

Selection of the Most Appropriate Sustainable Buildings Assessment Categories and Criteria for Developing Countries: Case of Ethiopia

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Abstract: Sustainable/green buildings can save for 36% of total energy use, 65% of electricity consumption, and 30% of greenhouse gas emissions, 30% of raw materials use, 30% of waste output, and 12% of potable water consumption. Several sustainable/green building assessment tools were existed and used by both developed and developing countries. However; Ethiopia's buildings were not critically assessed and evaluated from sustainability points of view because there was no such type of studies conducted so far. This paper aims to explore the most significant and widely used as well as the basis for other sustainable/green building assessment tools such as Building Research Establishment Environmental Assessment Methodology (BREEAM), Leadership in Energy and Environmental Design (LEED), Comprehensive Assessment System for Built Environment Efficiency (CASBEE), Sustainable Building Tool (SBTool), Comprehensive Environmental Performance Assessment Scheme (CEPAS), Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB), Green Mark and Green Star. The methodology employed for this paper is the selection of the 10 most commonly and widely utilized SBATs from the 57 SBATs based on desk review and document analysis. The results of the study identified that all these 10 SBATs have their own assessment categories and criteria based on many factors like climatic conditions, availability of resources plus methods employed demographic dynamics, and legal aspects of the sector for assessing the sustainable/green buildings. It distinguishes the most commonly and repeatedly used assessment categories and criteria and uses a consensus-based approach with experts in the building sectors, a four-quadrant model, and a Circular and Helical flow model, to develop a new sustainable building assessment tool (SBAT) suitable for Ethiopia.

Keywords: Sustainability, Four Quadrant Model, Helical Flow Model, Sustainable/Green Buildings, Assessment Tools

1. Introduction

The concept of green building is derived from the term "Arcology" which stands for a combination of architecture and ecology [1]. It aims to minimize the effects of the construction sector on the natural habitat as well as on individuals. Green building is a reaction in addressing

environmental and health problems which arise from buildings.

Green buildings can save for 36% of total energy use 65% of electricity consumption and 30% of greenhouse gas emissions, according to studies [2]. The application of the idea of green building in the building construction sector is indispensable as it prioritizes environmentally responsible and efficient resource allocation.

Currently, many SBAT were existed worldwide and are utilized by both developed and developing countries. Some of these tools are LEED (Leadership in Energy and Environmental Design), CASBEE (Comprehensive Assessment System for Building Environmental Efficiency), BREEAM (Building Research Establishment Environmental Assessment Method), and SBTool (Sustainable Building Tool).

Ethiopia's buildings were not critically assessed and evaluated from sustainability points of view because there was no such type of studies conducted so far. No institution is responsible to evaluate and certify the buildings (both new and existing) but still, the buildings are constructed at an increasing rate. Therefore; the development of the SBAT for the Ethiopian context is indispensable.

1.1. The Benefits of Sustainable/Green Buildings

It is well known that a sustainable or green building minimizes or eliminates negative aspects and has the ability to create positive impacts on the natural environment through its design, construction, and operation. In other words, sustainable or green buildings preserve precious natural resources and improve the quality of life. Sustainable/green building makes a unique contribution to our global community and our future, a future that can be more abundant and prosperous for all of us. Thus, it can be understood that sustainable building has become a future development trend in the building sector, as argued by [3].

Moreover, sustainable/green buildings also have the following benefits: they provide better health for building occupants due to the improved indoor quality; lead to the development of more energy-efficient products and services; improve comfort, satisfaction, and well-being of building occupants; the environmental and emissions costs are lower; enjoy the support of climate change protocols; improve the quality of life for individuals; use fewer natural resources so as to protect the ecosystem; lead to the reduction of annual water cost savings; increase the occupant safety and security; lead to lower operational and support costs; lowering waste disposal costs in green buildings, making risk management manageable (economic, financial, market, etc.), and greatly lowering the cost of maintenance in green buildings as noted by [4]. Furthermore, sustainable/green buildings benefit the triple bottom line of sustainability (social, economic, and environmental). Therefore, in order to address the mentioned benefits, identifying and selecting the most relevant and appropriate sustainable building assessment categories and criteria as per the local context for the given regions is very important because there are regional variations across each region.

1.2. The Rationale for Developing a New Sustainable Building Assessment Tool/Method

Ethiopia's building sector is highly increasing from time to time as of technological development, especially in Addis Ababa. Private sectors, real estate developers, government, individuals, and cooperatives construct buildings. These

buildings are used for residences, commercial, institutions, services (Health and Education), and others. Addis Ababa is the capital of the African Union and seat for international organizations.

Ethiopia's concern for the environment and sustainable development has been increased recently. There are no sustainable building assessment tools and evaluation criteria so far. There is a need to develop new methods and practices for considering the theory of green building philosophy and applications for the success of sustainable development.

The existing environmental assessment methods like BREEAM, LEED, SBTool, and CASBEE were developed for different local purposes and are not fully applicable to all regions [5, 6]. Consideration of the consensus of Ethiopian experienced experts, involved in the construction industry, on applicable sustainability categories and criteria will be the best solution.

2. Materials and Methods

The methodology employed for this paper is the selection of the 10 most common and widely utilized SBATs from the 57 SBATs based on desk review and document analysis by considering the following parameters [5]:

Consideration of the region-wise (continental) importance like from Africa 1 rating tool (Green Star – SA); from Asia 4 rating tools (CEPAS – Hong Kong, CASBEE – Japan, Green Mark – Singapore, and Green Building Index (GBI) – Malaysia); from Europe 3 rating tools (BREEAM – United Kingdom, HQETM – France and SBToolPT – Portugal) and from North America 1 rating tools (LEED® – United States of America);

Consideration of the most significant and internationally predominant environmental assessment techniques and basis for the development of other evaluation tools like LEED – USA, BREEAM – UK and CASBEE – Japan, and

Consideration of the most repeatedly utilized tools by a number of countries like DGNB which is utilized by almost 15 countries (Austria, Thailand, China, Bulgaria, Czech Republic, Denmark, Germany, Greece, Hungary, Poland, Russia, Spain, Switzerland, Ukraine, and Turkey); BREEAM by 9 countries (BREEAM AT – Austria, BREEAM DE – Germany, BREEAM LU–Luxembourg, BREEAM – NL – Netherlands, BREEAM – NOR–Norway, BREEAM ES – Spain, BREEAM SE – Sweden and BREEAM CH–Switzerland, BREEAM – United Kingdom) and LEED by 6 countries (LEED® – India – India, LEED®–Italy, LEED® – Canada – Canada, LEED® – USA, LEED® – Argentina – Argentina and LEED® – Brazil – Brazil).

