STUDY ON THE RELATIVE IMPORTANCE OF GREEN BUILDING ATTRIBUTES IN PHILIPPINE URBAN SETTING USING ANALYTICAL HIERARCHY PROCESS

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Abstract: Along with the increase in the construction of buildings and infrastructure comes the inevitable adverse environmental effects. These effects are evident throughout the life cycle of a building from construction until its eventual closure and decommissioning. Green building practices seek to address these unwelcome environmental impacts by promoting environmentally responsible construction practices and building schemes that reduce the carbon footprint through energy and resource efficiency. LEED, an internationally recognized green building rating system, and BERDE, a locally developed one based on LEED, served as benchmarks for this study. The different green building attributes were identified and evaluated for relative importance using analytical hierarchy process. Respondents come from four distinct groups: engineers, architects, urban planners and end users. Energy and atmosphere, water efficiency and sustainable sites were the three most important green building attributes based on the survey responses while management and operation improvements, transportation and waste management practices figured in the bottom of priorities. Urban planners gave sustainable sites the biggest weight while the three other sectors tagged energy efficiency as the most important parameter. On a pie of 100, engineers would give a more or less equal points for the different attributes while the end-users would allot big fractions for energy and water efficiency and indoor environmental quality. This study finds its niche in the development of a locally calibrated green building rating system for the Philippines.

Key words: Green building, analytical hierarchy process

1 INTRODUCTION

1.1 Background of the Study

Buildings and infrastructure have inevitable adverse effects on the natural environment. Effects range in scale from local, such as displacement of ecological habitats, to global, such as greenhouse gas emission ultimately leading to global warming and climate change. Various effects arise throughout the life cycle of a building, from construction to operation and up to its eventual closure and decommissioning. Construction and maintenance impacts are mainly brought about by the consumption of natural resources. The operation of such, on the other hand, may also result to pollutants emission both directly and indirectly. Green building practices and technologies seek to address these foreseeable adverse environmental effects

The United States Environmental Protection Agency (2012) defines green buildings as the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and demolition. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Green building is also known as a sustainable or high performance building.

A sustainable green building can save our natural resources by reducing environmental impacts, lowering transportation costs, and decreasing water consumption. Not only do green buildings have environmental benefits, but they also have economic and social benefits. Green buildings create jobs, inspire growth and innovation in the local community, enhance occupant health and comfort, maintain a healthier indoor environment and air quality, minimize strain on public infrastructure and improve overall quality of life. Green buildings also have economic benefits. They reduce operating costs, improve occupant productivity, and enhance profits. Therefore, green buildings have the power to change our way of life and transform the future by being sustainable today.

1.2 Green Building Rating Systems

Leadership in Energy and Environmental Design (LEED), the most popular of the green building rating systems, was developed in the United States of America but is used internationally. Different building types in various places, however, have unique design and efficiency needs depending on their function and exposure to climate. The Philippine Green Building Council (PHILGBC) saw the need to find a viable and locally applicable solution that will help promote environmental conservation and protection in the Philippines. Hence, Building for Ecologically Responsive Design Excellence (BERDE), was developed. BERDE was designed to measure the environmental performance of buildings. According to PHILGBC, BERDE is a tool to measure, verify and monitor the environmental performance of buildings. It is consensus driven and was developed through a multi-stakeholder consultation and collaboration process. The certification is credible, unbiased and impartial because it is achieved through a third party process in line with international standards.

BERDE was developed using the United Nations Sustainable Development Indicators of Sustainable Development and other existing international green building tools including LEED by the United States Green Building Council (USGBC), Green Star by the Green Building Council of Australia (GBCA) and BRE Environmental Assessment Method (BREEAM) by the United Kingdom Building Research and Establishment (BRE). BERDE formulated two technical manuals, BERDE for New Construction and BERDE for Existing Buildings. The study conducted in this research will be patterned with the latter.

Furthermore, PHILGBC (2011), in its technical manual states that, BERDE was designed to certify the sustainability of ongoing operations of existing buildings. Buildings such as offices, retail and service establishments, institutional buildings (i.e. libraries, schools, etc.), hotels, as well as residential buildings (of four or more habitable stories) are eligible for certification. BERDE encourages owners and operators to implement sustainable practices and reduce the environmental impacts of their building.

