

## *Original Paper*

# An Integrated Green Building Assessment Tool for Low-Cost Housing Development in Zambia

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### **Abstract**

*Green building rating tools developed to assess the impact of buildings on the environment may not have all the appropriate methods and criteria for different environmental, economic, social and cultural conditions in the world. Assessment tools should be developed to meet minimum green building standards and aspirations. The challenge in developing countries like Zambia is that there is limited access to green building rating tools and a lack of technology and resources to have local tools. Analytical Hierarchy Process (AHP) was used to select methods and criteria for assessing green low-cost housing in Zambia from literature review and interviews with building practitioners. The 11<sup>th</sup> Sustainable Development Goal was part of literature review and some strategies were adopted as part of the criteria for green building assessment. A sequential mixed-method design was used to collect and analyze data through interviews and an online AHP evaluation of preferred criteria and methods. The results from the study suggest that the most preferred method of green building assessment is a Local Based Assessment, with local strategies and materials. Energy, water, health and wellbeing were determined to be the most preferred criteria for green building assessment. The proposed criteria could be used for guiding designers and planners in housing projects and for reviewing current building bye-laws.*

### **Keywords**

*Green Building Model, Assessment Criteria, Analytical Hierarchy process*

## 1. Introduction

The rapid growth of cities and human settlements has put a strain on the environment and is contributing to climate change. The expansion of settlements has demanded more resources and growth has taken place with very little planning and provision of infrastructure and services. The development of housing cannot take place without considering aspects of sustainability and the creation of safe and resilient human settlements. The uncontrolled use of resources comes with it several negative effects on the environment, some of which includes degradation of forests, geological structures, air and noise pollution right up to the contamination of underground aquifers.

Zambia, a Southern African country like many other developing countries has struggled to deliver decent housing. The housing backlog is estimated to be at 2 million, due to a vast growing urban population and also the rural-urban migration (Ministry of Local Government, 2019). The failure of the government and private developers to meet this housing demand has resulted in the mushrooming of unplanned settlements which lack infrastructure and services. According to the Zambia Sustainability Housing Guidelines (ZSHG) (2016), “80 percent of existing housing in Zambia can be classified as informal and has limited or no formal services such as electricity, water and sewage.” The production of building materials in urban settlements require a significant amount of energy which must be shared among other competing needs. Housing construction is regarded as an area where there is significant opportunity to address climate change and as a means of contributing towards greening the economy (Chibwe et al., 2016).

To mitigate the effect of climate change United Nations Member States adopted the 2030 Agenda for Sustainable development in 2015. The agenda promotes sustainable housing development through the 11th SDG. According to UN sustainable development (2020) making cities sustainable means creating careers and business opportunities, safe and affordable housing and building resilient societies and economies. Sustainable housing does not only depend on environmental strategies but rather includes social and economic strategies.

Rating buildings generates awareness on the effect of harmful building materials on occupants and Green Building Rating Tools (GBRTS) assess the performance in terms of energy use and other resources, thereby reducing the impact on the environment (Liu et al., 2019). The absence of local assessment tools could be contributing to the slow pace of the application of green technology in developing countries. The challenge in Africa is that it lacks economic as well as political drive to develop new tools that are adaptable to their environment (Aghimien et al., 2018). Studies have shown that the sustainability level in construction projects being delivered in these developing countries is low, and Zambia is no exception (Alabi, 2012; Aje, 2016; Baron & Donath, 2016; James & Matipa, 2004). Some investors feel that trying to make a building sustainable comes with additional cost and there is no market case for going green. The challenge with the use of the existing tools is the inclusion of LCA strategies incorporated in the tools which tend to be very data-intensive and collecting and updating the needed data can involve significant costs (Bragança et al., 2007). The other challenge is the expenses

associated with these tools make them inaccessible to many building professionals and in turn makes assessment levels susceptible to economic downturns (Aspinall et al., 2013). The development of a framework can increase opportunities for practitioners in the building industry to implement and assess green buildings projects. The research answers to the challenge of having tools that are relevant, ease to use and appropriate.

The use of AHP in developing building assessment tools has been seen in studies like (Doczy & AbdelRazig, 2017; Said, 2017; Wang et al., 2019). According to Wang et al. (2019) AHP was adopted to determine the weight of attributes and a fuzzy comprehensive evaluation method was established to carry out the evaluation. The novelty of the study was the integration of interview results, the 11th SDG and five GBRTS in AHP which allowed for a broad selection of criteria. Many studies have looked at the selection of weights based on case studies, however the research was based on an integration of several methods allowing for impute from the practitioners and literature from the building industry. The integration of the five GBRTS enabled the inclusion of environmental, social and economic criteria that is suitable for Zambia. The involvement of practitioners would bring to the table wide experience of green building strategies which are appropriate for the Zambian building industry.

## **2. Literature Review**

### *2.1 Green Building Rating Tools*

Buildings have and will continue to have a direct and indirect impact on the environment. According to the World Watch Institute (WWI) (2014), building construction and operations are responsible for 40 percent of the world's total electric energy use, 55 percent of timber harvests, 16 percent of freshwater withdrawal, 35 percent of global carbon dioxide (CO<sub>2</sub>) emissions and 40 percent of municipal solid waste sent to landfill (Tafazzoli, 2017). The building sector is estimated to be worth 10 percent of the global GDP (amounting to USD 7.5 trillion) and employs 111 million people (Desai, 2016). According to Ojo-Fafare et al. (2018) green buildings provide better health for building occupants due to the improved indoor quality, development of more energy efficient products and the use of less natural resources for the satisfaction and welfare of building tenants, also to protect the ecosystem.