Depending upon the mentioned parameters, this study explores the world's most important and internationally predominant sustainable building assessment tools (SBATs) like BREEAM, CASBEE, CEPAS, DGNB, GBI, Green Mark–Singapore, Green Star SA, HQE™–France, LEED, and SBTool^{PT} to determine the key similarities and differences and thus develop the most important categories and criteria by amalgamating them into new SBATs suitable to Ethiopia

[5, 6]. The methodological framework for this study is shown in the figure 1 below.

For developing SBATs for Ethiopia, the researcher investigates the various existing SBATs used by different countries which were highly focused under the WorldGBC [8]. The World Green Building Council (WGBC) supports the use of SBATs. The WorldGBC believes that there is no need to compromise the quality standards for each assessment tool so that all sustainable/green building assessment-rating tools should meet these standards.

The WorldGBC aims to ensure that the development and operation of SBATs are vigorous, transparent, and to the best standard. To enhance this, WorldGBC published the Quality Assurance Guide for Green Building Assessment/Rating Tools in 2015 [8].

2.1. The Selected Sustainable Building Assessment Tools (SBATs)

An analysis of the main existing sustainable/green building assessment tools is considered by far the most comprehensive and methodological tools developed to examine sustainability issues. The analysis of these tools is mainly focused on the identification of the most repeatedly and widely used categories and criteria of the selected ten (10) SBATs and then identifying the best categories and criteria suitable to the Ethiopian context by considering the environmental, socio-economic as well as physical conditions. An analysis of the 10 SBATs as well as the identified 69 categories and 374 criteria has been carried out by the researcher as shown in Table 1 below.

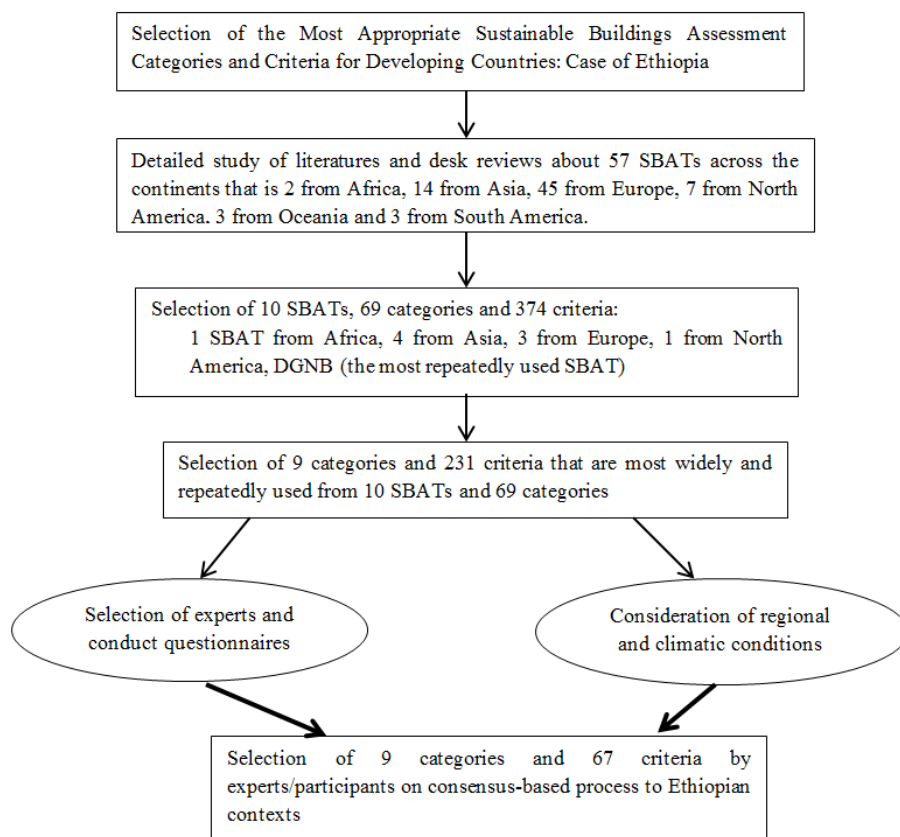


Figure 1. The Research Methodological Framework.

Table 1. Lists of the 10 selected sustainable building assessment tools, categories, and criteria.

S/No.	Name of SBATs	No. of categories	No. of criteria
1	BREEAM – United Kingdom	10	49
2	CASBEE - Japan	6	22
3	CEPAS – Hong Kong	8	20
4	DGNB -	5	43
5	GBI - Malaysia	6	17
6	Green Mark-Singapore	5	22
7	Green Star-South Africa	8	94
8	HQE™ - France	4	14
9	LEED – United States of America	8	67
10	SBTool ^{PT} - Portugal	9	26
	Total	69	374

Source: compiled by the researcher from the selected 10 rating tools, 2021.

2.1.1. Building Research Establishment Environmental Assessment Methodology (BREEAM) - UK

The Building Research Establishment Environmental Assessment Methodology (BREEAM) was launched in 1990 and utilizes a fixed weighting system. It is the most effective scheme around the world for the measurement and description of the environmental performance of a building [9]. The project was conceived in the UK in 1988 by the Building Research Establishment (BRE).

BREEAM was initially designed to focus predominantly on environmental aspects but in the past decade, it has also highlighted economic and social aspects. It has been applied in 77 countries [10]. The BREEAM is a set of ten (10) categories describing sustainability through forty-nine (49) criteria and the environmental weightings.

Based on the weightings (%) and the credits available, the BREEAM tool has a rating benchmark and score such as Outstanding for $\geq 85\%$, Excellent for 70%, Very Good for 55%, Good for 45%, Pass for 30%, and Unclassified for $< 30\%$.

