Developing Sustainable Building Assessment Tool (SBAT) for Ethiopia: The Case of Addis Ababa

Doctoral Dissertation in Urban and Regional Planning

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ABSTRACT

Developing Sustainable Building Assessment Tool (SBAT) for Ethiopia: The Case of Addis Ababa.

Mekonnen Abebe

Addis Ababa University, 2023

Currently different types of buildings are constructed in Ethiopian Cities especially in Addis Ababa but these buildings were not critically assessed and evaluated from the sustainability points of view because no Sustainable Building Assessment Tool developed so far and no institution is responsible to evaluate and certify the buildings. The research methodology is employed mixed approach types, a purposive sampling for the respondents, and both primary and secondary sources of data. Data was collected through field observation, interviews, survey questionnaires, and document analysis. These data were analyzed by using Statistical Packages for Social Science, MS-Excel, Reliability Analysis and Analytic Hierarchy Process. The findings are based on qualitative and quantitative examination of a rating and assessment systems for sustainable/ green buildings used in both developed and developing nations tailored to the local context. A sustainable building assessment categories and criteria were framed depending upon a consensus-based approach with 100 experienced experts working in the construction sector. The study's findings revealed that there are 68 criteria for the development of a sustainable building assessment for Ethiopia (Ethio-SBAT) under eight assessment categories with relative priority values are materials and resources (18.66%), sustainable sites and ecology (16.92%), energy efficiency (16.78%), indoor environmental quality (12.60%), economic aspects (10.41%), management (10.30%), water efficiency (8.06%), and location and transportation (6.27%) were also identified. Therefore it is crucial to put the developed Ethio-SBAT into practice because it will provide, for instance, good indoor environmental quality for users.

Keywords: Sustainability, Rating systems, Green/Sustainable Buildings, Assessment Tool, Relative Priority Values

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Throughout this extensive academic path, swimming helped me learn a lot and improve my prior experience. In addition, the opportunities I have had have allowed me to build social connections and network with new students who have a range of real-world professional experiences. In order to comprehend the latest emerging knowledge in the field of urban and regional planning, the practical scenario of daily living is combined with modern science and technology. I am therefore thankful to Addis Ababa Science and Technology University (AASTU), my University, for providing me with such a platform.

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Mekonnen Abebe Anshebo

Addis Ababa, 2023

ABBREVIATIONS/ACRONYMS

AACACB	Addis Ababa City Administration Construction Bureau
AACAHDC	Addis Ababa City Administration Housing Development Corporation
AACASHDE	Addis Ababa City Administration Saving Housing Development Enterprise
ACEM	Association of Consulting Engineers Malaysia
AHP	Analytical Hierarchy Process
BCA	Building Construction Agency
BEE	Built Environment Efficiency
BREEAM	Building Research Establishment Environmental Assessment Methodology
BRS	Building Rating System
CA	Commissioning Authority
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
CBE	Commercial Bank of Ethiopia
CBOs	Community based organizations
CFC	Chlorofluorocarbon
CFLs	Compact Fluorescent Lamps
CI	Consistency Index
CO_2	Carbon dioxide
CR	Consistency Ratio
CSA	Central Statistical Authority
CWRA	Construction Works and Regulatory Authority
DGNB	Deutsche Gesellschaft für Nachhaltiges Bauen
EA	Energy and Atmosphere
EAs	Economic Aspects
EBCSs	Ethiopian Building Codes and Standards
ECA	Ethiopian Construction Authority
ECC	Earth Craft Communities

ECE	Early Childhood care and Education
EE	Energy Efficiency
EGGBC	Egyptian Green Building Council
EPA	Environmental Protection Authority
EPE	Environmental Policy of Ethiopia
ES	Ecology and Sustainable Sites
ETS	Environmental Tobacco Smoke
Ethio-SBAT	Ethiopian Sustainable Building Assessment Tools
FDRE	Federal Democratic Republic of Ethiopia
FMoTBUAs	Federal Ministry of Transport, Building and Urban Affairs
GBC	Green Building Challenge
GBCA	Green Building Council of Australia
GBCSA	Green Building Council of South Africa
GBCSL	Green Building Council of Sri Lanka
GBG	Gullele Botanic Garden
GBI	The Green Building Index
GBPs	Green Building Practices
GMC	Green Mark Certified
GMG	Green Mark Gold
GMGP	Green Mark Gold Plus
GMPL	Green Mark Platinum
GoE	Government of Ethiopia
GPRS	Green Pyramid Rating System
GPS	Global Positioning System
GRIHA	Green Rating for Integrated Habitat Assessment
GSs	Green Spaces
GWP	Global Warming Potential
HoA-REC and N	Horn of Africa- Regional Environment Centre and Network
HoA-REC and N-AAU	Horn of Africa Regional Environment Centre and Network-Addis Ababa University
HQE	Haute Qualité Environnementale

HVAC	Heating, Ventilation, Air-Conditioning
ID	Innovation in Design
IEQ	Indoor Environmental Quality
IHDPs	Integrated Housing Development Programs
iiSBE	International Initiative for a Sustainable Built Environment
ISO	International for Standard Organization
ITU	International Telecommunication Union
IUCN	International Union for Conservation of Nature
kWh	Kilo Watt Hour
LCA	Life Cycle Assessment
LEDs	Light Emitting Diodes
LEED	Leadership in Energy and Environmental Design
LGBC	Lebanon Green Building Council
LRT	Light Rail Transport
LT	Location & Transportation
MCDM	Multi-Criteria Decision Making
MoUI	Ministry of Urban and Infrastructure
MoUDC	Ministry of Urban Development and Construction
MoUDHC	Ministry of Urban Development, Housing and Construction
MoWUD	Ministry of Works and Urban Development
MRs	Materials and Resources
MSEs	Micro and Small Enterprises
NC	New Construction
NEA	National Environment Agency
NGOs	Non-governmental organizations
ODP	Ozone Depleting Potential
OECD	Organization for Economic Co-operation and Development
PAM	Pertubuhan Arkitek Malaysia / Malaysian Institute of Architects
PSDPRP	Plan for Sustainable Development and Poverty Reduction Program
QSAS	Qatar Sustainable Assessment System
RM	Resources and Materials

RP	Regional Priority
SA	South Africa
SBATs	Sustainable Building Assessment Tools
SBTool	Sustainable Building Tool
$SBTool^{PT}$	Sustainable Building Tool for Portugal
SDGs	Sustainable Development Goals
SEAM	Sustainable Environmental Assessment Method
SMEs	Small and Micro Enterprises
SPSS	Statistical Package for Social Sciences
SSs	Sustainable Sites
SSPM	Sustainable Site Planning and Management
TERI	The Energy Resource Institute
UN	United Nations
US	United States
USDHUD	United States Department for Housing and Urban Development
USEPA	United States Environmental Protection Authority
USGBC	United States Green Building Council
VOCs	Volatile Organic Compounds
WE	Water Efficiency
WGBC	World Green Building Council

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CHAPTER ONE

1. Introduction

The green/sustainable building aims to minimize the effects of the construction sector on the natural habitat as well as on individuals as stated by He et al. (2018). A few of the major problems that result from not implementing green buildings include not using renewable or recyclable materials (thus increasing the buildings' pollution problems and producing waste and emissions), not maintaining the indoor environmental quality of the buildings (thus increasing the cost of energy and water consumption and making the buildings uncomfortable for users or customers), not using energy-efficient equipment, and reducing the quality (visual and thermal) of the buildings. It addresses environmental and health problems as well as minimizes the effects of the construction sector on the natural habitat and individuals. Green buildings are also more energy-efficient so that the adverse effect of building on the environment and inhabitants is reduced.

The built environment, including building, operating, and management normally require enormous amounts of energy, water, and raw materials, generating large quantities of waste and causing air and water pollution. The only solution is to develop greener and more resource-efficient construction, renewal, operations, and maintenance strategies as noted by Mouhamed, (2016). Therefore, green building is a reaction in addressing environmental and health problems that arise from building construction and maintenance.

Currently different types of buildings are constructed in Ethiopian Cities especially in Addis Ababa but these buildings were not critically assessed and evaluated from sustainability points of view because no Sustainable Building Assessment Tool developed so far and no institution is responsible to evaluate and certify the buildings (both new and existing). Therefore; it is crucial to put the developed Ethio-SBAT into practice because it will provide, for instance, good indoor environmental quality for users.