According to the United States Building Council (USGBC, 2018) green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building life cycle from siting to design, construction, operation, maintenance, renovation, and deconstruction. In the study, green buildings have been defined as buildings whose design process, material selection, construction, utilization and demolition take into consideration sustainable resources that do not have a negative impact on the environment. Rating buildings is one of the processes of measuring the impact of buildings on the environment and imperial evidence is cardinal to quantify their performance. GBRTS examine the performance or expected performance of a whole building and translate that examination into an overall assessment that allows for comparison against other buildings (Banani, 2011). The GBRTS are intended to foster sustainable building designs, construction and

operation by promoting and facilitating better integration of environmental solutions with cost and other traditional design criteria. Sustainable construction in most developing countries around the world has been characterized as poor. Studies have shown that the sustainability level in construction projects being delivered in these developing countries is low (Alabi, 2012; Aje, 2016; Baron & Donath, 2016).

It is argued that individual characteristics of each country, such as the climate and type of building stock, necessitate a unique GBRT for use and to varying degrees, assessment tools for different countries use different parameters (Reed, 2011). Sharifi and Murayama (2013) argued on the importance of having assessment tools that are region-specific or that take into consideration adaptation to a locality. According to Rana and Bhatt (2016) most of the internationally devised rating systems have been tailored to suit the building industry of the country where they were developed. An example is the case of Indian strategy for assessing the building performance towards sustainability was to include all the dimensions of sustainability related to Indian construction industry (Arukala et al., 2018). Sharifi and Murayama (2013) and Fenner et al. (2008) have argued that the current tools have not done well in covering aspects of social and economic sustainability and they lack a mechanism for local adaptability and participation. The fact that various tools are being developed worldwide shows that there are gaps in the current tools that need to be addressed if universality is to be achieved.

## *2.2 Building Sustainability in Zambia*

Zambia is greatly affected by the impact of climate change and is grappling with issues of scarcity of energy and water. It has a 560 MW power deficit (Kaunda, 2013) and 4.8 million people (36 percent) are without access to clean water and sanitation (UNICEF, 2017). Estimates put the rural population with access to clean water at 37 percent while the urban population with access to clean water is estimated at 74 percent (Chitonge, 2020). The challenges of environmental degradation are mostly felt by the urban poor who make 65 percent of the population. The Zambian government had budgeted US\$ 13.7 million on housing and related infrastructure (GRZ, 2020), the cost of infrastructure could greatly be reduced if housing is planned and constructed sustainably. Research has also shown that there is a 20 percent reduction in the construction cost if buildings are built in a sustainable way (Gabay et al., 2014). Apart from the cost of construction and maintenance, there are benefits in reducing the cost of energy in the buildings. Buildings are one of the main consumers of energy, they consume 31-45 percent of the entire energy countrywide (Ryu & Park, 2016). Zambia is facing challenges of inadequate electrical energy and water supply and green buildings can contribute to reducing the demand on these resources.

The challenge that developing countries like Zambia are facing is the absence of local GBRTS and even access to the globally recognized ones. Foreign-based tools like Leadership in Energy and Environmental Design (LEED) or Building Research Establishment's Environmental Assessment Method (BREAM) may be too complex and expensive when dealing with poor economies where few buildings exceed 10,000 square meters. According to Wijewickrama et al. (2017) many developers are

concerned that adopting green features into their buildings will involve high upfront costs. Compared to conventional buildings, green building projects are often perceived as having higher initial design and construction costs. There is also a challenge of high costs of building materials, it is perceived that high cost of building materials are also a major obstacle for implementing green buildings across most Asian markets.

An assessment framework can be the basis on which GBRTS could be developed appropriate for the Zambian environment. Zambia has developed the ZSHG as a guide in the development of sustainable housing, however these guides lack the mechanism for assessment and cannot be used to evaluate the level of green building compliance. As stated in the Zambia Green Jobs programme of the International Labour Organisation (ILO) (2016), the guidelines developed do spell out what green buildings are, as well as give performance criteria and guidance on social, environmental and economic aspects including a checklist for criteria. However further research was required to realise these guidelines into a framework that could actually be used for assessment. The research is the first of its kind in Zambia where possible methodology and criteria are explored for use in assessing green buildings. The framework was developed based on local experience and integrated with the best practices in green buildings assessment.

The 11th SDG goal has targets to deliver adequate, safe and affordable housing and basic services and upgrade slums by 2030. It is hoped that by 2030, there should be provision to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons. The goal is to reduce the environmental effect of pollution through air pollution and solid waste management. The Zambian government has incorporated these goals in the 2020-2024 National Housing Policy (NHP). The efforts to achieve sustainability have been hampered by the poor use of local building materials and the rigid building standards, regulations and guidelines. There is also poor investment in knowledge and finance of sustainable housing (Ministry of Local Government, 2019). The challenge with the NHP is that it lacks specific green building targets and solutions that are measurable.

### *2.3 Analytical Hierarchy Process (AHP)*

The selection of AHP to compare and select the various criteria for green buildings was in line with other studies like Sauchy (2017) who used it to perform unbiased decision making on the environmental rating selection. In building process such as, assessment of sustainability in buildings (Markelj et al., 2014), development of new rating tools (Hazem et al., 2020), available land for buildings (Pandav et al., 2016) and location selection (Nahid & Gholam, 2010) was seen in literature.