2.1.2. Comprehensive Assessment System for Built Environment Efficiency (CASBEE) - Japan

Comprehensive Assessment System for Built Environment Efficiency (CASBEE) was developed in Japan in 2001. CASBEE is comprised of assessment tools tailored to different scales: construction (houses and buildings), urban (town development), and city management. BEE is an indicator calculated from Q (building environmental quality and performance) as the numerator and L (building environment loadings) as the denominator [11]. BEE's formula is given as:

$$(BEE) = \frac{Q}{L} \quad (1)$$

Where BEE = Building Environmental Efficiency,
Q = Building environmental quality and performance,
L = Building environmental loadings.

For sustainability ranking of the building by BEE, comprehensive assessments are ranked in five grades such as Poor (C), Fairly Poor (B-), Good (B+), Very Good (A), and Excellent (S) as displayed in figure 2 below.

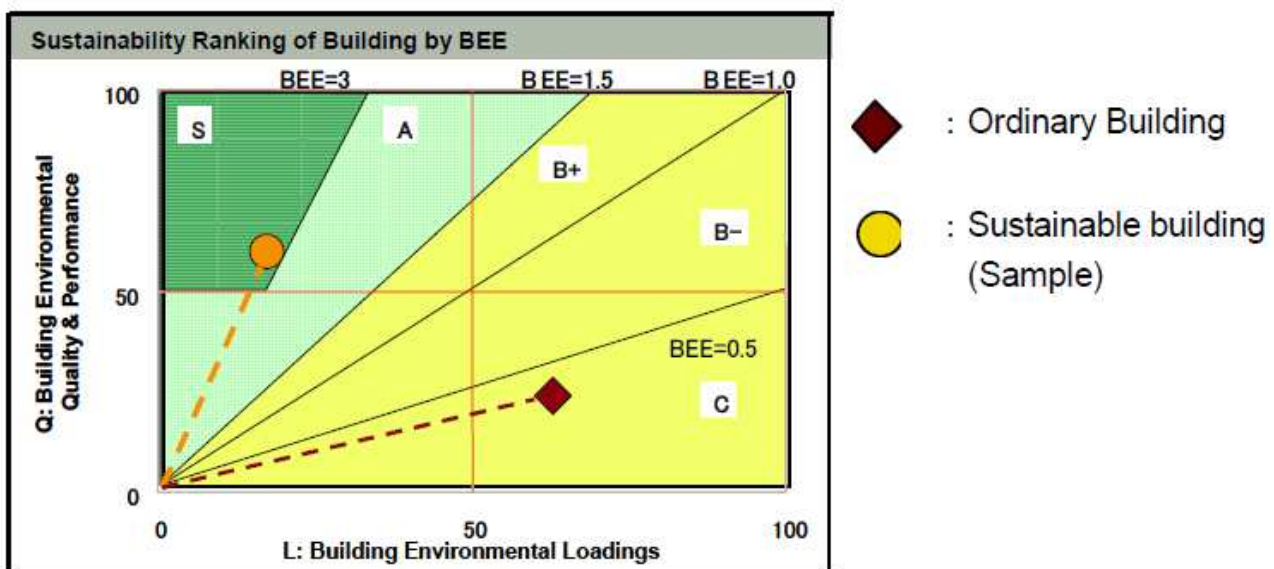


Figure 2. Environmental Labeling Based on Building Environmental Efficiency (BEE).

CASBEE has two (2) categories namely quality (Q), which is Built Environment Quality and Performance, and load (L) which is the Built Environment Load as well as twenty-two (22) criteria (10 for Q and 12 for L).

2.1.3. Comprehensive Environmental Performance Assessment Scheme (CEPAS) - Hong Kong

The Comprehensive Environmental Performance Assessment Scheme (CEPAS) was initiated in Hong Kong under the 2001 Government Policy Objectives to prepare green building labeling scheme. In 2007, the tool became publicly available for self-assessment and it is also used to assess the long-term sustainability of the building [12]. It aims to improve the environmental performance of buildings in Hong Kong. The CEPAS has eight (8) categories and

twenty (20) criteria. It also aims to keep in line with the global trend of building sustainability [12].

2.1.4. The Deutsche Gesellschaft Für Nachhaltiges Bauen (DGNB)

The DGNB certification system was initially developed for the new office and administration buildings, in Germany in 2008 [13]. It emphasizes an integrated view over the whole life-cycle buildings plus with a focus on the following main groups of criteria: ecology, economy, socio-cultural and functional topics, techniques, processes, and location.

The DGNB tool has five (5) categories and forty-four (44) criteria for the assessment of buildings for certification [13]. The objective is to identify solutions that are environmentally friendly, resource-efficient, and

economically optimized.

Depending on the degree of compliance and the weighted values that the evaluated buildings are awarded the rating points (scores) as Gold for $65 < X \leq 80\%$, Silver for $50 < X \leq 65\%$, Bronze for $35 < X \leq 50\%$ and $X = 35\%$ for Certified [14].

2.1.5. The Green Building Index (GBI)-Malaysia

Green Building Index (GBI) is an environmental rating system for buildings developed by PAM (Pertubuhan Arkitek Malaysia / Malaysian Institute of Architects) and ACEM (Association of Consulting Engineers Malaysia) and is officially launched in August 2008 [15]. The GBI initiative of Malaysia has pointed out that the index is derived from existing tools, including the Singapore Green Mark and Australian Green Star system. For evaluating the environmental design and performance of Malaysian buildings, six (6) main categories and seventeen (17) criteria have been identified [15]. The GBI initiative has developed a series of building rating classifications based on the assessment categories, criteria, and allocated points like Platinum for 86 to 100 points, Gold for 76 to 85 points, Silver for 66 to 75 points and Certified for 50 to 65 points [15].

2.1.6. The Green Mark - Singapore

Singapore's "Green Mark" scheme was launched in 2005 to encourage the construction of more environmentally friendly buildings [16]. The Green Mark provides a comprehensive framework for assessing the overall environmental performance of new and existing buildings. It aims to promote sustainable design, construction, and operations practices in buildings.

There are four different ratings of Green Mark certification. Five (5) categories and twenty-two (22) criteria have been identified. Green Mark Certified (GMC) for a score of 50 - 75, Green Mark Gold (GMG) for a score of 75 - 85, Green Mark Gold Plus (GMGP) for a score of 85 - 90, and Green Mark Platinum (GMPL) for a score of ≥ 90 .