1.1. Background of the study

One of the main development barriers in developing countries is the construction industry. This is mostly due to the fact that developing nations (although varied degrees amongst nations) heavily rely on the expansion & development of their physical infrastructure, such as buildings, roads. The argument drawn by Rees (2015) and Lorenz et al. (2018) is that the worldwide depletion of natural resources is greatly influenced by the construction sector. The studies also made it clear that industrialized nations have been slow to adopt the idea of sustainability in the construction industry. However, the introduction of ideas and phrases like "green building," "sustainable building," "high-performance building," and "sustainable construction" has helped to achieve this.

The concept of sustainable/green building is derived from the term "Arcology" which stands for a combination of architecture and ecology Doğan, (2019); He, (2018) and Zhao, (2015) which aims to minimize the effects of the construction sector on the natural environment as well as on individuals. Studies showed that green buildings can reduce 30% greenhouse gas emissions, 65% of electricity used, and 36% of overall energy use Behnam (2017). The application of the idea of green building in the building construction sector is indispensable as it prioritizes environmentally responsible and efficient resource allocation. According to a study by Elizabeth (2018) and Tan (2010), green buildings offer a substantial number of advantages and financial advantages over conventional/standard buildings. Additionally, Elizabeth (2018) pointed out that studies by Zhao (2015) and Yudelson (2008) revealed that thermal comfort, environmental friendliness, financial benefits, quality of internal environment, low maintenance costs, and use of fewer natural resources were the main advantages of green buildings.

The other advantages of green buildings include: improving indoor air quality, which will improve building occupants' health; spurring the development of more energy-efficient products and services; increasing building occupants' comfort, satisfaction, and well-being; and reducing environmental and emissions costs; enjoying the support of climate change protocols, enhance individual quality of life, conserve natural resources to protect the environment, reduce annual water cost savings, increase occupant safety and security, lead to lower operational and support costs. In addition, waste disposal costs in green buildings are lower, make risk management manageable (economic, financial, market, etc.), and significantly lower the cost of maintenance in green buildings.

The advantages of the green building mentioned in the above paragraph are because of the existence of Sustainable Building Assessment Tools (SBATs) in use in both developed and developing nations. Some of these tools include BREEAM (Building Research Establishment Environmental Assessment Method), CASBEE (Comprehensive Assessment System for Building Environmental Efficiency), LEED (Leadership in Energy and Environmental Design), and SBTool (Sustainable Building Tool). As illustrated in the following paragraphs, countries like Egypt, India, Lebanon, China, and Sri Lanka either adopted (accepted the SBAT as it is) or adapted (modified the SBAT to their context) these SBATs for their unique local contexts.

The Green Pyramid Rating System (GPRS) was developed by the Egyptian Green Building Council (EGGBC) in its initial iteration and modified in 2017 based on the third LEED edition Ammar 2012 and Ismaeel et al. 2018. The GPRS's replication of LEED without local context adaption is one of its biggest flaws; whereby certain criteria were picked without taking into consideration local capabilities, while others were not applied while appearing to offer workable answers for addressing Egypt's current needs and concerns Attia (2017).

Under the Ministry of New and Renewable Energy, The Energy Resource Institute (TERI) in New Delhi created the official green building rating scheme called Green Rating for Integrated Habitat Assessment (GRIHA), and it uses a 5-star rating system that is solely based on how well a building protects the environment. The pros of the GRIHA are: reduced energy consumption while maintaining comfort levels; reduced destruction of natural areas, habitats, and biodiversity, as well as reduced soil loss due to erosion; air and water pollution reduction; water consumption has been reduced; reduced waste generation as a result of recycling and reuse; pollution loads have been reduced; enhanced user productivity; and image and marketability enhancements. On the hand it has cons like it is highly centralized.

The Lebanon Green Building Council (LGBC) created the ARZ Building Rating System (BRS) to assess the degree to which existing commercial buildings in Lebanon are safe, comfortable locations for people to work and conduct business, consuming the proper amount of energy and water, while having a low impact on the environment.

The Green Building Council of Sri Lanka (GBCSL) was established as a non-profit organization in November 2009 to promote the use of green building techniques in Sri Lanka's construction industry.

China is rapidly urbanizing and developing economically. China has a relatively short life expectancy for buildings, roughly 30 years, compared to around 80 years in Europe and 44 years in the USA Hu et al. (2009). To encourage green buildings in China, the authors Gobas (2003); Mohurd (2006); MEP (2007) have recently issued several Chinese standards for green building/energy efficient building assessment or design codes. Therefore, it is crucial to start sustainable building initiatives to mitigate any potential effects from the building sector.

In Ethiopia, especially in Addis Ababa, buildings are constructed but not critically assessed and evaluated from a sustainability point of view as compared to that of the mentioned countries above and use of the SBATs because there is limited study conducted so far. As there are no SBATs, 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.

Thus this study tries to assess the absence of SBAT to evaluate and certify the buildings from sustainable/green building perspectives by developing a sustainable building assessment tool (SBAT) for Ethiopia, specifically for Addis Ababa.

1.2. The Research Motivations

The inspiration for this research is largely due to the existing scenarios in the building construction sector of Ethiopia. These buildings are of different types and constructed by governments, cooperatives, real estate developers and private sectors as well as individuals. Most of these buildings need sustainability aspects like environmental, economic, and social because it is assumed that these buildings will be stayed for an average of 50 years. As it is clearly known in a construction of any type of buildings, there is always disturbance of natural environments/ecosystems and results in environmental problems. This implies that the attention given to natural environment/ecosystem is too minimal and in turn it shows environmentally-friendly building construction is not the major concern in most developing countries including Ethiopia.

Since sustainable buildings optimize one or all of the following objectives during all phases of the life cycle like using resources more efficiently (e.g. energy, water), enhancing and protecting the health and well-being of the occupants, and reducing negative impacts (e.g. waste, sewage, pollution); studying the various types of sustainable building assessment tools (SBATs) employed in different nations based on their local contexts is highly trigger me in order to address the importance of having SBATs for Ethiopia by using various assessment categories and criteria.

Furthermore; the sustainability aspects of the whole building construction management processes are also main challenges to be addressed in order to attain the established sustainability and affordability criteria which are suitable for our scenario. Because of these and other related building construction problems, I took an initiative for developing sustainable building assessment tool (SBAT) for Ethiopia: The case of Addis Ababa.

1.3. Statement of the problem

The definition of the research question or the problem statement serves as the foundation for any research Wubishet (2004). Nonetheless, attempting to narrow the scope of the investigation was the most challenging task at hand. Potential research questions may come to us frequently, but it might be difficult to formulate them in a way that is meaningful as stated by Wubishet, (2004).

Any study's formulation of a research problem is reliant on a specific matters listed below: comprehension of the issues being looked at, determining the scope of the study's focus, expertise in the field, and research methodology experience Kumar (1999); Robert (2000); Yin (1994 & 2003); and Wubishet (2004).

Experience, theory, and relevant literatures are three places where research issues might be found, according to Burns (2000). Similar to that, this study's research problem heavily relies on my prior practical expertise. But, the theory and associated literature that I read through time and while completing the course work for my research dissertation revealed the existence of connected issues and provided additional insight for this investigation.

Regarding the building construction sector in the built environment, I observed that there are numerous difficulties in terms of urbanization, efficient utilization of energy, climate changes like increasing in temperature, demographic shifts, etc. In addition to this, not using renewable or recyclable materials, increasing the buildings' pollution problems, producing waste and emissions, increasing the cost of energy and water consumption, making the buildings uncomfortable for users or customers, and not using energy-efficient equipment, are just a few of the major problems that result from not implementing sustainable/green buildings. On the other side, the construction and operation of buildings all include the use of energy, materials, water, and land. In turn, these built environments become part of our living environment and have an impact on our quality of life, social cohesion, and public health.

To design sustainable/green and healthy buildings, it is crucial to investigate environmentally friendly, socially acceptable, and economically sound designs and development techniques. This promotes innovation in building systems and designs, which ultimately leads to the creation of sustainable/green buildings.