According to Ogrodnik (2019), AHP method is used for the decomposition of a decision problem using a hierarchical structure tree, then making comparisons through element pairs that are located at given levels of the structure and assessing the consistency of the comparisons by using consistency ratio. According to Harputlugil (2018) AHP structures the problem in a hierarchical structure when the

alternatives to be selected by the decision maker/s, criterion and sub-criterion, are listed for the specified purpose. As a compensatory method, it assumes complete aggregation among criteria and develops a linear additive model. According to Ramanathan (2001) AHP is a method of (1) breaking down a complex, unstructured situation into its component parts; (2) arranging these parts, or variables into a hierarchic order; (3) assigning numerical values to subjective judgments on the relative importance of each variable; and (4) synthesizing the judgments to determine which variables have the highest priority and should be acted upon to influence the outcome of the situation. Information from the experts is utilized to estimate the relative magnitudes of factors through pair-wise matrix. Questionnaires are used to compare the relative importance between the two items. The pairwise matrix is created by using the scale of relative importance. The selection of an item is based on several criteria that will enable the best choice to be made on that item. In the case of the study, it was a selection of the best methodology and criteria to use in the assessment based on various criteria found in selected GBRTS.

### **3. Method**

The research adopted an integrated strategy using a sequential mixed-method design. The mixed-method included literature review, interviews and evaluation of the variables using AHP. The AHP was the design tool that was used in the quantitative component and included structured evaluation questions to identify the methods and criteria to use in the framework for green building assessment. The qualitative component was through interviews with ten practitioners from selected architectural firms. The evaluation was undertaken by 5 experts, who had not taken part in the interviews. The experts were purposively selected based on experience in green building rating tools. The design method was characterized by an initial qualitative phase of data collection through interviews and followed by a phase of quantitative data collection and analysis, with a final phase of integration or linking of data from the two separate studies under discussion.

#### *3.1 Study Population*

The study population was ten (10) practitioners who were interviewed and five (5) experts to carry out the evaluation. From an initial list of 10 practitioners from architectural firms who were approached only five (5) fully answered the evaluation questions. The sample size was sufficient because it combined practitioners from two study groups, it reduced the biasness of a small sample size. The two studies were meant to bring consistency to the results because in both studies the same questions were asked but the difference was in the collected data. An explanation was sent out to each of the evaluators where it was clearly outlined how AHP works and what was required from them. A multi-criteria decision tool called Transparency Choice (TC) was used to calculate the priority percentage weights for the criteria and the methods in the study.

### 3.2 Process

The process of carrying out AHP starts with structuring a decision problem and selection of criteria. The problem AHP was solving was selecting the most suitable methodology to assess the planning and designing of low-income housing. In structuring the decision problem, it was decomposed into individual parts which included the main goal, the performance indicators and the methods. AHP helped to arrange the criteria of methodology and parameters in a hierarchy that could be understood. It decomposed the complexity of the relationship and helped to identify the magnitude of each criterion for accurate comparison. The steps in coming up with a decision were outlined as follows:

Develop a model for the framework

Derive weights for criteria

Consistency check if weights are assigned correctly

Derive overall priorities and final decision.

### 3.3 Research Design

#### 3.3.1 Hierarchy Development

The qualitative results were obtained by interviewing ten (10) purposively selected practitioners who showed knowledge and experience on GBRTS. The interviewees were two (2) senior architects, one (1) director in a government institute, one (1) senior lecturer and six (6) partners in architectural consulting firms. An interview guide with open-ended questions was used to conduct the interviews. The interview results were used to come with variables for selecting the methods and criteria, then an online link was sent to ten (10) purposively selected architects who had experience in using a GBRT, between March and April 2020. They were asked to rank the method of assessment, criteria and alternatives from the interview results and from the summary of the five (5) GBRTS using AHP. The levels of comparison are shown in Figure 1. the main goal is to develop a framework for assessing green low-cost housing. The performance indicators are relevance, ease of use, comprehensiveness and cost of assessment. The methods to achieve the goal were: Life Cycle Assessment (LCA), which measures the energy and resources use of building materials throughout their life cycle; Locally Based Method (LBA) that looks at adopting criteria that are considered very important for the development of green buildings locally; It looks at economic/social/cultural assessment suitable for a particular locality as described by Ali et al. (2009). Assessments that are developed through an effective green building rating system according to the local context. The Integrated Whole Building (IWBA) looks at the various process and activities undertaken in the construction industry and how these can be used in an integrated way so that the assessment of buildings takes all those different activities and incorporate them in one assessment. According to Prowler et al. (2012) whole Building design in practice also requires an integrated team process in which the design team and all affected stakeholders work together throughout the project phases. The next level of comparison was between the methods of assessment and the performance indicators such as cost of the assessment, ease of use of the method, comprehensiveness and relevance of the method.

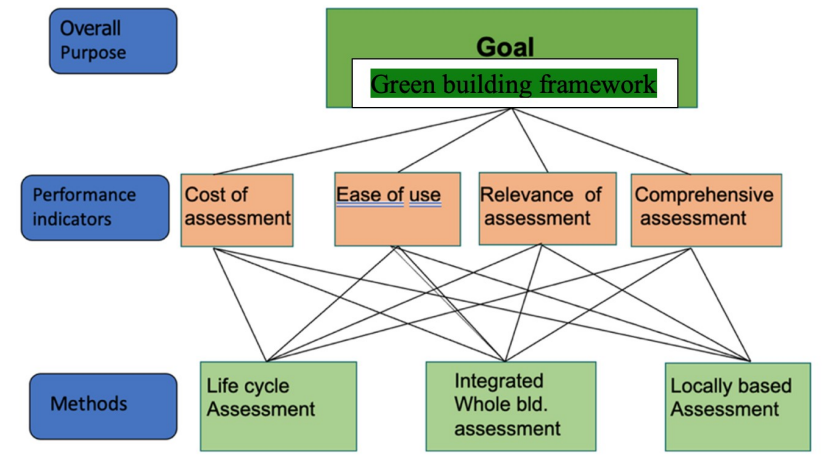


Figure 1.0 Hieratical Development

Figure 1. Hieratical Development

3.3.2 Pairwise Comparison Matrix

Using the pairwise comparison a scale from one to nine is created to rate the relative preference of two items. The Table 1.0 shows the preference in selecting the ranking of the criteria. There are one (1) to nine (9) scales of preference, 1 is equally preferred and 9 is extremely preferred while 2 is moderately preferred. Even numbers (2, 4, 6, 8) are intermediate values for the scale.