The study conducted also uses the LEED 2009 manual for Existing Buildings Operations and Maintenance. In the USBGC (2009) technical manual, LEED 2009 for Existing Buildings is described as a set of performance standards for certifying the operations and maintenance of existing commercial or institutional buildings, and high-rise residential buildings. It was created to promote environmentally sound practices in existing buildings. As of 2013, there are five LEED-certified buildings in the Philippines, namely: Asian Development Bank, Nuvali One Evotech, Shell Shared Services Office, and Texas Instruments in both Baguio and Clark.

In 2009, the Quezon City Government passed its Green Building Ordinance No. SP-1917 (QCGBO). According to the Primer on the Green Building Program of Quezon City (2009), “It requires the design, construction or retrofitting of buildings, other structures and movable properties to meet minimum standards of a green infrastructure, providing incentives thereof and for other purposes.” Those who are planning to construct new buildings or retrofit existing structures in Quezon City are required to comply with the Implementing Rules and Regulations (IRR) of the Green Building Ordinance. The Quezon City Green Building criteria have specific mandatory requirements for a building to be considered green. These include specific actions undertaken for site sustainability, energy efficiency, water efficiency, materials and resources, indoor environment quality, sewage treatment plant, and for transportation.

The LEED, BERDE and QCGBO rating systems were created on the premise of the available technologies and innovations in the particular criteria. Having more of these advancements contributes to a bigger contribution to the weight appropriated to a particular criterion. The technical manuals of LEED and BERDE indicate the technologies available for use in their respective countries; it can be observed that more are available for LEED than there are for BERDE, which is an indication of the lagging of the Philippines compared to the United States and other first world countries in terms of these technologies for green building. On the other hand, an importance-based type of rating system is reliant on the opinions and needs of those who will use these green structures and systems. For a third world country like the Philippines, it is more beneficial to have this type of system due to the unavailability and/or costliness of said technologies. Implementing a needs-based system will surely encourage designers, as well as users to apply these green building practices in the Philippines. The structures would then, not have to suffer receiving lower ratings for not being able to comply with the preferred technological implements.

1.3 Problem Statement

There is a need for a green building rating system that is tailor fit for the Philippine setting, with each factor rated and calibrated for its local importance rather than on the availability of existing and practicable technologies. This study intends to achieve a scientific determination of the relative importance of each green building factor.

Specifically, this research aims to:

1. Compare and contrast the existing green building rating systems, both local and international
2. Identify the key areas and factors affecting the sustainability and greenness of a building
3. Conduct a multi-partite survey, involving architects, engineers, urban planners, and end users on the importance of the green building factors

This would be instrumental in the development of a locally-calibrated green building rating system, or possibly in the recalibration of existing tools in the country. The study is specifically conducted in the context of highly-urbanized locations, as in Metro Manila where ___% of the buildings in the country are situated.

2 RELATED LITERATURE

Green building rating systems are recognizably varied in methodology and criterion set, among the many other distinctions. Having been developed in different countries, the variability could be inferred to arise from the difference in the conditions in the countries where the rating systems were developed. In 2008, Ali and Al Nsairat conducted a study on developing a green building assessment tool for developing countries. The research studied internationally recognized green building assessment tools such as BREEAM, LEED, Japan's Comprehensive Assessment System for Building Environmental Efficiency (CASBEE), GREEN STAR, among others. The outcome of the research was a suggested green building assessment tool that suits the Jordanian context. The research integrated criteria from different assessment methodological frameworks and built on the strength of each, and provided a more holistic assessment approach showing particular attention to local Jordan context.

The review focuses on the strengths and weaknesses, as well as the elements of success of implementation of these systems. It identified the local context of Jordan, its natural and physical conditions, and classified the current conditions as either positive or negative. The researchers used interviews with, and questionnaires and observations of stakeholders, investors, and builders of the private, public, and government agencies.