Along with creating SBATs, the authors Ayyoob and Akito (2013) reviewed critically seven chosen neighborhood SBATs from Australia, Europe, Japan, and the United States of America, including LEED-ND, EarthCraft Communities (ECC), BREEAM Communities, CASBEE-UD, HQE2R, Ecocity, and SCR. In Australia, the authors also looked at the comparison of sustainable community rating tools Bo et al. (2015). All these suggested that countries have developed their building assessment tools according to their context.

The necessity of these tools in the building construction sector is important to have sustainable/green buildings and achieve sustainable development that was determined by the usage of all the above mentioned SBATs and other SBATs like BREEAM-UK, CASBEE-Japan, LEED-USA, SBTool-Portugal, Green Star-SA, GBI-Malaysia, and HQE-France to mention few.

Even though there were numerous SBATs accessible around the globe, Ethiopia has no such type tool suitable to its local context so far. Some of the issues/gaps in Ethiopia's building construction industry are listed below:

a) Buildings of several types and functions have been built, but their sustainability has not been carefully assessed and evaluated.
b) Even though there are legal frameworks for the construction of buildings, including the Ethiopian Building Codes and Standards (EBCSs) and the Building Proclamation (Proclamation No. 624/2009); Buildings Regulation (Regulation No. 243/2011); Building Directives (Directive No. 5/2003); and Construction Industry Policy (Policy No. 2006), their implementation has been difficult as there are no SBATs and evaluation criteria.
c) Because no sustainable building evaluation tool has been created specifically for the Ethiopian context, no organization is in charge of evaluating and certifying buildings, for both new and existing, from a sustainability point of view.
d) Although no studies of this type have been done yet, the number of buildings being built in urban areas is rising.

To have sustainable/green buildings, which are essential for attaining sustainable development in terms of the social, economic, and environmental realms, these gaps must be filled by formulating assessment categories and criteria for sustainability of buildings and develop a sustainable building assessment tool (SBAT) that is appropriate for the Ethiopian context.

1.4. Objective of the study

1.4.1. General objective

The main objective of this research is to develop sustainable building assessment tool (SBAT) for Ethiopia: The case of Addis Ababa.

1.4.2. Specific objectives

The following are the study's specific objectives:

1. To select the most appropriate sustainable building assessment categories, and criteria for the Ethiopian context.
2. To develop an SBAT that is appropriate for the Ethiopian context for the evaluation and certification of buildings.

1.5. Research Questions

1. How to select the most appropriate sustainable building assessment categories and criteria are best suited to the Ethiopian context?
2. How to develop an SBAT that is appropriate for the Ethiopian context for the evaluation and certification of buildings by using the selected categories and criteria?

1.6. Scope of the study

Creswell (2003) has clearly stated that four different criteria, such as significance, delimitations, definitions, and study limitations, can be used to construct a research's scope. Therefore, these criteria were employed to determine the parameters for this study.

Various literatures were reviewed on the subject matter of sustainable building assessments/ratings, evaluations, and certifications utilizing assessment categories and criteria created so far in other nations, but no such assessment methods, categories, or criteria have been seen in Ethiopia.

Therefore, the scope of the study is focuses on the economic, social and environmental significance as well as reviews the theoretical and the definitions of the various SBATs, categories and criteria to develop a sustainable building assessment tool for Ethiopia, specifically in Addis Ababa.

1.7. Significance of the study

By enlightening the stakeholders involved in the area of building construction from the design stage to the operational stage, this study is notable for the development of the SBAT for the Ethiopian context for the evaluation and certification of the buildings of the urban environment. The developed SBAT gives the decision-maker the ability to evaluate the effectiveness of the criteria in attaining the overall goals of the assessment of sustainable buildings. Furthermore, it can draw the attention of the decision-makers to several areas where the criteria need to be changed to more effectively support the objectives of the sustainable building assessment.

As a result, projects can accomplish their objectives efficiently and effectively from the sustainability standpoint, as well as serving as a guide for those navigating various legal frameworks (proclamations, regulations, directives, policies, strategies, guidelines, codes, and standards) in management of building construction.

1.8. Research Limitations

Any research is unable to take place without several limitations on how the study is conducted, processed, and written. During the study of my dissertation, I too came into these limitations.

The development of an assessment tool for the sustainable building was the one of the limitation. Buildings of all kinds are constructed, but none of them are evaluated from a sustainability perspective because there was no such assessment tool in Ethiopia so far.

In addition to these, it is observed that the principles and implementations of sustainable building are not the main concern right now. Because of our different levels of development, it is difficult for me to address the participants in this study about fundamental and practical foundations and concepts.

1.9. Description of the study Area

Addis Ababa, the capital city of Ethiopia and the African Union, is frequently referred to as the "African Capital." Addis Ababa serves as a significant administrative hub for both Ethiopia and all of Africa. The city has experienced a boom in building construction, with huge buildings sprouting up everywhere like residential, commercial, offices, and others which are constructed by the government, cooperatives, real estate developers, and private sectors as well as individuals. Most of these buildings need to address sustainability issues like environmental, economic, and social because it is assumed that the constructed buildings would stay for a long period.

The prediction for Addis Ababa's population in 2021 is 5,005,524. Addis Ababa's population has increased by 331,674 over the past year, a 3.85% yearly rise, and is thought to be around 5,165 people per square kilometer Nations United (2018). These population projections and estimates are based on the most recent UN World Urbanization Prospects report. The populations of Addis Ababa as well as nearby suburban areas are often included in the urban agglomeration of Addis Ababa, which these numbers indicate Nations United (2018).

1.10. Organization of the Document

This study aimed to develop Sustainable Building Assessment Tool (SBAT) for Ethiopia: The Case of Addis Ababa. There are five chapters. The study's introduction, background, problem statement, general and specific study objectives, research questions, study scope, study significance, study limitations, and study area description are all covered in the first chapter. The literature review which includes its contextual/theoretical, conceptual, methodological reviews/frameworks is discussed in chapter two, and the research methodology is covered in chapter three. Compilation, analysis, and discussion of the data are included in chapter four. Finally, chapter five also contained an overview of the conclusions and recommendations.

CHAPTER TWO

2. Literature Review: Sustainability

2.1. Contextual Framework

The contextual literature review helps in the identification of existing theories, their relationships, the breadth of their exploration, and the development of new testable hypotheses. This section includes the contextual elements of building sustainability and affordability, which are utilized to guide the study. Also, the affordability of the 40/60 condominium buildings from different categories and criteria as well as the context of the building construction with respect to the sustainable building assessment tools/ratings was assessed. A few clues about the sustainable/green buildings in our case were also provided by the case study.

2.1.1. Sustainability - Definition, Dimensions, and Benefits

Definitions: Sustainability is the practice of residing within the boundaries of the physical, environmental, and social resources that are readily accessible in a way that ensures the long-term viability of the living systems in which people are ingrained. The author Jucker (2003) has defined the term sustainability as being achieved when all people on earth can live well without compromising the quality of life for future generations. According to the other authors John (2010), sustainability is a situation in which the total amount of natural and artificial resources stays at least consistent for the near future to prevent a fall in the standard of living for upcoming generations. On the other hand, it can also be defined as the process of living within the limits of available physical, natural, and social resources in ways that allow the living schemes in which persons are entrenched to flourish in permanence. The whole definition of sustainability requires the following: maintenance of resources, particularly the use of renewable resources; passing on of resources, the environment, and social benefits for coming generations; safeguarding of biodiversity and the integrity of the environment; protection of technology and economic progress, boosting the welfare of the human population, maintenance of technological and economic development, enhancing the well-being of the human population, and nurturing and enhancing of a comfortable and fulfilling lifestyle for the human inhabitants.

The term sustainability can be defined in the Ethiopian case as ensuring that our all activities about nature do not put risks to the future of the nation, challenging its capacity to renew and restore, and considering the triple bottom lines of sustainability i.e. social, economic, and environment. It is also defined as a result of the subjects related to the built environment acting in line with all aspects of sustainability i.e. social, economy, and environment in an integrated and balanced manner for the long-term, and the threats to sustainability come from against or ignoring one or more legal framework aspects like proclamation, legislation, regulations, policies, strategies, and principles of sustainability for the overall building construction processes.

The definitions shown above demonstrate that the utilization of resources, both natural and artificial, such as those created by constructions, was done so while taking future generations into account.