Table 1. Preference Scale

Verbal Judgment of Preference	Numerical Rating
Extremely preferred	9
Very strongly to extremely preferred	8
Very strongly preferred	7
Strongly to very strongly preferred	6
Strongly preferred	5
Moderately to strongly preferred	4
Moderately preferred	3
Equally to moderately preferred	2
Equally preferred	1



The rules to come up with the number of entries filled in by decision makers is made by the formula  $(n^2-n)/2$ , where  $n$  is the number of elements to be compared. Synthetization which involves the computation of eigenvalues and eigen vectors is the next step. The exact mathematical procedure required to perform synthetization involves the computation of eigenvalues and eigenvectors to come up with the priority vector.

The pairwise comparison in the questionnaires had ten (10) pairwise comparison matrices; 1 for the main criteria, 3 for the performance indicators, 6 for the methods. The questionnaire was sent to the evaluators and the results were worked out by the Transparency Choice software in which priority vectors with consistency ratios were calculated.

#### **4. Findings and Discussion**

##### *4.1 Interview Results*

The interview results have been summarized in Table 2. The code in the table represents the interviewees identification numbers and the main criteria is what has been selected by the practitioners for assessment. The sub-criteria represents the summarized opinions based on the coded results of the interviews. The main criteria included: local assessment; energy; water; materials; sustainable site; social; Health and wellbeing; economic and management. According to National Institute of Building Science (2018) it is important to Evaluate the use of locally produced products in order to stimulate local economies and to reduce transportation burdens and greenhouse gas generation. Based on the interviewees, preference should be given for materials found in the region. Water management, heating and cooling systems, sustainable site and renewable energy criteria describes all the necessary requirements to utilize and conserve, energy and water. The heating and cooling systems that were suggested were cross ventilation, solar heating and biomass for warming buildings.

According to one key informant the management performance criterion includes occupants building manuals, sustainable building materials that are easy to use, recycled, non-hazardous and low embodied energy materials. Health and well-being of internal environment is promoted by using finishes and fixtures in buildings that are non-pollutants or hazardous. It includes good visual comfort, use of passive ventilation and utilization of daylight. They mentioned the use of outdoor space for sitting and cooking rather than indoor use of space. The integration of environmental and economic sustainability was key to the development of the framework. The economic criterion allows the users to select, activities that can boost local economies in a sustainable way and included local building production, diversification in economic activities to enable the housing tenants gain wealth through the housing projects. It promotes the involvement of the local experts and tradesmen in utilizing GBRTS.

**Table 2. Selection of Criteria and Sub-Criteria from Interview Results**

CODE	CRITERIA	SUB CRITERIA
KII-1	Local assessment	Local materials like clay bricks
KII-3		Reduction in cement use /Hydrafoam blocks
KII-4		Use of sisal as a binder Education of local experts/Development of local assessment tools Green Building regulations developed
		Reuse and recycling of construction waste
KII-3	Energy	Reduced energy use/Renewable energy
KII-7		Energy metering/solar panels/type of light fitting
KII-5	Water	Recycling of gray water/Rainwater harvesting
KII-3		Reduction of run-off water /Water metering
KII-1		Recycling of materials
KII-4	Materials	use of stabilized blocks, bamboo, brick
KII-10		recycled materials/Clay tiles
KII-6		Reduced distance from site, public transport,
KII-4		Reduced pollutants
KII-7	Sustainable site	Use of brown field/Maintenance of ecosystems
		Recreation facilities and social cohesion
		Reduce waste to land fill by 25%
KII-7		Health and well being
KII-8		Cross ventilation
KII-5	Health and well being	Wide windows for natural lighting
		Solar heating and biomass for heating
		Natural roof and wall insulations
KII-8	Social	Recreation facilities and social cohesion
KII-1	Economic	Local building material production
KII-7		Training of local people on green buildings
KII-9		Local business in construction projects
KII-7	Management	Project and facilities management
KII-9		waste management/sustainable building materials
KII-10		education of green buildings professionals, tradesmen
		innovation of new ideas in the use of local building materials and strategies

The education, pollution and social cohesion criteria integrates education in the development of green buildings. In reducing pollution and waste a criterion is selected that describes solutions for waste

disposal to include reduction in emission from refrigerants, household recycling and waste segregation, construction waste management, reuse of sewage waste and reduction of landfill waste. Social cohesion allows tenants the opportunity to interact with their neighbours and their surrounding and enhances both physical, physiological as well as mental development.