2.1.7. Green Star-SA (South Africa)

Green Star SA tool was developed in 2013 to provide the property industry with an objective measurement for green buildings. It also works in collaboration with emerging green building councils throughout Africa and allows the adaptation of the Green Star SA tools for certification in the respective countries [10]. The Green Star SA used nine (9) categories and ninety-four (94) criteria. The Green Star-SA has certified ratings of buildings by labeling them as a star-like 4 Star Green Star SA Certified Rating. A 1-3 Star rating can also be achieved and awarded, recognizing that existing buildings are on a long journey to be green while occupied and in operation.

2.1.8. Haute Qualité Environnementale (HQE™)

The Haute Qualité Environnementale standard (HQE™) was developed in 1994 in France by the HQE™ Association

[17]. This assessment tool covers buildings throughout their life cycle, such as design, construction, operation, and renovation. It is addressed to non-residential, residential buildings and detached houses. The environmental performance requirements of the HQE™ are organized into four (4) categories and fourteen (14) criteria [16]. The global performance level reached by the buildings is calculated based on the total number of stars obtained in each issue. The assessment levels and the scoring scale (stars) are HQE™ Exceptional for a scoring scale of $X \geq 12$, HQE™ Excellent for a scoring scale of $9 \leq X \leq 11$, HQE™ Very Good for a scoring scale of $5 \leq X \leq 8$, HQE™ Good for a scoring scale of $1 \leq X \leq 4$ and HQE™ Pass for 0 scoring scale (star).

2.1.9. Leadership in Energy and Environmental Design (LEED)

The USGBC created the LEED in 1998 and has been accepted as the most widespread and recognized rating system in the United States. During the year 2018, LEED has issued over 78,000 certifications for about 150 countries.

It has eight (8) categories and sixty-seven (67) criteria for the assessment and certification of existing buildings. LEED (Leadership in Energy and Environmental Design) has identified four levels of certifications based on the evaluation criteria [18]. These are the Certified award for the buildings that score 40 - 49 points, Silver award for 50 - 59 points, Gold award for 60 - 79 points, and Platinum award for 80+ points.

2.1.10. Sustainable Building Tool (SBTool)

SBTool is an international assessment method, which has been under development since 1996 by the International Initiative for a Sustainable Built Environment (iSBE). The SBTool covers a wide range of sustainable building concepts, and not just green buildings; it reflects socio-economic issues as well [19, 20].

This tool has nine (9) categories and twenty-six (26) criteria by considering the triple bottom lines (dimensions) of sustainability. It is designed to consider environmental, social, and economic factors as well as regional conditions and cultural values too. In the SBTool, 0 is unsatisfactory; 0 is minimum acceptable performance; 5 is best practice; 1- 4 is intermediate performance levels, and 2 is normal default.

2.2. Sustainable Development Categories and Criteria

The fundamental purpose of SBATs is the investigation of the existing building environmental performance, including a list of categories and criteria being assessed and ranked as compared to the performance of the building concerning the triple bottom lines of sustainability.

Table 1 above shows that there are 10 SBATs, 69 categories, and 374 criteria and the researcher has identified the most commonly repeated and widely used categories as presented in Table 2 below.

Table 2. The most repeated categories from the 10 selected SBATs.

S/No.	Categories	Sustainable Building Assessment Tools				
		BREEAM-UK	CASBEE-Japan	CEPAS- HK	DGNB	GBI- Malaysia
1.	Management	√				
2.	Health and Well-being	√				
3.	Energy	√	√	√	√	√
4.	Water	√			√	√
5.	Material	√				
6.	Waste	√				
7.	Transport	√		√		
8.	Land use and Ecology	√			√	
9.	Innovation	√				√
10.	Indoor Environmental Quality	√	√	√	√	√
11.	Resource and Materials		√	√	√	√
12.	Off-site environment		√			
13.	Pollution	√		√		
14.	Quality service		√		√	
15.	Sustainable Site Planning and Management			√		√
16.	Comfort					
17.	Regional Priority					

Table 2. Continued.

S/No.	Categories	Sustainable Building Assessment Tools				
		Green Mark-Singapore	Green Star-SA	HQE™-France	LEED-USA	SBTool ^{PT} -Portugal
1.	Management		√			
2.	Health and Well-being			√		√
3.	Energy	√	√	√	√	√
4.	Water	√	√		√	√
5.	Material					
6.	Waste					√
7.	Transport		√		√	√
8.	Land use and Ecology		√			√
9.	Innovation		√		√	
10.	Indoor Environmental Quality	√	√		√	
11.	Resource and Materials				√	√
12.	Off-site environment					
13.	Pollution					
14.	Quality service					
15.	Sustainable Site Planning and Management	√		√	√	√
16.	Comfort				√	√
17.	Regional Priority				√	

Source: Extracted from the 69 categories of the 10 selected SBATs by the researcher, 2020.

As can be seen from Table 2 above, the highlighted categories are the least repeatedly used SBATs whereas the not highlighted categories are the most repeatedly used SBATs so that a total of nine (9) categories were identified/selected for further analysis.

Categories include "Energy" in BREEAM, "Occupant's Health and Comfort" in SBTool, and "Water" in GBI, Green Mark-Singapore, LEED, and SBTool. The category which is found in one SBAT might be seen in other SBATs with similar category names or with a slight change. The criterion like "Visual Comfort" in the BREEAM is also found in the

SBTool under the category of "Occupant's Health and Comfort". These direct similarities and a slight change of category names have many criteria with a similar name (duplication of names).

"Waste Management" has similar assessment criteria in different categories of different SBATs. This similarity shows that countries have used the criteria by adapting to their local context.

There are a total of nine (9) categories and 231 criteria, of which some of the criteria are repeatedly used in various categories as shown in Table 3 below.

Table 3. The identified categories and the criteria found under each category of the 10 selected SBATs.

S/No.	Name of categories	No. of criteria
1	Health and Well-being	16
2	Energy	53
3	Water	17
4	Location and Transport	19
5	Land use and Ecology	31
6	Innovation	4
7	Indoor Environmental Quality	44
8	Resources and Materials	26
9	Sustainable sites planning and Management	21
	Total No. of criteria	231

Source: Extracted from the selected categories by the researcher, 2020.