Dimensions: The author Burton (1987) has clearly described that the three (triple-bottom-lines) dimensions of sustainability are: environmental, economic, and social-political.

- The environmental component recognizes the interdependence of living systems and finite natural resources.
- The economic component defines the flow of human capital and man-made resources as well as the parameters of work and productive human activity.
- The socio-political component refers to the relationships between human institutions, systems, and collective decision-making.

Sustainability is about more than just the economic benefits of recycling materials and resources; it also accounts for the social and environmental consequences of human activity which is known as the triple-bottom lines of sustainability which serves as the true sustainability depends upon the three interlocking factors namely environmental conservation, social equity, and economic viability. First, sustainable human activity must protect the environment like conserve resources, protecting nature, and preserving wildlife. Second, people and community must be treated equally and fairly particularly to promote community, eradicate poverty and ensure equity. Third, sustainability must be economically feasible; human development depends upon long-term production, use, and management of resources to balance the global economy. The following Figure 2.1 shows the triple-bottom-line of sustainability.

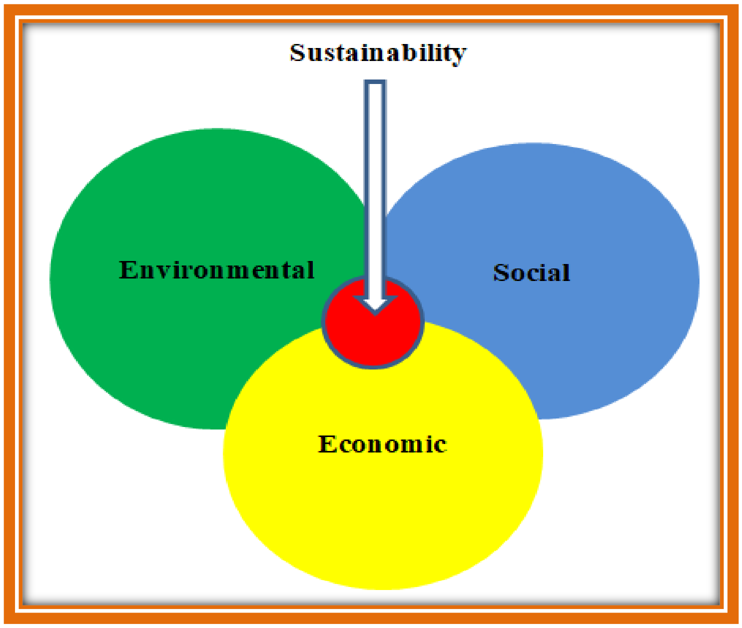

Figure 2.1: The interrelationship of the triple-bottom-line of Sustainability

(Source: Burton (1987))

Environmental Sustainability

Specifically, environmental sustainability is a state of stability, adaptability, and interconnectivity that permits human society to satisfy its needs without exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs Our Common Future (2013). Environmental sustainability is defined as meeting the resource and service needs of current and future generations without compromising the health of the ecosystems that provide them.

As Justice (2019) cited the authors Brodhag (2006) that the environmental sustainability is about the natural environment and how it remains productive and resilient to support human life. Ecological stability and the ecological footprint of the natural surroundings are associated with environmental sustainability. The authors Goodland (1996) have also argued that environmental sustainability requires that natural capital be sustainably used as a source of economic inputs and as a sink for waste. The inference is that trash must be produced less rapidly than it can be absorbed by the environment, and natural resources must be used less rapidly than they can be replenished as noted by Diesendorf (2000). This is to ensure that balance can be kept within the constraints of the planetary systems' restrictions or boundaries.

Other scholars Chugan (2013) also have said that environmental sustainability requires being sensitive in the subjects of protection of aliveness and diversity on the earth, conservation of life-support systems, sustainable usage of renewable resources, saving in using nonrenewable resources, minimizing harm to the environment and living things, and protection of cultural and historical environments. The consequences of climate change include warming of the atmosphere and oceans, diminishing ice levels, rising sea levels, increasing acidification of the oceans, and increasing concentrations of greenhouse gases as described by Du (2016). All of these are important issues of environmental sustainability because they have implications for how the natural environment remains productively stable and resilient to support human life and development.

Economic Sustainability

Economic sustainability requires that current economic activity not disproportionately burden future generations and it should also involve analysis to minimize the social costs of meeting standards for protecting environmental assets nevertheless not aimed at decisive what those values should be.

Economic sustainability refers to a manufacturing system that meets current levels of consumption not jeopardizing the needs of future generations. The economic system itself must be sustainable for the existence of "economic sustainability."

The author Amos (2015) has stipulated that the economic sustainability of green building practices (GBPs) may be evaluated based on the criteria of the maintenance of non-declining capital stocks required in the production of green buildings. Amos (2015) has also identified several factors which may play a decisive role in the maintenance of non-declining capital stocks for building construction purposes, especially green buildings. Some of the factors are public awareness, public access to construction finance, the political will to facilitate GBPs, the size of the construction industry, and finally, local capacity to produce green building materials.

In the sustainable building construction sectors, the economic sustainability approach is more of a cyclic process; which considers both input and output factors, efficiently integrating all five capital components into the human activity to create the best quality of life as noted by Zhou and Lowe (2003). Hence; sustainable construction should have identical features and the economic principles that include value for money, maximum output with minimum input, and integration of short-term return and long-term benefits, stakeholder partnerships, and human quality of life. The consideration as well as the implementation of the economic sustainability dimension in any economic activities, is very essential to attain the goal of sustainable development.

Social Sustainability

Social sustainability was defined by the author Colantonio (2010) as a combination of social principles in which fundamental necessities, such as housing and health, equality, and social justice, are met, combined with new ideas like a feeling of peace, happiness, and quality of life. According to the other authors, it is also defined as "improvement and/or growth that is compatible with the peaceful development of civil society, fostering an environment conducive to the compatible sharing of culturally diverse groups, and improvements in quality of life for all population segments while simultaneously promoting community cohesion among diverse groupings" Polese (2000). Similarly Kefayati (2015) noted that social sustainability plans attempt to improve the quality of human existence and as a result, focus on well-being and the most important human necessities, such as psychological and cultural issues, resilience, and development.

The authors James et al. (2016) have recommended that applying social sustainability processes to construction projects in the developing world has to include the community throughout the project's life cycle, acquire the property in a way that is lawful and respectful of indigenous context, design the project with consideration for the local culture, and design for maximum efficiency of limited water supplies, design sustainable systems for energy and thermal comfort, design for the safety of the occupants by incorporating local codes while acknowledging international standards, design projects that can be safely constructed by the local population, build using locally understood construction methods and build with locally sustainable and affordable materials. All the authors stressed that the issues of social sustainability are highly considered in performing any activities which ultimately benefit the society at large in combination with both environmental and economic sustainability because all these three are always go hand in hand. Therefore; incorporating the dimensions of sustainability in the construction and other sectors are very essential for the attainment of sustainable development goals.

Benefits: From the above contextual definitions of sustainability, one can easily identify the benefits of sustainability. Here are some of the major benefits of embracing sustainability in any sector for the welfare and well-being of the population as well as promotes the health of people and societies. Sustainability encourages the development of a robust economy with less pollution and waste lower emissions, better employment opportunities, and more equitable income distribution.

While evaluating any types of buildings from sustainability perspectives, the clearly described definitions, dimensions, and benefits of sustainability with respect to the wise utilization of the available resources were taken into account. I acknowledged those authors who are delivering such definitions, dimensions, and benefits. To assess or evaluate the buildings from various viewpoints, it was also vital to understand the context in which these sustainability issues were critically addressed in this study.

2.1.2. Descriptions of Sustainable Developments

The phrase "sustainable development" was first used in the Brundtland Commission's 1987 report on the state of the world's environment and development. "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" is how the commission defined sustainable development Our Common Future (1987). Beyond this description, Needham (2011) states that sustainable development is "the ability to meet the demands of the present while [helping to] [meet] the needs of the future generations." Therefore, "a pattern of economic growth in which resource utilization attempts to meet human needs while maintaining the environment so that these needs can be met not only in the present but also for generations to come" could be used to describe sustainable development.

Economic development, social development, and environmental protection are referred to as the interrelated and mutually reinforcing pillars of sustainable development in the UN declaration of the 2005 World Summit. However, the phrase "human development" is frequently used to refer to the idea of social development Our Common Future (1987).