#### 4.2 The Performance Indicators for Development of GBRTS

The practitioner’s perceived ranking of the performance indicators to aid in the development of a green building assessment framework were selected from the interview results. The evaluators selected the methods based on the Likert scale between 1 to 9 with 1 (one) being unimportant and 9 (five) being extremely important. The results in Table 3.0 shows the normalized matrix of the performance indicator using the normalized arithmetic averages. As a result of the normalisation, matrix A is transformed into matrix B = [bij]. The elements of matrix B are calculated according to the following formula:

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^n a_{ij}} .$$

calculation of Normalized Matrix)

The contribution of each parameter to achieving green building assessment is determined by calculations made using the priority vector (or Eigenvector) shown in Table 3.0. Calculating the preference between the elements under investigation (eigenvector w = [wi]) is performed by calculating the arithmetic averages from the row of the normalised comparison matrix. The components of this vector are calculated according to the formula:

$$w_i = \frac{\sum_{j=1}^n b_{ij}}{n} .$$

The maximum eigenvector is calculated according to the equation:

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^n \frac{(Aw)_i}{w_i} .$$

**Table 3. The Practitioners Perceived Percentage Contribution of Performance Indicators to Develop a Green Building Framework**

Performance indicators	Cost of assessment	Ease of use of tool	Relevance	Comprehensive	Criteria sum	Eigenvector
Cost of assessment	0.19	0.38	0.13	0.20	0.89	0.22
Ease of use of tool	0.06	0.13	0.13	0.20	0.31	0.13

Relevance of tool	0.38	0.25	0.25	0.20	0.88	0.27
Comprehensive tools	0.38	0.25	0.50	0.40	1.13	0.38
Totals	1.00	1.00	1.00	1.00	3.20	1.00

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**Maximum eigenvector ( $\lambda_{max}$ )**  $[(0.22 \times 5) + (0.13 \times 13) + (0.27 \times 4) + (0.38 \times 2)] = 4.6$

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The above calculation was an approximation of the eigenvectors using excel. When the data was imputed into TC the results were as shown:

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**Maximum eigenvector ( $\lambda_{max}$ )**  $[(0.22 \times 4.8) + (0.12 \times 13) + (0.25 \times 4) + (0.38 \times 2)] = 4.1$

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When the approximate and the computerized principal eigenvectors were compared the difference was only 0.5, this means that the calculated maximum eigen was consistent. The degree of consistency is measured by the consistency ratio. The ratio is such that values of the ratio exceeding 0.10 are indicative of inconsistent judgments. The consistency ratio can be an approximation and not the exact. The maximum eigenvector taken was the one that was calculated from TC.

$\lambda_{max} = 4.1$

Consistency index (C.I) =  $CI = \frac{\lambda_{max} - n}{n - 1} = \frac{4.1 - 4}{4 - 1} = 0.0333$

$CI = 0.0333$

where n is the number of compared elements

consistency index(C.I)= 0.0333, the random Index (R.I) is derived from table 4.0.

Consistency Ratio = Consistency Index (C.I)/Random Index (R.I)

Consistency Ratio =  $0.0333 / 0.90 = 0.0370 < 0.10$

**Table 4. Random Index**

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Ammarapala V. et al. (2018)

The result of the investigation shows that Consistency Ratio is less than 0.1 which is the standard, it can be assumed that our matrix is reasonably consistent. The percentage criteria weight age contribution of the performance indicators to achieving green building assessment as ranked by the five

(5) evaluators are given in Table 5.0. The highest ranking is comprehensiveness of the tools at 46 percent, followed by relevance at 27 percent, followed by cost of assessment (22 percent) and least ranking was ease of use at 13 percent.

**Table 5. The Percentage Ranking of the Performance Indicators**

Criteria	Criteria weight %
Comprehensive ass.	38
Relevance of tool	27
Cost of assessment	22
Ease of use of tools	13

*4.3 The Method of Assessment for Development of GBRT*

The method of assessment determined the features and characteristics of green buildings assessment framework. In order to come with the method of assessment a comparison was undertaken by five (5) practitioners to select the most preferred method among LCA, LBA and IWBA. Pairwise matrix shown in Table 6.0, based on the ranking by the practitioners shows that LBA was six (6) times more preferred than the other two (2) methods and LCA was four (4) times more preferred and the least preferred was IWBA

**Table 6. Pair-Wise Comparison Matrix of the Methods of Assessment**

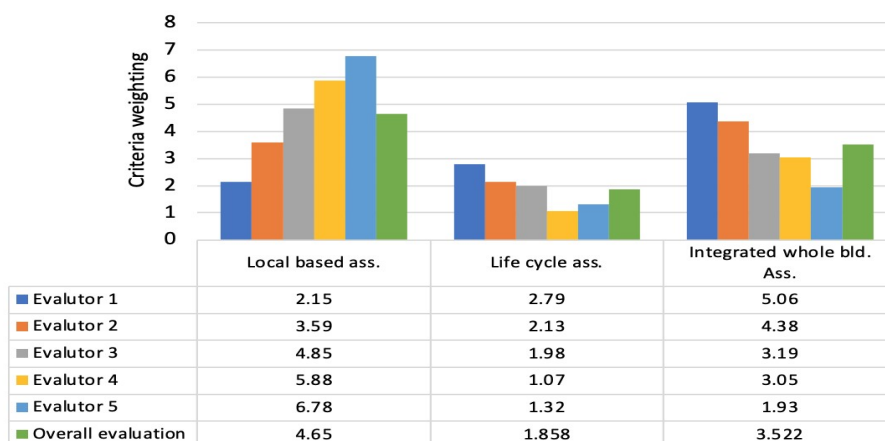
	Integrated whole bld.	Local based Assessment	Life cycle assessment
Integrated whole bld.	1	3	2
Local based assessment	0.33	1	0.5
Life cycle assessment.	0.5	2	1
Total	<b>1.83</b>	<b>6.0</b>	<b>3.5</b>

The normalized matrix of the method of assessment using the normalized arithmetic averages was worked out as shown in Table 7.0. The criteria weights which are ratios of the contribution of each of the methods to achieving assessment of buildings were; IWBA 0.35, LBA 0.47 and LCA 0.18. The percentage increase showed that LBA is 47 percent more preferred than other methodology and IWBA is 35 percent more preferred than other methodology. LCA is the least preferred than all the other methodology (18 percent).