By benchmarking the established internationally used rating systems to the Jordan green building rating system, the items to be assessed were established. The three main assessment items are environmental, social and economic indicators. Analytical Hierarchy Process (AHP) was used to determine the relative importance of the items assessed. It was then synthesized into an overall rating system. Following are the results:

Table 1 Assigned weights to assessment categories based on the study by Ali and Al Nsairat in 2008

Assessment Categories	**Index**	**Weight**
Site	S	0.108
Energy Efficiency	E	0.231
Water Efficiency	W	0.277
Material	M	0.103
Indoor Environment Quality	IEQ	0.118
Waste and Pollution	W & P	0.064
Cost and Economics	C & E	0.099

The outcome of the study was a green building residential type assessment tool for Jordan called (SABA Green Building Rating System). This system is a powerful green building rating system for Jordan because it is based on scientific research and technical knowledge. In addition, the assessment framework suits the local context of Jordan—its culture, issues, resources, priorities, practices and institutions. From the table above, utmost priority is placed on water efficiency which is intuitively a result of Jordan being a desert country.

3 METHODOLOGY

3.1 Analysis of green building indicators

Three rating systems, namely LEED, BERDE and QCGBO were assessed based on their indicators or assessment categories. Distinct categories from each of the rating systems were defined, compared and contrasted. From this a definitive list of green building indicators was formed. The percentage weight of these indicators was computed for the three rating systems based on the ratio of maximum attainable score for the category and the maximum attainable total score. Following is the list of the identified indicators and their corresponding shorthand indices:

Table 2 List of green building indicators

Indicator	**Index**
Sustainable Sites	SS
Water Efficiency	WE
Energy Efficiency	EE
Materials and Resources	MR
Indoor Environmental Quality	IEQ
Management and Operations	MO
Transportation	T
Emissions	E
Waste Management	WM
Heritage Conservation	HC

LEED's category on Regional Priority Credits (RPC), which is not clearly defined for the Philippine context, was not included in the list. Further, Innovations in Operations, which is present in both LEED and BERDE was merged with BERDE's distinct Management. In LEED, Emission forms part of the Energy Efficiency criterion and waste management is under materials and resources. In BERDE, these were made distinct indicators. Heritage conservation criterion is also a unique feature of BERDE. The following shows the Venn diagram for the three rating systems.

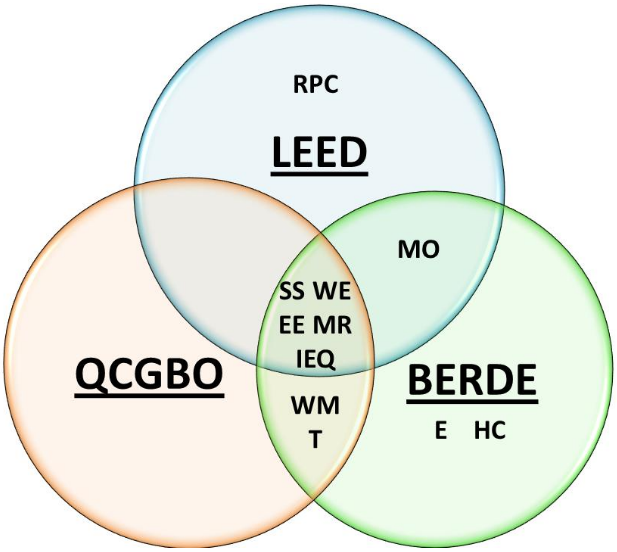

Figure 1 Venn diagram of green building assessment categories

3.2 Development of the survey tool

The study made use of a fieldwork approach—that is, using survey questionnaires and interviews—to arrive at the desired results. The questionnaire provided for the determination of the hierarchy of criteria was made in the form of a matrix, where the criteria were listed in both directions (i.e. column and row). The objective was for the respondent to use pairwise comparison, and provide weights for each of the criteria being compared. The values of the weights ranged from 1 through 5, and were in fraction and whole-number forms, which were indicative of the relative importance of each criteria with respect to another parameter. Table 3 shows the sample matrix provided for data collection while table 4 shows the possible responses and their corresponding interpretation.