To increase our prospects of attaining sustainable growth, this issue needs to be addressed. However, these pillars have largely been considered as different realms of life. Several significant issues on the subject of sustainable development need to be resolved. Climate change, energy use, waste production, risks to public health, poverty, social isolation, resource management, biodiversity loss, and land use are a few of these issues.

2.1.3. Sustainable Building Construction

Sustainable building construction can be viewed as a subset of sustainable development applied to the construction industry. The author Kibert (2005) defined sustainable building construction as "the creation and responsible management of a healthy built environment based on resource efficient and ecological principles". After the definition of sustainable construction defined by Kibert (2005), the scholars Bowen (1997) have pointed out the four principles of sustainable building construction such as social, economic, biophysical and technical.

There are seven principles of sustainable building construction forwarded by (Kibert (2005) which inform decision makers during each stage of the design reducing resource consumption; reusing resources; using recyclable resources; protecting nature; eliminating toxins; applying life-cycle costing; and emphasizing quality. The author Khalfan (2002) has described that creating better-built environments for human lives is one of the objectives of sustainable building construction. However, to achieve this objective, there is a need to pay attention to sustainability aspects to make sure that the built environment lasts for the next century and beyond.

Other scholars like Du (2002) depicted that Agenda 21 for sustainable construction in developing countries defined as a holistic process, it aims to maintain and restore equilibrium between the natural and built ecosystems and build communities that uphold economic equality and human dignity. The potential impacts of changing to sustainable building construction are related to construction industry demands, needs, and drivers and to the acceptance of sustainability concepts. I agree that implementing sustainability principles and understanding the long-term advantages of sustainable building construction are crucial for the construction sector in developing nations, as the majority of developing countries were concentrating on subsistence life rather than sustainability issues.

2.1.4. Sustainable/Green Building: Origin, Definitions, and Benefits

Origin: The authors Doğan (2019) have pointed out that the history of sustainable/green buildings dates back to ancient times and also said that the cave dwellers utilized environmentally friendly materials and resided in their homes in compliance with the landscape. Throughout the eras, human interference with the environmental balance causes problems as depicted by Doğan (2019). This was the beginning of the sustainability and green building movements. Natural Stone Institute (2019) has elaborated that even though the green building movement has been accelerated throughout the past 10 years; its origins can be detected as early as the end of the nineteenth century.

Doğan (2019), He (2018) and Zhao (2015) argued that the philosophy of sustainable/green building is resulting from the term “Arcology" derived from the combination of both disciplines of architecture and ecology. The scholars Doğan (2019) and Khoshbakht (2018) have also pointed out that green building is an application in the construction sector that prioritizes environmentally responsible and efficient resource allocation in the whole life-cycle of a building.

Definitions: A sustainable/green building is a building that minimizes or eliminates negative aspects and can create positive impacts on the natural environment through its design, construction, and operation. In other words, sustainable/ green buildings preserve precious natural resources and improve quality of life.

The authors Mouhamed (2015) have defined sustainable/green buildings as it is structures that are built in an environmentally responsible manner by optimizing the use of materials, minimizing the use of resources, and ensuring the health and well-being of occupants and the surrounding built environment.

Sustainable/green building (also known as green construction) refers to both building and the application of processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from planning to design, construction, operation, maintenance, renovation, and demolition.

High-performance building – (also termed "green building" or "sustainable building") – is called that way because of its higher efficiency in using energy, water, and other resources; reducing waste, pollution, as well as environmental deterioration; safeguarding occupant health; and enhancing productivity of humans. High-performance buildings are designed, built, renovated, and operated in a resource-efficient manner. The main objective of the sustainable/green building strategy is to reduce the overall impact on human health and the environment.

The author Yun (2014) also confirmed that the implementation of sustainable/green building needs to utilize green technologies that are more involved in the development and utilization of products, equipment, and mechanisms that protect the environment and natural resources. He also added that these technologies can improve the performance of the buildings on the environment, people, and economy. On top of this, as illustrated by Neyestani (2017) and Yun (2014), many case studies were also shown that home builders and developers have incorporated the concepts of eco-friendly building and emphasized green technologies with buildings to increase ventilation control, enhance temperature control, enhance lighting control and increase day-lighting. Accordingly, green technologies can significantly be correlated with a high level of productivity and performance in buildings. The authors Neyestani (2017) and Wills (2009) have clearly articulated that there are many equipment and tools used for the development of green technologies for buildings and they can be categorized into four main groups in the construction industry, as follows:

- **Energy**: Passive solar, heat pumps, and solar energy;
- **Water technology**: Water harvesting and aqueduct system;
- **Natural lighting**: Design with retractable awnings and day-lighting design (sunlight transportation systems, energy-efficient light bulbs, compact fluorescent lights (CFLs), light emitting diodes (LEDs), sustainable lighting, and
- **Natural ventilation**.

The authors Neyestani (2017) and Jalali (2011) revealed that green materials are the main aspect of sustainable/green buildings. Currently, the construction industry uses large quantities of natural resources worldwide. Neyestani (2017) and Jalali (2011) have also confirmed that in the USA, construction activities utilize 60 percent of the raw materials, and similarly, 60 percent of the nation's surplus and non-hazardous solid wastes belong to the construction industry. Some materials can be used in constructing buildings, as widely known green materials. Such materials are reusable and recyclable to reduce energy waste in homes. Similarly, recovering and reusing building materials can minimize energy use and greenhouse gas emissions by lowering the requirement to collect, process, and export new technologies. In addition to this, Neyestani (2017) and Jalali (2011) have also said that green materials reduce the economic and environmental impact of waste disposal.

Benefits: The authors Greg (2006) have explained the sustainable/green building as it encompasses designing, constructing and maintaining buildings to decrease energy and water usage and improve the efficiency and permanency of building schemes, and reduce the loads that structures enforce on the setting and community. Likewise, Elizabeth (2018) and Tan (2010) have also depicted that sustainable/green buildings bring a significant amount of benefits and profitable rewards compared with normal/standard buildings.

Elizabeth (2018) has identified that thermal comfort, environmentally friendly, financial advantages, inward environment quality, cost of maintenance is low, and use less natural resources were the major benefits of green buildings. The findings of the authors Zhao (2014) and Yudelson (2008) are almost similar to that of the authors Elizabeth (2018) about the benefits of sustainable/green buildings that include: 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 less natural resources to protect the ecosystem; lead to the reduction of annual water cost savings; increase the occupant safety and security; lead lower operational and support costs; waste disposal costs in the green buildings are lower; make risk management manageable (economic, financial, market, etc.); and the cost of maintenance in green building is greatly reduced.

The authors Greg (2006) have clearly identified the benefits of sustainable/green buildings by comparing it with that of the conventional building with respect to economic, social, and environmental features as discussed below.

Economic Benefits: As sustainable/green building becomes more popular, the financial benefits for developers and homeowners are becoming clearer. The majority of savings from sustainable/green buildings are in maintenance and utility costs. To witness the financial benefits provided by sustainable/green buildings, for instance, the author Yun (2014) has found that the financial benefits of sustainable/green buildings are 10 times more than the average initial investment required to design and construct a sustainable/green building in long term. This author also investigated that the benefits of life cycle cost savings on utility costs and maintenance costs make building green especially attractive to owners, and certain aspects of sustainable design mirror value engineering principles in right-sizing the building and systems.

The other authors Jalali (2011) have pointed out that without doubt; the greatest benefit of green buildings is to lower energy and water bills. By the same token, the results of several studies showed that sustainable/green buildings can save USGBC (2016): 36% of total energy use and 65% of electricity consumption; 30% of greenhouse gas emissions; 30% of raw materials use; 30% of waste output; and 12% of potable water consumption.

Social Benefits: The social benefits of sustainable/green buildings are related to improvements in the quality of life, health, and well-being. Buildings, communities, and society as a whole can all reap these advantages. The scholars Korkmaz et al. (2009) have argued that acceptance of the sustainable/green building guidelines in various societies can be attributed to comparatively a long history of the movement of sustainable/green buildings' benefits for societies. The author Venters (2008) has also noted that the factor of "feel-good" is a social motivation to construct sustainable/green buildings, especially in huge cities. As a result, sustainable/green buildings have better indoor air quality, comfort, and economy; likewise, sustainable/green buildings are more likely to convince buyers for possessing a direct impact on their health and happiness.