From these 231 criteria, some criteria were repeatedly used in different selected categories as mentioned in the above paragraphs. Using all these criteria for the assessment of buildings is very difficult to manage. Different countries have used the assessment categories and criteria for their SBATs based on their local context. Ethiopia needs new SBATs for the building construction sector. The following points are

taken into account to select suitable categories and criteria: merging of the repeated criteria, omitting some criteria which are not suitable for the Ethiopian context, and taking some criteria as it is which fits the Ethiopian context. The process was done by a consensus-based with the experienced experts who were involved in the building construction sectors as shown in Table 4 below.

Table 4. The sustainable building assessment criteria of the eight categories used by the selected 10 SBATs.

S/No.	Sustainable building assessment criteria	Sustainable Building Assessment Tools				
		BREEAM-UK	CASBEE-Japan	CEPAS- HK	DGNB	GBI- Malaysia
Economic Aspects						
1.	Affordability of the building concerning distance for transportation services	√		√	√	√
2.	Affordability of the building concerning distance for employment /workplace			√	√	
3.	Affordability of the building concerning distance for getting health services		√	√	√	
4.	Affordability of the building concerning distance for getting education services			√	√	
5.	Affordability of the building concerning distance for getting shops/markets					
6.	Affordability of the building concerning rental for residential purpose					
7.	Operation and maintenance cost			√		
8.	Life cycle cost	√	√	√	√	
9.	Investment risk	√				
10.	Construction cost	√			√	
Energy Efficiency						
1.	Use of energy monitoring /management system	√	√			√
2.	Energy for internal lighting	√	√			√
3.	Energy for external lighting	√	√			
4.	Use of energy-efficient equipment	√	√			
5.	Use of natural energy resources/ renewable energy	√	√		√	√
6.	Use of hot water/steam	√	√			
7.	HVAC systems	√	√		√	√
8.	Energy savings	√	√			
Water Efficiency						
1.	Water consumption	√	√			√
2.	Regular water leak detection and monitoring	√				√
3.	Use of rainwater harvesting	√	√			√
4.	Use of water-efficient fittings and equipment	√	√			√
5.	Regular water usage monitoring	√				
6.	Recycling wastewater	√	√			√
7.	Recharge of groundwater	√				
Location and Transportation						
1.	Availability of alternative modes of transportations					√
2.	Provision of the car parking area and parking capacity	√	√			
3.	Community/local connectivity	√	√			
4.	Density development location	√	√			
5.	Sensitive land protection					

S/No.	Sustainable building assessment criteria	Sustainable Building Assessment Tools				
		BREEAM-UK	CASBEE-Japan	CEPAS- HK	DGNB	GBI- Malaysia
6.	Surrounding density and diverse uses				√	
7.	Accessibility to public transportation	√	√			
Sustainable Sites and Ecology						
1.	Site selection and protection	√	√	√	√	√
2.	Reuse of land	√	√			
3.	Ecological/land value	√	√		√	
4.	Reclaimed contaminated land	√	√			
5.	Enhance site ecology	√	√			
6.	Use of local /indigenous plants/flora			√		
7.	Protect or restore open space	√				
8.	Existence of open space, green area, playground area, and public space	√	√			
1.	Noise level	√	√		√	√
2.	Sound insulation	√	√		√	√
3.	Sound absorption	√	√		√	√
4.	Thermal comfort for cooling control and comfort	√	√		√	√
5.	Thermal comfort for heating control and comfort	√	√		√	√
6.	Thermal comfort for humidity control and comfort	√	√		√	√
7.	Lighting & illumination for lighting controllability	√	√	√		√
8.	Lighting & illumination for view out	√	√			√
9.	Lighting & illumination for glare measure and control	√	√	√		√
10.	Indoor air quality	√	√	√	√	√
11.	Visual comfort	√	√	√	√	√
12.	Existence of natural ventilation	√	√			
13.	Availability of ventilation system	√	√		√	
14.	Air purification- supply of fresh air	√	√			
1.	Use of Materials of low environmental impact	√	√			
2.	Use of non-renewable-virgin materials	√	√	√		
3.	Reuse of structural frame materials	√	√	√		√
4.	Use of locally available materials	√	√			
5.	Use of materials with recycled content	√	√	√		√
6.	Use of finishing materials	√		√	√	√
7.	Material efficiency over its life cycle (LCA)	√	√		√	√
1.	Facility management	√				√
2.	Commissioning	√	√		√	√
3.	Consultation	√				
4.	Construction process planning and management	√	√	√	√	√
5.	Waste management during construction and operation	√	√		√	
6.	Security	√		√		√

Table 4. Continued.

S/No.	Sustainable building assessment criteria	Sustainable Building Assessment Tools				
		Green Mark-Singapore	Green Star-SA	HQE TM - France	LEED- USA	SBTool ^{PT} - Portugal
1.	Affordability of the building concerning distance for transportation services	√	√		√	√
2.	Affordability of the building concerning distance for employment /workplace				√	√
3.	Affordability of the building concerning distance for getting health services					√
4.	Affordability of the building concerning distance for getting education services					√
5.	Affordability of the building concerning distance for getting shops/markets					√
6.	Affordability of the building concerning rental for residential purpose					√
7.	Operation and maintenance cost				√	√
8.	Life cycle cost		√			√
9.	Investment risk					√
10.	Construction cost					√
1.	Use of energy monitoring /management system		√	√	√	√
2.	Energy for internal lighting	√			√	√
3.	Energy for external lighting	√			√	√
4.	Use of energy-efficient equipment	√	√			

