and challenges of data availability at the time that this study was undertaken. The research findings could be more thorough and extensive if more existing green buildings can be studied.

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