**Table 7. Calculation of Weighted Sum Value**

	<b>Integrated whole bld.</b>	<b>Regional based</b>	<b>Life cycle assessment</b>	<b>weight sum value</b>	<b>criteria weight</b>
<b>Integrated whole bld.</b>	0.32	0.38	0.29	0.99	0.35
<b>Local based assess.</b>	0.48	0.43	0.55	1.46	0.47
<b>Life cycle assessment</b>	0.20	0.19	0.16	0.55	0.18
<b>Total</b>	<b>1.000</b>	<b>1.000</b>	<b>1.000</b>	3.00	1.00

Further comparison was run where criteria weights from all the evaluator’s were imputed into the TC comparative tool. The practitioners evaluated the methods based on the perceived priority ranking of the variable’s contribution to achieving assessment. The results in Figure 2.0. show that all the evaluators ranked LBA highest except evaluator one (1) and two (2), who ranked IWBA highest. The overall ranking shows that LBA was highest at 4.6 followed by IWBA at 3.5 and least ranked was LCA at 1.9. These results are in line with the earlier comparison thus showing the consistency of the results.



**Figure 2. The Practitioners Perceived Contribution of the Methods for Assessment of Green Low-Cost Housing**

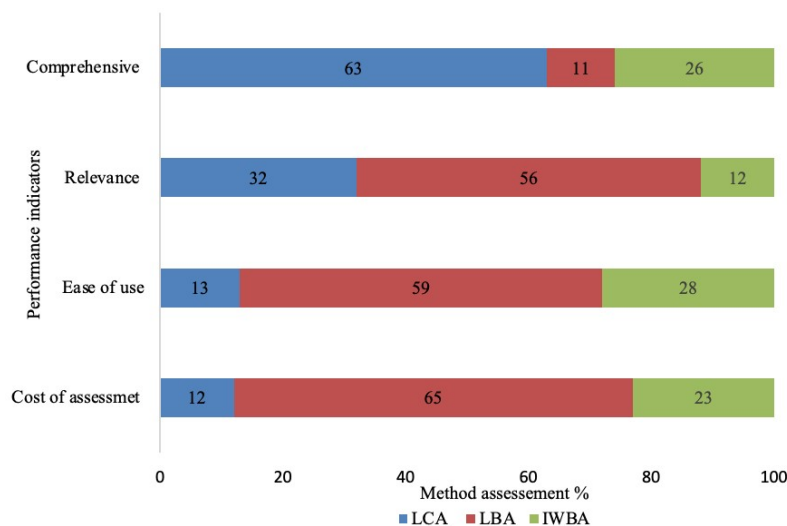
The practitioners pairwise comparison among the methods of assessment based on cost of assessment is shown in Table 8.0. The most costly method to attain assessment is LCA at 12 percent, for IWBA at 23 percent and the least costly was LBA at 65 percent. The practitioners perceived that using LBA was the least costly to achieve the assessment of green buildings.

**Table 8. Ranking of Methods Based on Cost of Assessment**

<i>Ranking based on cost of assessment</i>	<i>LCA</i>	<i>LBA</i>	<i>IWBA</i>	<i>Eigenvector</i>	<i>criteria sum</i>
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LCA	0.13	0.13	0.11	0.12	0.46
LBA	0.63	0.65	0.67	0.65	1.94
IWBA	0.25	0.22	0.22	0.23	0.69
<b>Totals</b>	1.00	1.00	1.00		

The summarised comparison among the performance indicators and the method of assessment on their perceived percentage of contribution to achieving green building assessment is shown in figure 3.0. The highest perceived percentage contribution of comprehensiveness of the tools was LCA 63 percent, while the highest contributor of the tools being relevant was LBA at 56 percent. The highest contributor of easy to use tools was LBA at 59 percent and finally the highest contributor to making the tools less costly was LBA at 65 percent. The contribution of IWBA to ease of use, comprehensiveness and relevance was evenly distributed.



**Figure 3. The Comparative Ranking of the Performance Indicators and Assessment Methods**

The results show that LBA is the most preferred in terms of ease of use and relevance and was supported by the interview results which showed that community participation, use of local tools and materials was preferred. When the interviewees were asked which method, they considered important some thought integrating important characteristic like life cycle cost of materials and professional participation in assessment would be the best model. Similar studies like Bahaudin et al. (2014) selected five of the rating systems available in terms of similarity and contrast and proposed a new framework based on the project life cycle for the development of green building criteria. According to Ahmad et al. (2015) designers must optimize combinations of particular systems and techniques to be integrated in overall design.

An integration of LBA and LCA was considered in the framework based on the results from AHP and the interviews. The integration was based on enhancing local based assessment and with life cycle cost

of materials and processes. The methods considered included the involvement of local communities in the kind of materials and design strategies to adopted and utilization in low-cost housing development.