S/No.	Sustainable building assessment criteria	Sustainable Building Assessment Tools				
		Green Mark-Singapore	Green Star-SA	HQE™-France	LEED-USA	SBTool ^{PT} -Portugal
5.	Use of natural energy resources/ renewable energy	√			√	√
6.	Use of hot water/steam		√		√	√
7.	HVAC systems	√			√	√
8.	Energy savings			√	√	√
1.	Water consumption		√		√	√
2.	Regular water leak detection and monitoring				√	
3.	Use of rainwater harvesting				√	√
4.	Use of water-efficient fittings and equipment	√	√		√	√
5.	Regular water usage monitoring	√	√	√		
6.	Recycling wastewater				√	√
7.	Recharge of groundwater				√	√
1.	Availability of alternative modes of transportations	√			√	√
2.	Provision of the car parking area and parking capacity		√		√	√
3.	Community/local connectivity				√	√
4.	Density development location				√	
5.	Sensitive land protection				√	
6.	Surrounding density and diverse uses				√	
7.	Accessibility to public transportation				√	
1.	Site selection and protection	√	√	√	√	√
2.	Reuse of land		√		√	√
3.	Ecological/land value		√		√	√
4.	Reclaimed contaminated land		√		√	√
5.	Enhance site ecology		√		√	√
6.	Use of local /indigenous plants/flora				√	√
7.	Protect or restore open space				√	√
8.	Existence of open space, green area, playground area, and public space			√	√	√
1.	Noise level		√	√	√	√
2.	Sound insulation		√	√	√	√
3.	Sound absorption		√	√	√	√
4.	Thermal comfort for cooling control and comfort	√	√	√	√	√
5.	Thermal comfort for heating control and comfort	√	√	√	√	√
6.	Thermal comfort for humidity control and comfort	√	√	√	√	√
7.	Lighting & illumination for lighting controllability	√	√		√	√
8.	Lighting & illumination for view out	√	√		√	√
9.	Lighting & illumination for glare measure and control	√			√	√
10.	Indoor air quality	√	√	√	√	√
11.	Visual comfort	√	√	√	√	√
12.	Existence of natural ventilation	√	√		√	√
13.	Availability of ventilation system	√	√		√	√
14.	Air purification- supply of fresh air	√	√	√	√	√
1.	Use of Materials of low environmental impact		√		√	√
2.	Use of non-renewable-virgin materials	√	√		√	√
3.	Reuse of structural frame materials	√	√		√	√
4.	Use of locally available materials		√		√	√
5.	Use of materials with recycled content	√	√	√	√	√
6.	Use of finishing materials		√			√
7.	Material efficiency over its life cycle (LCA)		√	√	√	√
1.	Facility management		√	√	√	
2.	Commissioning		√		√	√
3.	Consultation					
4.	Construction process planning and management		√			√
5.	Waste management during construction and operation	√			√	√
6.	Security					

Source: developed by the researcher, 2021.

2.3. Proposed Categories and Criteria for the New Schemes

Table 4 discussed the most appropriate eight (8) categories

and sixty-seven (67) criteria independently which were developed by a consensus-based with the experienced experts who were involved in the building construction sectors through the brainstorming and carry out deliberative measures, based

on the discussion of ideas, to generate lists of applicable categories and criteria for the Ethiopian built environment. The new proposed categories and criteria are the result of this intensive discussion and covers the following eight (8)

categories: Economic Aspects, Energy Efficiency, Water Efficiency, Location and Transportation, Sustainable Sites & Ecology, IEQ, Materials & Resources, and Management as demonstrated in figure 3 below.

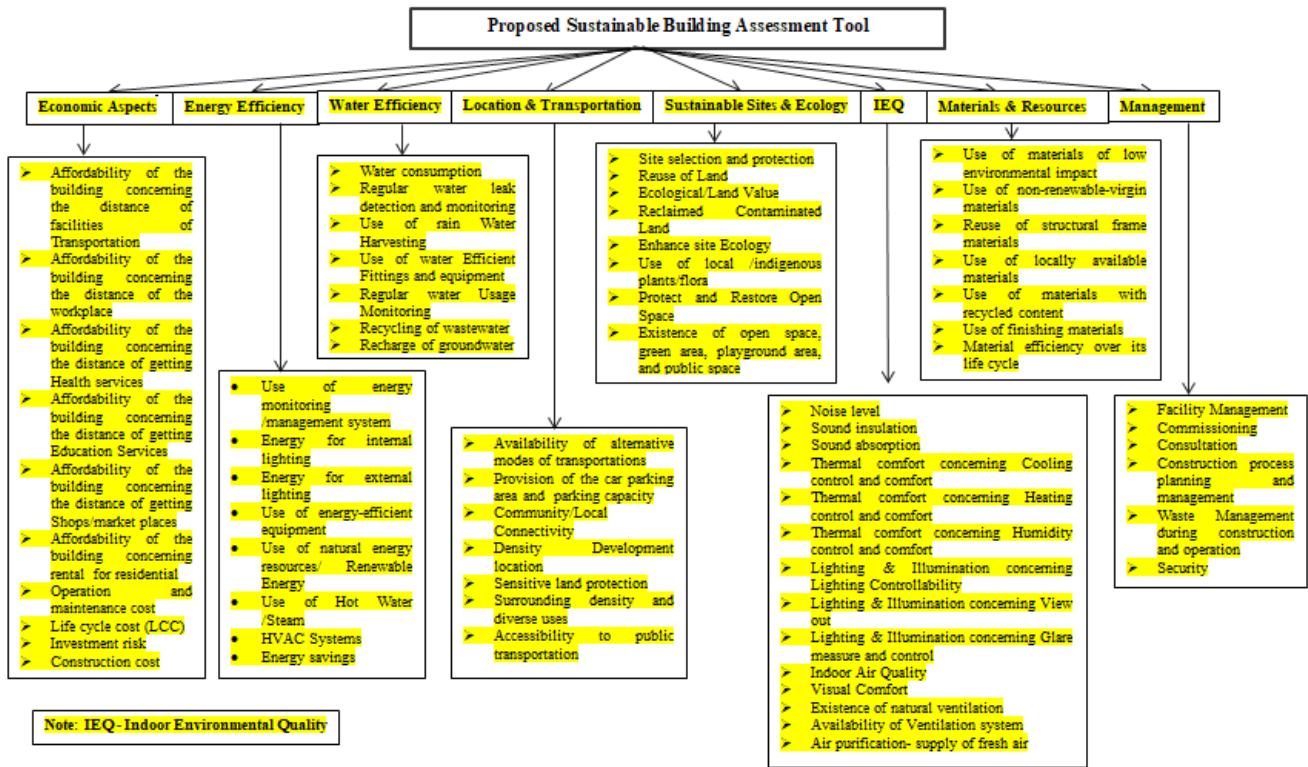


Figure 3. Proposed categories and criteria for the development of sustainable building assessment tools for the Ethiopian contextSource: Researcher; (2021).

2.4. Approaches for the Development of the New Proposed Sustainable Building Assessment Tool

There are various types of environments like physical, biological, and socio-economic and the sustainability of these environments play significant roles in the realization of sustainable development. For this, applying the environmental assessments by using different assessment tools is indispensable as there are several assessment tools available.