Table 3 Pairwise comparison of green building indicators

	SS	WE	EE	MR	IEQ	MO	T	E	WM	HC
SS	1/1									
WE		1/1								
EE			1/1							
MR				1/1						
IEQ					1/1					

MO						1/1				
T							1/1			
E								1/1		
WM									1/1	
HC										1/1

Table 4 Possible responses to the survey questionnaire

Column is 5x more important than **Row**	1/5
Column is 4x more important than **Row**	1/4
Column is 3x more important than **Row**	1/3
Column is 2x more important than **Row**	1/2
Column is as important as **Row**	1/1
Row is 2x more important than **Column**	2/1
Row is 3x more important than **Column**	3/1
Row is 4x more important than **Column**	4/1
Row is 5x more important than **Column**	5/1

3.3 Conduct of the Survey

Survey respondents included stakeholders from different fields of expertise such as structural engineering, architecture, environment, transportation, water resources, and urban planning among others. Also surveyed were members of the general public whom the researchers determined had an influence on certain sustainable development practices. The survey also aimed to determine whether the different sectors had different opinions on the importance of the criteria being compared. The number of surveyed respondents totaled to 55, with 43.64% of the whole being engineers, 23.64% users, 16.36% architects, and 16.36% being urban planners. In some cases, interviews were also conducted prior to and/or after the participants answered the survey to gain more insight on the opinions and judgments of the respondents. Aside from the responses collected, the interviews provided clarification and supplementary understanding with regards to the manner of surveying, as well as to the response. Furthermore, the discussions with the experts imparted further knowledge and new ideas in relation to sustainability and in the design of green buildings. The use of the different existing rating systems such as LEED and BERDE locally were also discussed; this shed light on the merits and demerits of both system, and thus stresses the value of this study.

3.4 Analytical hierarchy process (AHP)

According to Saaty (1990), the most effective way to concentrate judgment is to take a pair of elements and compare them on a single property without concern for other properties or other elements. Judgments were used by the AHP to determine the ranking of the criteria of the rating systems; pairwise comparison was also conducted to compare the criteria from both systems. For the comparison, there were n criteria represented by A1, …, An, with weights given by w1, …, wn. The matrix was formed with the pairwise ratios whose rows were the weights of each criterion with respect to the others. The smaller of each pair was taken as the unit, and the larger was defined by multiples of the smaller unit. The eigenvector of the resulting matrix was then computed and normalized. This corresponds to the relative weights of each green building indicator.

Because the responses were sorted according to expertise (i.e. division into engineers, architects, users and urban planners), it was possible for the individual replies to be averaged. Consequently, from the 55 total responses, there were 4 averages that described the set of data. For the representation of the whole, the mean of the 4 values was taken and assumed to be descriptive of the opinion of the entire sample.

The rationale behind using this method was that the AHP was a mathematical technique which allowed the consideration of both qualitative and quantitative aspects of the decision. Furthermore, the AHP was less biased compared to the alternative—the study by Nguyen and Altan that was a simple evaluation and was subjective, which was why this method was more desirable. In a study by Kasperczyk and Knickel, it was noted that the AHP is a preferred method of multi-criteria analysis due to its flexibility and because users generally perceive this method to be straightforward. Moreover, it was chosen for its ability to decompose a decision problem into constituents and is able to build hierarchies of criteria. The AHP method was also able to make use of both subjective and objective evaluation measures.

3.5 Post processing of results

The responses obtained from the survey questionnaires were diverse—each of the respondents had a different opinion on which criteria was more important relative to another; however, each of the four sectors had a general response. In the analysis of the data, it could be seen that the respondents of a particular field of expertise held some criteria to be important than another, and the trend was observed throughout the responses of the entire sector. The analysis was performed per division, since the responses tended to be more similar.

Applying AHP to each of the respondent's surveys resulted to individual rating systems of each respondent. The average response of each of the groups was then taken. In order to analyze these results, a statistical analysis was conducted to compare whether there were significant differences between the ratings of the respondent groups. This was done by comparing each green building system criteria with each type of group respondent. For example, the results for sustainable sites between engineers, architects, users and urban planners were statistically analyzed to see if there are significant differences between the groups. Tukey's Pairwise Comparison Test was used to measure if the mean of each criterion differed. This test is used when confidence intervals are needed or sample sizes are not equal. Since the number of respondents differs between each group, Tukey's test is best used.

4 RESULTS AND DISCUSSION

The results of the analytical hierarchy process were expressed in percentages as shown below.