Environmental benefits: Protecting the environment is the primary benefit of sustainability in the construction industry. The indoor environmental quality (IEQ) of a building, which serves as a shelter, is intended to offer people a pleasant and attractive setting. The authors Greg (2006) have clearly described that the environmental benefits of sustainable/green buildings include the conservation of natural resources, waste reduction, and improvement of air and water quality and protection of the ecosystem. Other authors like Korkmaz et. al. (2009) have identified that the buildings and the built environment play a major role in the natural environment. It is very clear that sustainable/green buildings have the potential to reduce the negative effects on the environment and offer business and occupant health-related benefits as noted by Xia et al. (2013) and Korkmaz et al. (2009). Moreover; the other authors Jalali (2011) have confirmed that sustainable/green buildings use energy, land, and water more efficiently as well as produce less waste and pollution as compared to conventional buildings. As it was articulated by the author Wills (2009), at present modern American buildings should consider environmental issues and also follow sustainable criteria for constructing and improving the buildings' energy use, air pollution, water quality, site selection, materials, and interior air quality, among other aspects.

2.1.5. Sustainable/green buildings assessment tools

Sustainable/green building rating tools, also known as certification, are used to assess and recognize buildings that meet certain green requirements or standards. Rating tools, often voluntary, recognize and reward companies and organizations that build and operate sustainable/green buildings, thereby encouraging and incentivizing them to push the boundaries on sustainability Jalali (2011).

Rating tools vary in their approach and can be applied to the planning and design, construction, operation and maintenance, renovation, and eventual demolition phases of a sustainable/green building. The sorts of buildings that different rating methods are used for can also vary, with certain techniques or subsets of techniques being used for various types of buildings including residences, offices, commercial buildings, or even entire communities Jalali (2011).

2.1.6. The Horn of Africa Regional Environment Centre (HoA-REC) Green Building

Introduction

When compared to conventional buildings, a green building consumes less water, maximizes energy efficiency, protects natural resources, produces less waste, and offers its occupants a better environment. Although there are no green construction regulations or codes in our nation, there is the Ethiopian Building Code and Standard (EBCS), which focuses mostly on conventional buildings rather than green ones. This implies that Ethiopia has yet to adopt a comprehensive and effective green construction code.

LEED was created by the USGBC. In the modern world, LEED is a widely respected green building certification system that offers third-party verification for a building or community that was built using strategies to increase performance in metrics like energy conservation, water efficiency, decreased CO_2 emissions, improved indoor environmental quality, resource stewardship, and sensitivity to their impacts. As many as 57 countries have embraced LEED's green markers. Green building designs utilize less energy than their traditional equivalents, making them more popular with building users and customers in the long run. They also produce healthier indoor air quality and utilize renewable resources. Smaller designs and alternative and salvaged building materials can be less expensive than conventional methods and use fewer precious resources.

The Horn of Africa Regional Environment Centre and Network at Addis Ababa University (HoA-REC&N-AAU) aims to bring together academics and professionals in order to advance protection of the environment, sustainable resource management, and ecological management throughout the Horn of Africa. Initiated by the Faculty of Science in 2006, the HoA-REC & N-AAU was established. The Centre and Network have been striving to promote cooperation with the financial support of numerous foreign development partners, including the Embassy of the Royal Kingdom of the Netherlands. and knowledge exchange between organizations with environmental expertise, including Non-governmental organizations (NGOs), Community-based organizations (CBOs), research institutions and universities from Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan and Sudan.

HoA-REC&N-AAU was formed by the University Council in 2010 as an independent center managed by a board of directors chaired by the Vice President for Research and Graduate Program who reports to the University President. It is positioned beneath the office of the President in the University's present organizational structure. The Network currently has far more than 40 members, with Ethiopia accounting for around 40% of that total. The Network is constantly growing with environmental organizations from the Horn of Africa showing an interest to join.

Site location of the HoA-REC Building

The HoA-REC is housed in a brand-new, environmentally friendly building in Addis Ababa, Ethiopia in the Gullele Botanic Garden (GBG) and has a total area of 54,000m^2. The building, which was constructed under the "cradle-to-cradle" concept, is where the whole personnel of the Center is located. GBG is an initiative that Addis Ababa University and the Addis Ababa City Administration are working on together. Through the provision of both technical and financial support, the Royal Government of the Netherlands has been instrumental in its establishment.

The coveted Leadership in Energy and Environmental Design (LEED)® Gold Green Building Certification from the USGBC was awarded to HoA-REC on March 16, 2017.

The headquarters building of HoA-REC became the first green building in Ethiopia to achieve a LEED-GOLD Certification. This building was designed by the lead consultant known as ABBA ARCHITECTS PLC, consulting architects, engineers, and planners; and the sub-consultant called SYNERGY INTERNATIONAL in July 2010.

Figure 2.2: The 3D of the LEED GOLD Green Building Certified of the HoA-REC Building

(Source: From the Consultant (ABBA ARCHITECTS PLC), 2021)

According to the LEED 2009 for New Construction and Major Renovations Rating System, seven assessment categories with varied possible points assigned to them were taken into consideration for the HoA-REC green building evaluation. These are Sustainable Sites (SS) have a maximum score of 26, Water Efficiency (WE) has a highest score of 10, Energy and Atmosphere (EA) has the highest possible score of 35, Materials and Resources (MR) has a highest marks of 14, Indoor Environmental Quality (IEQ) has a highest score of 15, and Innovation in Design (ID) has a highest marks of 6. The following Table 2.1 presents the assessment categories and criteria, and its assessment findings.

Table 2.1: The LEED 2009 for New Construction and Major Renovations Rating System categories and criteria for the assessment of HoA-REC building and its assessment results

No.	Lists of assessment category	Assessment Criteria used	Allocated points	Assessment result
1.	Sustainable Sites (SSs)	• The site selection	1	The real assessment results (points) were not available. But the general assessment findings show that the HoA-REC green building has a preferred parking space provided to low-emitting and fuel-efficient vehicles; maximized vegetated open spaces; all landscapes of the building and its surroundings are native; existing landscape was protected during construction; sufficient storm-water quality control systems were also provided; the building has green roof for reducing the heat island effect (minimizing impacts on microclimates and human and wildlife habitats); and the site has provided public transportation and bike racks by the front for employee and visitor use.
		• Community connectivity and development density	5	
		• Brownfield redevelopment	1	
		• Alternative transportation	12	
		• The site development	2	
		• The storm-water design	2	
		• The heat island effect	2	
		• The light pollution reduction	1	
2.	Water Efficiency (WE)	• Water use reduction	prerequisite criteria	The real assessment results (points) were not available. But the general assessment findings show that all of the toilets in the building providing a 50% reduction in water use, all plumbing fixtures providing a 45% reduction in total water use, and the installed landscaping not requiring permanent irrigation systems.
		• Water-efficient landscaping	2-4	
		• Innovative wastewater technologies	2	
		• Water use reduction	2 - 4	
3.	Energy and Atmosphere (EA)	• Optimize energy performance	1–19	The real assessment results (points) were not available. But the general assessment findings show that the shade for south-facing windows, minimal glazing on the west façade, and R-30 insulation in the roof save 53% more energy which includes achieving over 37% decrease in interior lighting power using Compact Fluorescent Lamps (CFLs) and Light Emitting Diodes (LEDs), not needing cooling or heating due to location, saving over 1500 kWh of energy usage, and employing photovoltaic to yield 25,719 kWh
		• On-site renewable energy	1–7	
		• Enhanced commissioning	2	
		• Enhanced refrigerant management	2	
		• Measurement and verification	3	
		• Green power	2	

				yearly.
4.	Materials and Resources (MRs)	• The storage and collection of recyclables	Prerequisite requirement	The real assessment results (points) were not available. But the general assessment findings show that recycling is encouraged throughout the project; more than 95% of construction waste was recycled; more than 20% of the materials used in construction came from local suppliers, like adobe brick and eucalyptus; and over 5% of the materials used in construction came from quickly renewable sources
		• Building reuse	1-4	
		• Construction waste management	1-2	
		• Materials reuse	1-2	
		• Regional materials	1-2	
		• The recycled content	1-2	
		• Renewable materials	1	
		• The certified wood	1	
5.	Indoor Environmental Quality (IEQ)	• Outdoor air delivery monitoring	1	The real assessment results (points) were not available. But the general assessment findings show that smoking is not permitted within 25 feet of the building, all building materials are low-emitting (contain low volatile organic compounds or VOCs), and more than 96% of frequently occupied spaces have access to views of the outside.
		• Increased ventilation	2	
		• Construction indoor air quality management plan	2	
		• Low-emitting materials	4	
		• Indoor chemical and pollutant source control	1	
		• Controllability of systems	2	
		• Thermal comfort	2	
		• Daylight and views	2	
6.	Innovation in Design (ID)	Innovation in Design	1-5	The real assessment results (points) were not available. But the general assessment findings show that there was a LEED Accredited Professional involved as per the criteria. This professional is an Ethiopian.
		LEED Accredited Professional	1	