However; as clearly stated by the researchers [3, 4], there is a lack of a clear path towards establishing an applicable environmental assessment method that reflects and prioritizes certain environmental, social and economic issues. Hence; using the Four Quadrant Model and helical approaches illustrates the development steps which lead to the development of an SBAT suitable for Ethiopia as shown in figure 4 below.

This Four Quadrant Model approach is organized into four quadrants that all development steps are subject to evaluating points to achieve vigorous development. These four quadrants are:

Quadrant 1: Identification and selection of the 10 SBATs and categories and criteria.

Quadrant 2: Evaluate and customize the categories and criteria.

Quadrant 3: Corroborate the development process.

Quadrant 4: Plan the next step.

For the development of a new SBAT, five steps are carried out. These steps are labeled below:

Consolidate and use the proposed categories and criteria: The review aims to identify, consolidate and use the most prominent, reliable, and widely used ten (10) SBATs by a set of criteria. This is the starting point for the development of the new SBAT [5, 6].

Consideration of local variation to the Ethiopian context: this is a significant step because each region has its unique characteristics. So that this variation matters to develop a new SBAT for each region [5, 6].

Conduct panel of experienced experts' discussion: It is crucial to select and acquire expert opinions from a range of different fields on a common platform, such as government, academia, and industry (contractors and consultants) [5, 6].

Application of AHP: AHP will play a fundamental role to establish a potential weighting system that is capable of reflecting local needs as accurately as possible, plus being able to prioritize building environmental aspects, legal framework, plus socioeconomic concerns. To establish a valid weighting system, the following processes were taken into account: hierarchy constructions, pairwise comparisons, derive relative weights (Normalization), and checking of Consistency Ratio (CR) and Consistency Index (CI).

Development of new SBAT: The creation of new SBAT must be accompanied by an intensive testing process to make sure that they are most reliable and appropriate. The

outcomes of this process must be compared against the most well-known SBATs to allow for rational justification of their resemblances and dissimilarities.

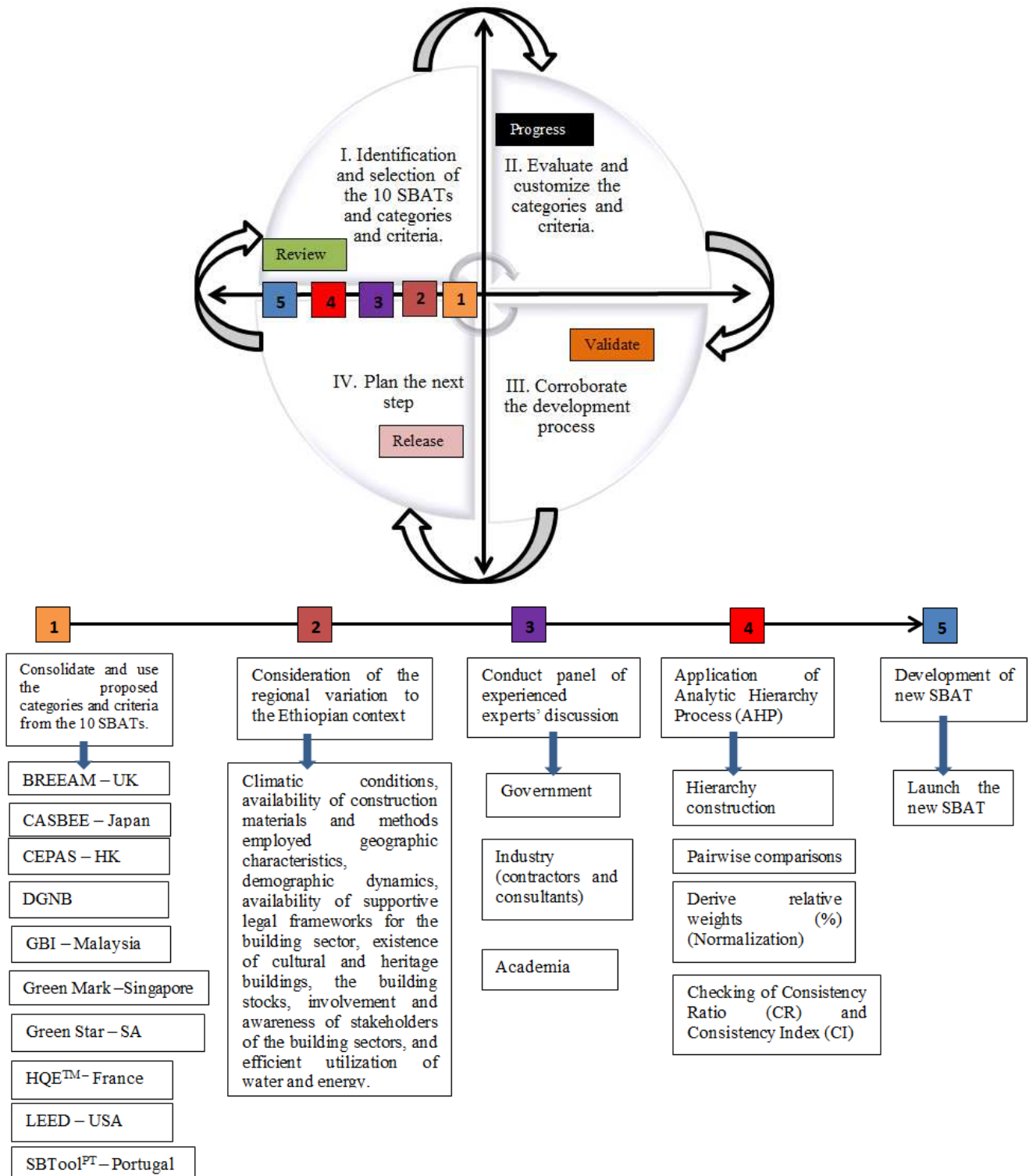


Figure 4. Four Quadrant model and Helical flow of relating phases for developing SBAT for Ethiopia.

3. Discussion

Grounded theory is a set of systematic inductive methods

for conducting qualitative research aimed toward theory development [21]. This study paper addresses an objective and scientific subject which is best addressed in close consultation with experienced professionals of various

disciplines (Architects, Engineers, Urban Planners/Designers, Construction Managers for reaching consensus on key SBATs categories and criteria of the selected ten (10) SBATs.