Table 5 Mean Weights of Green Building Criteria.

	Engineers	**Architects**	**Users**	**Urban Planners**
SS	11.92%	10.62%	9.06%	14.34%
WE	12.89%	13.10%	16.02%	11.58%
EE	12.90%	12.73%	16.98%	12.53%
MR	9.05%	11.82%	8.86%	10.21%
IEQ	9.26%	8.62%	11.02%	9.94%
MO	8.53%	11.03%	6.64%	9.75%
T	7.68%	7.56%	5.35%	8.41%
E	7.83%	7.47%	9.68%	7.73%
WM	9.60%	7.48%	9.74%	6.80%
HC	10.34%	9.55%	6.65%	8.71%

It can be observed that Water and Energy Efficiency are consistently among the top priorities of all sectors. Other than these two, Sustainable sites also figured in the top three of urban planners and engineers, materials is in the architects' top three and indoor environmental quality in the end users' top list.

Energy efficiency is the most important green building indicator for engineers and end-users while water efficiency is the foremost consideration for the architects. For the urban planners, sustainability of the siting took the foremost priority as was anticipated.

These values reflect the premium placed by each of the groups on the criteria that they perceive to be most important to their individual practice. The reason for WE and EA being most important for all groups may be that these commodities are more costly, and are thus perceived as highly important. Having innovations in these categories are thus beneficial to all stakeholders. It can be inferred that SS is most important to engineers and urban planners because their line of work focuses on the proper allocation and use of land. The priority allotted to land use and development is recognized by the engineers and urban planners. Similarly, MR is given importance by architects as their field deals with the use of the physical components of construction. In designing a structure, crucial to architects is the type of materials that go into the building. Lastly, IEQ is important to end users because they are the ones to occupy the structures once these are finished. Lighting, comfort, and air quality are among the things that users give a premium to when it comes to the structures. Having said these, it can be seen that the priorities of the respondents were taken into consideration in the completion of the survey questionnaires.

Also observable is the range of the weights given across the different sectors. The computed weights from the engineers, architects and urban planners are closely spaced as compared to that of the end users. For the end users, transportation takes less than a third in importance as compared to its highest ranked attribute, which is energy efficiency.

The results were statistically processed using Tukey's test to check for significant variability across sectors, as follows:

	N	Mean	Grouping
Urban Planners	9	14.340	A
Engineer	24	11.923	A
Architect	9	10.623	A
Users	13	9.058	A

Figure 2 Analysis of Sustainable Sites criterion using Tukey's Test

	N	Mean	Grouping
Users	13	16.025	A
Architect	9	13.101	A
Engineer	24	12.894	A
Urban Planners	9	11.578	A

Figure 3 Analysis of Water Efficiency criterion using Tukey's Test

	N	Mean	Grouping
Users	13	16.984	A
Engineer	24	12.897	A
Architect	9	12.733	A
Urban Planners	9	12.532	A

Figure 4 Analysis of Energy Efficiency criterion using Tukey's Test

	N	Mean	Grouping
Architect	9	11.824	A
Urban Planners	9	10.206	A
Engineer	24	9.050	A
Users	13	8.858	A

Figure 5 Analysis of Materials and Resources criterion using Tukey's Test

	N	Mean	Grouping
Users	13	11.023	A
Urban Planners	9	9.942	A
Engineer	24	9.263	A
Architect	9	8.619	A

Figure 6 Analysis of Indoor Environmental Quality using Tukey's Test

	N	Mean	Grouping
Architect	9	11.031	A
Urban Planners	9	9.750	A
Engineer	24	8.531	A
Users	13	6.636	A

Figure 7 Analysis of Management and Operations criterion using Tukey's Test

	N	Mean	Grouping
Urban Planners	9	8.410	A
Engineer	24	7.676	A
Architect	9	7.561	A
Users	13	5.347	A

Figure 8 Analysis of Transportation criterion using Tukey's Test

	N	Mean	Grouping
Users	13	9.680	A
Engineer	24	7.829	A
Urban Planners	9	7.726	A
Architect	9	7.474	A

Figure 9 Analysis of Emissions criterion using Tukey's Test

	N	Mean	Grouping
Users	13	9.743	A
Engineer	24	9.597	A
Architect	9	7.483	A
Urban Planners	9	6.800	A