(Source: Compiled by the researcher, 2023)

Figure 2.3: The HoA-REC headquarter building of the LEED-GOLD award certificate from the USGBC, 2017

(Source: From the Consultant (ABBA ARCHITECTS PLC), 2021)

Figure 2.4: The HoA-REC headquarter building of the LEED-GOLD award Certificate from the USGBC, 2017

(Source: From the Consultant (ABBA ARCHITECTS PLC), 2021)

2.2. Conceptual/Theoretical Framework/Review

The categorization, description, and outlining of concepts pertinent to the subject or issue, including pertinent theory and empirical research, are the objectives of the conceptual literature review. The investigation is guided by the conceptual/theoretical reviews of building affordability and sustainability that are covered in this section.

2.2.1. Concept and Need/Importance of Sustainability

Concepts: When the term "sustainability" was first used in forestry, it meant never taking more from a forest than it produces in new growth Wiersum (1995). The scholar Vogt (2009) has identified that since antiquity, a shared understanding of the concept of sustainability has existed, particularly in rural cultures. This concept showed that the roots of the term can be traced back to the world of hunting, where hunters and gatherers were keen to secure their livelihood. The term "sustainable" or rather "to sustain" has also been described by Vogt (2009) as being "proven to be a derivation of the noun "sustenance" (literally retain, what one retains) used towards the end of the 18^{th} century." In addition to this as clearly described by Grober (2010), the Bible requires mankind to take care of the earth and to look after it; this could be seen as early proof of sustainability. Moreover; the author Solow (1992) has responsively elaborated that if 'sustainability' is anything more than a slogan or expression of emotion, it must be equivalent to an order to maintain production capacity indefinitely. In the same manner, other authors namely John (2010) said that sustainability is a matter of what resources—natural resources, quality of the environment, and capital—we bequeath to coming generations. On top of these; sustainability is a concept related to the development of products, goods, and services that involve meeting our present needs without compromising the ability of future generations to fulfill their own needs. Moreover; sustainability as a concept recognizes that the environment is an exhaustible resource. For the sake of the Earth, our environment, humanity, and all living creatures, it is crucial to use the environment and its resources wisely and to safeguard them.

Need/Importance: The reasons people care about sustainability are frequently intricate, unique, and varied. It is unrealistic to create a list of reasons why so many individuals, groups, and communities are working towards the goal of sustainability. Yet, for most people, sustainability comes down to the kind of future that people are leaving for the next generation. Many people and organizations share the concept of sustainability, and they show this value via their policies, routine activities, and practices. Individuals have played a major role in developing current environmental and social circumstances. Sustainability improves the quality of our lives, protects our ecosystem, and preserves natural resources for future generations.

2.2.2. Concepts and principles of sustainable development

The author Črnjar (2009) stipulated that the term sustainable development was originally introduced in the field of forestry, and it included measures of afforestation and harvesting of interrelated jungles which must not destabilize the organic regeneration of forestry. Likewise IUCN (1980) revealed that this term was first mentioned in the Nature Conservation and Natural Resources Strategy of the International Union for Conservation of Nature (IUCN) published in 1980. Although sustainable development was primarily viewed from an ecological perspective, rapidly it spread to social and economic aspects of the study. Even though it is somewhat vague, this concept of sustainable development aims to maintain economic advancement and progress while protecting the long-term value of the environment. The author Ortiz et al. (2009) have also well-defined sustainable development as cultivating the quality of life and therefore enabling individuals to reside in healthy environments, and societal, economical, and ecological situations are improved for both the current and future generations. In addition to all the definition of sustainable development, the author Klarin (2018) has outlined the concept of sustainable development as the core principles, namely: ensuring the needs and welfare of the community for both the current and the coming generations; advancements were made equality and the quality of life; safeguarding and conserving the environment, species diversity, and ecological systems; safeguarding and conserving the environment's assets with the wise use of renewable resources and decreased exhaustion of quasi resources; adjusting consumption and production with consideration for ecosystem management; utilizing sustainable power and cutting-edge technology to ensuring that the requirements of the society, both current and future, are met while minimizing the adverse effects on the environment; enhancing regional, provincial, and local international cooperation; establishing a regulatory capacity with a broad stakeholder base engaged in putting the idea of sustainable development into practice, etc. It is a fact that sustainable development requires the integration of economic, environmental, and social objectives across sectors, territories, and generations. Hence, to advance toward truly sustainable growth, segmentation must be eliminated, meaning that societal, economical, and ecological issues must be incorporated into all decision-making procedures.

2.2.3. Sustainable/Green Building: Concepts, Objectives, Elements, and Principles

Concepts: Nowadays the concept of sustainable/green building has worldwide popularity. The popularity of this sustainable/green building concept is because of the negative influence of construction on the environment. The authors Doğan (2019), Oliveira (2017), Balaban (2012), and Tan (2011) have said that the sustainable/green building concept is a final reaction to addressing environmental and health problems which arise from buildings and minimizing the effects of the construction sector on the natural habitat as well as on individuals. The other authors Doğan (2019) and Zhukov (2014) confirmed that in corporate development and execution procedures, including energy-saving measures, the sustainable/green building concept considers both social and environmental preservation.

As Mouhamed (2015) noted that the design, construction, operation, and maintenance of buildings normally require enormous amounts of energy, water, and raw materials; generating large quantities of waste and causing air and water pollution; whereas sustainable/green buildings is the only answer through creating healthier and more resource efficient models of construction, renovation, operation, and maintenance. Thus the application of the concept of sustainable/green building in the building construction sector is very essential.

Objectives, elements, and principles: The objectives that could be attained to satisfy the end users for sustainable/green buildings include resources and materials efficiency, energy efficiency (including greenhouse gas emissions reduction), water efficiency, pollution prevention (including indoor air quality and noise reduction), harmonization with the environment (including environmental assessment) and integrated and systemic approaches (including environmental management system).

Elements: The author Madhumita (2000) described that there are elements to be considered to have sustainable/green buildings like solar water heating systems and the use of glass panels to allow natural light inside the building during daytime; rainwater harvesting; environmentally friendly building materials and specifications; waste minimization ensuring healthy indoor environment; maximizing energy use in buildings; water conservation and efficiency measures and energy-efficient equipment.

Principles: Concerning the principles of sustainable/green buildings, several authors developed different principles. For instance Vale (1991) marked that sustainable/green building seeks to create buildings that are more environmentally sound and sustainability responsible. The other author Kibert (2005) said that the main principles of sustainable/green building are designing the building to be integrated with nature, the site, conserving energy, and providing high-energy efficiency; concerning the climate, using locally available and non-toxic building materials, respecting the users and taking advantage of traditional local building techniques. It is also clearly known that there are different types of buildings constructed in various parts of the urban areas or cities of the world. Most of these buildings were not considered issues of sustainability, especially in developing nations. For this, the guiding principles for sustainable/green buildings were developed for both existing and new buildings like optimizing energy performance; employing integrated assessment, operation, and management principles; protecting and preserving water; improving indoor environmental quality; and lessening the ecological effect of materials.

2.3. Methodological Framework

In a variety of fields, methodological frameworks/reviews—reviews that focus on research procedures rather than study outcomes—have been used to enhance research practice, stimulate discussion, and pinpoint key practices. In addition to this, a methodological review emphasizes the analysis process rather than the content of what was said. This method allows researchers to draw on a wide variety of knowledge ranging from the conceptual level to practical documents for use in fieldwork in the areas of ontological and epistemological consideration, quantitative and qualitative integration, sampling, interviewing, data collection, and data analysis techniques. It also provides a framework of understanding at different levels (i.e. those of theory, substantive fields, and research approaches).