Sustainable building assessment categories as well as criteria are multidimensional and have to be properly identified, assessed, and evaluated concerning the triple bottom lines of sustainability to assign an appropriate weight so that an SBAT can be prepared for a given region/country. It is important to deliver SBAT categories and criteria which are consensus-based by experienced experts. The weighting systems for these categories were determined by employing the AHP technique. By exploring the most trustworthy and prominent tools, an intensive discussion on several issues concerning the philosophy of building assessment and evaluation will be performed.

Weighting system: SBATs are depending upon many factors including climatic conditions, availability of resources plus methods employed demographic dynamics, and legal aspects of the sector. It is very difficult to use a single SBAT for every local and regional variation in these factors. The existing SBATs have various methods for assessing the categories and criteria, for instance, BREEAM and SBTool employ a weighted system that prioritizes environmental issues, while LEED uses a simple additive approach (1 for 1) which makes the process very simple and easy to carry out [5, 6]. CEPAS uses a weighting system for each category that engages the specific values and needs.

CASBEE evaluates the environmental efficacy of buildings by considering the weighting coefficients which can be modified as per the local circumstances of the regions [11, 17] while CEPAS uses a weighting system for each category which engages the specific values and needs. Green Star SA certification is awarded for 4-Star, 5-Star, and 6-Star as well as 1-3 Star Green Star SA ratings by considering the weighted score of each assessment category and criteria [17]. The DGNB evaluation technique has a fixed relative importance scoring and rating system [1].

The HQETM also used the scoring scale to appraise buildings' performance by calculating the total number of stars obtained in each assessment criteria [16]. Nevertheless, assessing without weighing almost inevitably leads to criticism, due to the limitation of scientific evidence and environmental priorities.

Establishing a framework for regional and local priorities is of vital importance [5, 6].

Sustainable building assessment categories and criteria: Each SBAT comprises a list of categories and criteria considering key assessment elements like water, materials, energy, sustainable site, ecology, etc. BREEAM-UK, CASBEE – Japan, and CEPAS – Hong Kong encompasses 24 categories and 91 criteria; DGNB, Green Mark–Singapore, and GBI – Malaysia includes 16 categories and 82 criteria whereas Green Star–South Africa, HQETM – France, LEED – USA and SBTool^{PT} – Portugal consists of 29 categories and 201 criteria. From these SBATs, 69 categories and 374 criteria were identified.

Economic Aspects: Under this category, the Life cycle cost of buildings and construction cost was considered as an assessment criterion by BREEAM – UK, DGNB, and SBTool^{PT} – Portugal. The other criteria affordability of the building concerning distance for transportation services was most commonly utilized criteria by BREEAM – UK, CEPAS – Hong Kong, DGNB, GBI – Malaysia, Green Mark – Singapore, Green Star – South Africa, LEED – USA, and SBTool^{PT} – Portugal.

Energy - Efficiency: In this category, Energy monitoring /management system criteria were utilized as an assessment tool by BREEAM – UK, CASBEE – Japan, GBI – Malaysia, Green Mark – Singapore, Green Star – South Africa, HQETM – France, LEED – USA and SBTool^{PT} – Portugal. Criteria like utilization of renewable energy were also used by BREEAM – UK, CASBEE – Japan, DGNB, GBI – Malaysia, Green Mark – Singapore, LEED – USA, and SBTool^{PT} – Portugal. Sustainable buildings can save for 36% of total energy use and 65% of electricity consumption [20]. A survey of 99 sustainable buildings in the US indicated that an average of 30% less energy was consumed by sustainable/green buildings [20].

SBATs contribute their parts for the accomplishment of development by considering buildings' performance. It is very important to encounter issues like financial return, plus willingness because it has the potential to make the SBAT more fruitful.

4. Conclusion

This study has explored ten (10) most widely and commonly used SBATs. Each assessment tools have their weighting techniques for the categories and criteria. The same category is considered in various SBATs for instance, Energy Efficiency and Indoor Environmental Quality are considered in BREEAM – UK, CASBEE – Japan, CEPAS – Hong Kong, GBI – Malaysia, Green Mark – Singapore, Green Star – South Africa, and LEED – USA. In addition to this, the Materials and Resource category is considered in CASBEE – Japan, CEPAS – Hong Kong, GBI – Malaysia, LEED – USA, and SBTool^{PT} – Portugal. Each category is comprised of different evaluation criteria to diagnose buildings' performance aiming to attain sustainable/green practices for instance sustainable design, renewable energy, reusing and recycling of resources, plus rainwater harvesting systems.

The study has identified eight (8) categories and sixty-seven (67) criteria, for the assessment of sustainable buildings, which were most appropriate for the Ethiopian context and developed by a consensus-based with the experienced experts who were involved in the building construction sectors through the brainstorming and carry out deliberative measures, based on the discussion of ideas, to generate lists of applicable categories and criteria for the Ethiopian built environment. The eight (8) categories were economic aspects, energy efficiency, water efficiency, location and transportation, sustainable sites and ecology,

indoor environmental quality, resources and materials, and management. Each selected sustainable building assessment categories were composed of different assessment criteria for instance, economic aspects consists of ten (10) criteria, energy efficiency eight (8) criteria, location and transportation seven (7) criteria, sustainable sites and ecology eight (8) criteria, indoor environmental quality fourteen (14) criteria, and so on. For further development of the sustainable building assessment tools (SBATs) to Ethiopian context, these categories and criteria are playing the most substantial roles.

5. Future Work

The AHP technique will be utilized by following the steps like Hierarchy Construction, Pairwise Comparisons, Derive Relative Weights (%) (Normalization) and Checking of Consistency Ratio (CR) and Consistency Index (CI). This paper is a leading phase to develop a new SBAT for Ethiopia. The next phase will be to conduct a study depending upon consensus—a base process by experienced experts. Close consultation with ninety-three (93) experienced experts from government, industry (contractors and consultants), and academy from the various professionals like Architects, Engineers, Urban Planners / Designers, and Construction Managers will also be involved. This aims to detect the relevant and applicable categories and criteria, plus enable develop a weighting system that properly reflects the regional variations of the Ethiopian context.

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