4.4 Priority Ranking for Criteria of Assessment

**Table 9. The Priority Ranking for Criteria Weight of Assessment Parameters**

Eigenvector	2.80	2.23	1.16	1.68	0.88	0.66	0.55	0.66	0.25	0.31	0.14	0.13	
	Energy	Water	Mate.	Health	Sustain. site	Waste Man.	Trans.	Pollu.	Econ.	Edu.	Social Cohesion	Inno.	criteria sum
Energy	0.35	0.39	0.32	0.39	0.30	0.23	0.16	0.21	0.16	0.15	0.13	0.13	2.92
Water	0.07	0.20	0.24	0.26	0.24	0.19	0.14	0.21	0.14	0.13	0.11	0.12	2.06
Materials	0.09	0.07	0.08	0.04	0.12	0.12	0.12	0.17	0.13	0.12	0.10	0.10	1.25
Health and well being	0.12	0.10	0.24	0.13	0.18	0.27	0.12	0.17	0.13	0.12	0.10	0.12	1.79
Sustainable site	0.07	0.05	0.02	0.13	0.06	0.08	0.10	0.10	0.09	0.08	0.09	0.10	0.97
Waste Management	0.06	0.04	0.03	0.04	0.03	0.04	0.06	0.07	0.07	0.12	0.10	0.07	0.73
Transport	0.04	0.03	0.01	0.02	0.01	0.04	0.02	0.01	0.13	0.12	0.11	0.04	0.59
Pollution	0.06	0.03	0.02	0.03	0.02	0.02	0.10	0.03	0.13	0.10	0.11	0.10	0.76
Economics	0.04	0.02	0.01	0.02	0.01	0.01	0.00	0.00	0.02	0.03	0.07	0.10	0.35
Education	0.04	0.02	0.01	0.02	0.01	0.01	0.00	0.01	0.01	0.02	0.16	0.04	0.35
Social Cohesion	0.04	0.02	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.04	0.18
Innovation	0.04	0.02	0.01	0.02	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.15
<b>Total</b>	<b>1.00</b>	<b>1.00</b>											

The next level of investigation was ranking the criteria for assessment as derived from literature and interview results. The criteria were used to assess the greenness of housing at all stages of construction. Twelve (12) main criteria that were selected included the following: energy, water, materials, health and wellbeing, sustainable site, waste management, transport, pollution, economics, education, social cohesion and innovation. The summary of the priority ranking for criteria has been shown in Table 9. the ranking was based on averages from the five (5) evaluators.

The first stage was using pairwise comparisons to find the relative importance of one criterion over another on Likert scale. The figures seen in Table 9.0 represent the elements of the priority vector divided by the column sum for each element. The criteria sum is the sum of all the elements in the rows and the eigenvector is found by summing up all the elements in the priority vector divided by the total



number of elements. The last column is found by dividing the criteria sum over the criteria weight. The contribution of each criterion to the achievement of green building assessment is determined by calculations made using the priority vector (or Eigenvector). The results are summarized in Table 10.0. were the eigenvector results show that energy contributes 28 percent to achieve green building compliance in comparison to the other criteria. Water is 22 percent, Health and wellbeing 16 percent and materials is 11 percent.

**Table 10. The Percentage Weight age for Criteria**

Criteria	Criteria weight %	Ranking
Energy	28	1
Water	22	2
Health and wellbeing	16	3
Materials	11	4
Sustainable site	8.8	5
Waste management	6.6	6
Pollution	6.6	6
Transport	5.5	7
Education	3.1	8
Economic	2.5	9
Social cohesion	1.4	10
Innovation	1.3	11
Total	100	

The middle range is pollution at 7 percent and the least contributor to achieving green building assessment is innovation. The interview results supported the findings on the priority of criteria in that they preferred the efficient use of energy and water and passive solar designs as priority in green buildings. The discourse on the type of criteria to be included in GBRTS, showed that all the five (5) interviewees selected Energy, Water efficiency, Health and wellbeing as criteria for assessing green buildings.

The priority ranking of criteria was in line with the scores given in most GBRTS and had similar results to studies like Berawi et al. (2019) were the selection of criteria by respondents showed that 90 percent chose energy efficiency, 71 percent water conservation, 68 percent building and environment management, 66 percent indoor air, health and comfort and 63 percent material resources. Referring to the choice of the criteria preference in GBRTS, Tang et al. (2020) and Illankoon et al. (2017) mentioned that four criteria that all the rating systems compared cover are energy efficiency, water efficiency as

well as indoor environmental quality, health and welfare. Even though there were similarities in the selection of the criteria between literature and interview results, specific parameters differed for example, even though energy was ranked highest criterion, specific indicators like the use of HVAC, artificial heating and cooling systems and energy metering systems were not considered practical to be achieved in the Zambian low-cost housing construction, due to the high cost of installation. Al Omari and Dabbagh (2012) stated that although there is a similarity in the classification levels including the sustainable location, how to use (water, energy and materials resources) effectively, indoor environment quality and the design's innovation, they differ in other aspects in that importance relies on the environmental and local context. As stated by Ahmad and Thaheem (2015) since the design is contextual in its nature and function, the local climatic conditions dictate a lot of it.

The interview results also supported the perception that not all criteria found in GBRTS are suitable. The respondents mentioned that even though material efficiency is important for sustainable buildings, the materials in the GBRTS differ from region to region and this also applies for Zambia. In LEED and BREEAM the materials that are considered sustainable is wood, while in Zambia wood may not be sustainable because there is not enough preserved for construction purposes. The respondents selected water performance by use of rainwater harvesting for gardening and external use and also capturing storm water. When it came to heating, they advocated for the use of biofuel and cooling the buildings through cross ventilation. The choice on the materials to use for building envelop was hydra form blocks, sisal, clay and bamboo and for roofing materials it was clay tiles, iron sheets and thatch. In order to achieve daylighting, they preferred wide openings and window overhangs. To achieve sustainable sites, respondents suggested the use of landscaping, green open spaces, community spaces and walkways and cycling tracks. To reduce toxic waste, there should be a reduction of CFC, lead paints and lead, cooper and iron pipes in buildings. In the social form they considered issues of having common spaces in communities, play parks, community halls and projects.