Figure 10 Analysis of Waste Management criterion using Tukey's Test

	N	Mean	Grouping
Engineer	24	10.341	A
Architect	9	9.550	A
Urban Planners	9	8.715	A
Users	13	6.645	A

Figure 11 Analysis of Heritage Conservation criterion using Tukey's Test

As seen in the figures above, the results for all respondent groups for each green building criteria were the same. This implied that the means are not significantly different from each other. The engineers, architects, urban planners and users do not vary in their view of which green building criteria are most important. The results depended more on the country's environmental condition than their respective different professions. Since all the respondents were from the Philippines, their opinions of which criteria were important were similar. There are common concerns among the different rating systems; LEED and BERDE, such as emphasizing the consumption of energy in building, water efficiency, indoor environment quality, materials and resources, and sustainable sites. However, each rating system focuses on certain aspects more than others according to its country's local context.

The Green building criteria of the United States and the Philippines differ because of the contrast in environmental concerns of each country. Therefore, since the respondents from the survey conducted were all from the Philippines, their individual criteria have no significant difference between group of respondents.

The average weights across four sectors are as follows:

Table 8 Average green building criteria weights

Criterion	Percentage
Sustainable sites	11.49%
Water efficiency	13.40%
Energy efficiency	13.79%
Materials and resources	9.98%
Indoor environmental quality	9.71%
Management and operations	8.99%
Transportation	7.25%
Emission	8.18%
Waste management	8.41%
Heritage conservation	8.81%

The equality of percentages in the new rating system implies that most respondents do not highly prioritize a certain criteria from another. A slight difference is seen in both water efficiency and energy & atmosphere, which garnered the highest percentage.

Given that the Philippines is one of the countries that charges the most expensive electricity in the world, the respondents gave energy & atmosphere higher importance. Additionally, the air pollution of the country has worsen over the years, especially in Metro Manila, which is over congested. Since the respondents were all from Metro Manila, they gave energy & atmosphere higher importance. Likewise, the water pollution in the country has been covered in the news throughout the years. The current condition of Manila Bay and beaches around the Philippines has been degrading. Trash has been seen floating in Manila Bay recently and therefore making the bay dangerous to swim in. Water has been close to the hearts of the Filipinos given that the country is an archipelago, making the respondents give higher points to water efficiency.

Compared to LEED and BERDE, the calibrated rating system was based on the respondents' view of the importance of each criterion. On the other hand, LEED and BERDE are technology-based rating systems. LEED and BERDE rely heavily on technologies available in their respective countries. For example, as show in Table 9 below, BERDE only has 5.45 percent for water efficiency. Although based on the calibrated rating system, water efficiency had 13.40 percent, one of the highest percentages, which means that this criteria is important to the Filipinos. BERDE's percentage in water efficiency did not give due credit to the water crisis the Philippines is facing. The 5.45 percent from BERDE only means that there are few technologies which cater to the efficiency of using and saving water. Having a technology-based rating system will focus on the innovations available in the country and in cases where the technology is too expensive or unavailable, the rating obtained is lower than what is desired. On the other hand, the importance-based rating system takes into consideration what criteria is relevant to the place of application.

5 CONCLUSIONS

Energy and atmosphere, water efficiency and sustainable sites were the three most important green building attributes based on the survey responses while management and operation improvements, transportation and waste management practices figured in the bottom of priorities. Urban planners gave sustainable sites the biggest weight while the three other sectors tagged energy efficiency as the most important parameter. On a pie of 100, engineers would give a more or less equal points for the different attributes while the end-users would allot big fractions for energy and water efficiency and indoor environmental quality.

The average weights yielded in this study differ to those given by LEED and BERDE as the latter two are technology focused more than needs or context based. The setting for which LEED was developed is for the highly urbanized areas in the United States. Even in the Philippines, the importance of these weights will also vary if the setting was somewhere other than Metro Manila.

ACKNOWLEDGMENT

This research would not have been possible if not for the valuable cooperation of the engineers, architects, urban planners, building administrators and end users who shared their thoughts and insights on the importance of the different green building attributes.

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