When the respondents were asked concerning the use of GBRTS, some mentioned the need to develop local tools or have access to cheaper tools. They wanted to see materials that are supplied locally and demonstrate local solutions in the design strategies. Even though many studies have emphasized the environmental category (Bahaudin et al., 2014), the respondents felt some tools lacked assessment on other categories like economic, social and management. Sharifi et al. (2013) and Fenner et al. (2008) have argued that the current tools have not done well in covering aspects of social and economic sustainability and they lack a mechanism for local adaptability and participation. The respondents were asked to give what they considered local solutions and the selection of environmental, economic and social criteria was similar to other studies (Bahaudin et al., 2014; Vij et al., 2017; Ahmed, 2010; Chibwe et al., 2016). There were also similarities in achieving a sustainable site by using landscaping, having walkable distances to amenities and public transport systems, use of bicycles and having bicycle tracks. The results in the qualitative and quantitative studies differed when it came to the economic and social form. In the quantitative results few choose the economic and social form while in the qualitative

results many of the informants mentioned the need to link economy and social cohesion to sustainability. The informants mentioned the need to have economic benefits from green housing like job creation and local enterprises around housing. They also mentioned the need to have open spaces and parks to enhance social cohesion.

#### *4.5 Integration of the 11th Sustainable Development Goals with the Framework*

Some of the variables for assessment were adopted from the 11th SDG, particularly those which were in line with the findings of the study as shown in Table in 11.0. One of the goals is that by 2030, there should be access to safe, affordable, accessible and sustainable transport systems. The application of this goal is the provision of transport systems near housing development that cater for the disabled people as well and separate walkways and cycling tracks, bicycle storage and parking. The other goal was improvement of water quality and minimizing release of hazardous chemicals, reducing the proportion of untreated wastewater and increasing recycling and safe reuse. The application was the provision of solid waste outlets within the buildings and separating of waste, recycling and on-site water treatment

**Table 11. Integration of 11<sup>th</sup> SDGS with the ZIGBAM**

Number of the goal	Description of the goal	Application
1	provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons	<ul style="list-style-type: none"> <li>• Having transport systems near housing development</li> <li>• Special features on transport systems for the disabled</li> <li>• Separate walkways and cycling tracks, bicycle storage and parking</li> </ul>
2	By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries	<ul style="list-style-type: none"> <li>• Inclusion of all parties in the design up to completion of projects</li> <li>• Inclusion of client to maintain buildings after handover by training them and provision of ownership manuals</li> <li>• Training of professionals in using GBRTS</li> </ul>
3	By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	<ul style="list-style-type: none"> <li>• Allow for good air quality through cross ventilation</li> <li>• Use landscaping to reduce on site dust</li> <li>• Reduce municipal waste by <a href="#">site</a> recycling and segregation</li> </ul>
4	By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities	<ul style="list-style-type: none"> <li>• Provision of open spaces in housing design</li> <li>• Provision of public spaces around housing like play parks, swimming pools</li> <li>• Clear well light up walkways,</li> </ul>
5	Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials	<ul style="list-style-type: none"> <li>• Support community development of local materials</li> <li>• Support community projects</li> </ul>
6	ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance	<ul style="list-style-type: none"> <li>• Community business and commercial facilities</li> <li>• Building design that support community projects and business</li> <li>• Development and training of production of local materials</li> </ul>
7	improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and increasing recycling and safe reuse globally	<ul style="list-style-type: none"> <li>• Protecting points and separating waste</li> <li>• Recycling and on-site water treatment plans</li> <li>• Use of gray and rainwater harvesting</li> </ul>

#### 4.6 Categories

The results of the priority ranking were used to create categories for the framework, these included, environmental, economic, social, education, management and innovation. The environmental category included: energy, health and well-being, material use, water, sustainable site, pollution, transport and waste management. The economic category is job creation, locally produced materials and local labour, while the social category included recreation and social cohesion. The education category is offering education on green buildings to developers, tenants, tradesmen and professionals, while the management category is about management and maintenance of buildings after construction. The innovation is a category for creating sustainable ideas that cannot be placed in any other group.

#### 5. Limitation and Suggestions for further Research

The limitation of the study was that the study population was small and generalization of the results to the larger building industry population was difficult, future research should have a larger population. The limitation of the study population was reduced by the introduction of the literature review that was able to demonstrate other practitioner's experience with regards to utilizing GBRTS thus bring more data to the study. The AHP tool that was used to come up with preferred ranking of the methods and criteria limited the study by allowing only 5 evaluators to participate in the evaluation at a time. The selection of the AHP analysis tool was limited due to availability and affordability, otherwise better tools could have been used in the study. The introduction of the study variables to the study population could have introduced biasness as they were not given an opportunity to select their own parameters to rank.

#### 6. Conclusion

The study reported in this paper has demonstrated the process of developing methods and criteria for assessment of green low-cost housing. The research answers to the challenge of appropriate criteria that has been selected by practitioners to be used in the design of green low-cost housing in Zambia. The study demonstrated the use of local materials and strategies relevant to the environment. The study identified energy, health and wellbeing, water and material resources as criteria appropriate to the Zambian building industry and has shown that local based strategies like LBA were preferred method of assessment based AHP priority. The highest preferred indicators based on AHP results, were comprehensiveness of tools, relevance of tools and cost of assessment and these were in line with the interview results thus reliable and relevant data was used to come up with method and criteria. Availability of method and criteria will make assessment of low-cost green housing accessible to all stakeholders in the building industry.

##### 6.1 Recommendation

Arising from the above conclusions, the following are the main recommendations directed at integrating the framework in the planning and designing of green low-cost in Zambia:

the developed criteria could further be developed into a rating tool and could be used to certify the greenness of low-cost houses in Zambia and the region the method and criteria could be used to review the current building bye-laws to make them appropriate for green building development and to engage the Ministry of Local Government and Housing to adopt the criteria for development of low-cost houses.

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