The following sub-sections (2.3.1 and 2.3.2) have explained the methodologies employed for different sustainable buildings assessment tools (SBATs) used for the certification of buildings in different countries and the affordability categories and criteria of buildings.

2.3.1. Sustainable/Green Building Councils and rating tools

The WGBC (2016) has strongly supported the development and management of many of the worldwide rating systems by the Green Building Councils (GBC), which is a participant in the WorldGBC international platform. GBC members worldwide had certified 1.04 billion m^2 of sustainable/green building area by 2016 (a space 10 times larger than Paris).

In addition to this, the WGBC (2016) WorldGBC recognizes the power that rating tools have had in transforming the sustainability of the building and firmly supports their use. Additionally, it is acknowledged that each assessment system is unique and that each GBC member in a particular nation is in the greatest position to create or choose an evaluation method that is most suited to their specific market. Consequently, WorldGBC adopts a neutral stance toward various assessment systems and does not favor the usage of one instrument over the other. However, with the widespread use of rating tools around the world, WorldGBC believes that each sustainable/green building rating tool must meet quality standards.

The quality assurance guide for sustainable/green building assessment systems, a phase-by-phase manual for the workers of the novel, developing, and recognized assessment methods, was issued in 2015 by the WorldGBC to help assure the sound, open, and professional creation and use of those tools. This is an international consensus-based certification program for creating sustainable/green/high-performance buildings. Accordingly, various countries have developed and implemented different SBATs and evaluation categories and criteria based on their contexts. Based on sound scientific principles, LEED stresses state-of-the-art methods for environmentally friendly site planning, water conservation, energy efficiency, material choice, interior environmental quality, and innovative design. Through a complete system that provides project certification, professional accreditation, training, and useful resources, LEED fosters expertise in sustainable/green building Buente (2015).

According to the authors Yamanya et al (2016), three buildings in Egypt received LEED proposed suggestions, and in addition to LEED, Green Pyramid Rating System (GPRS) is used as a local rating system. They also discussed the applicability and implementation of LEED in Egypt. On the other hand, the authors Saleh et al. (2015) also created a sustainable assessment method for the built environment of Saudi Arabia that was based on the criteria and weights by using the Analytic Hierarchy Process (AHP). Moreover; Sustainable Environmental Assessment Method (SEAM) was proposed for the Saudi Arabian context. Along with this, the authors Taghizade (2018) found that the use of different sustainable building rating systems, such as LEED (USA), BREEAM (UK), CASBEE (Japan), Pearl (UAE), QSAS (QATAR), GPRS (EGYPT), and SEAM (SAUDI ARABIA), was essential for the selection and prioritizing of appropriate categories and criteria for assessing the sustainability of Iranian residential buildings using the AHP method.

Since the introduction of BREEAM in 1990, more than two million buildings have been registered for assessment as stated by the authors Elena et al. (2017). A certificate has been awarded to 566,811 out of the 2,275,541 buildings registered with BREEAM, according to UK BREEAM (2019). Additionally, the authors Prior et al. (2019) have noted that BREEAM is at the top of the list of sustainability assessments, with over 10,800 certified assessments being provided at both the design and post-construction phases between 2013 and 2017. In China, 2,965 buildings are registered or certified as green buildings by LEED. Furthermore, the author Buente (2015) found that 900 buildings in India have received LEED certification.

The author Keung (2011) has identified that 25 million m^2 of space, or about 12% of all built-up space in Singapore, as well as 12 million m^2 more in Vietnam, China, and

Malaysia, received the Green Mark certification in 2011. According to the GBI (2015), Malaysia already has 327 certified buildings.

As it was noted by the DGNB (2013), over 750 projects from all over the world have been registered using the DGNB technique. 200 of them hold the final certificate, while 235 have the preliminary certificate. The Green Star sustainable building assessment method validated 50 buildings as noted Richard (2011).

For the successful evaluations and certifications of the buildings by employing the aforementioned SBATs and others, a variety of data collection methods were used for the rating systems, including interviews, surveys, document analysis, observations, and others based on the settings of the different countries. Table 2.2 that follows lists some of the various types of studies and data-gathering techniques that various writers have employed regarding SBATs.

Table 2.2: Data collection instruments used by the authors for their studies about SBATs

Name of Author	Title of the study	Data collection instruments	Country	Data Analysis
Mila (2011)	Leadership in Energy and Environmental Design (LEED): Understanding the application and effectiveness of LEED–EBOM Research Essay about sustainability	Questionnaires, interviews, and document analysis	United States of America	Life Cycle Cost Analysis
David (2015)	LEED for existing buildings	Survey questionnaires, and document analysis	United States of America	Comparative Analysis
Sofia (2012)	Performance of LEED-Existing Buildings before and after their certification	Survey questionnaires	Chicago, USA.	t-test method of Data Analysis
Omair (2014)	Sustainability and green building rating systems: LEED, BREEAM, GSAS, and Estidama critical analysis	Questionnaires, and interviews	Dubai, United Arab Emirates	Life Cycle Cost Analysis
Ruqun (2016)	Green buildings and green users: An assessment of using green building environments to communicate sustainability to users, Michigan State University.	Questionnaires, and document analysis	Michigan State University, USA	Hierarchical Regression Modeling Analysis
Kimmo (2016)	How to measure sustainability? The assessment of sustainability in construction and architecture by BREEAM, LEED, DGNB, or CASBEE.	Document analysis, questionnaires, and interviews	UK, USA, Japan, and Germany	Complementary Analysis

(Source: Compiled by the researcher, 2020)

Additionally, various analytic systems were used to analyze the data gathered for the different building assessment/rating systems. Life Cycle Cost analysis (LCC), Multiple-Criteria Decision Making (MCDM), and the Analytical Hierarchy Process (AHP) were some of the analysis tools.

These tools may evaluate a variety of buildings, including single-family and multi-family homes, office buildings, and other buildings. While some of the methods can be used to evaluate a wide range of buildings, others can only be used to evaluate new construction or office buildings Viitaniemi (2008).

Some of the sustainable/green building assessment tools used the MCDM method for the analysis of the buildings are Green Star SA GCB (2015) and Haase (2013), DGNB-China Haase (2013) and DGNB (2015); CEPAS-Hong Kong Haase (2013); CASBEE-Japan CASBEE (2015) and Aotake et al. (2005); Green Mark-Singapore BCA (2015); BREEAM- United Kingdom Viitaniemi (2008); BREEAM (2015) and Grace (2000); LEED®-Canada Haase (2013) and CAGBC (2015); LEED®-USA (Viitaniemi (2008) and Haase (2013); and Green Star GBCA (2015) and Roderick et al. (2009). Moreover; the LCC analysis technique is also used by ELODIE-France Haase (2013); TEAM™-France Viitaniemi (2008) and Rialhe (2000); PAPOOSE-France Viitaniemi (2008) and Rialhe (2000); GABI-Germany Viitaniemi (2008); LEGEP®- Germany Viitaniemi (2008); SIMAPRO-Netherlands Castro et al. (2003); Eco-Quantum-Netherlands Viitaniemi (2008); EcoEffect-Sweden Viitaniemi (2008); Haase (2013) and Malmborg (2004); Envest 2-United Kingdom Viitaniemi (2008); and BEES 4.0-United States Viitaniemi (2008).

The LEED-USA rating system was taken into consideration when using the AHP technique to maintain and renovate a Nile University building in Egypt. This was done to determine how the environment impacts the outcomes of each rating system Nahla Hazem (2020).

Some of the lists of rating tools are shown in Table 2.3 below (including regions, country names, owner/management, year, types of methods, and references).

Table 2.3: Building Environmental Assessment Methods and Tools in use worldwide (Adapted from Haase (2012))

Region	**Country**	**Name**	**Owner/Management**	**Year**	**Type of method**	**References**
Africa	South Africa	SAT	CSIR	2002	MCDM	CSIR (2015) and Gibbert (2008)
		Green Star SA	South Africa GBC	2008	MCDM	GCB (2015) and Haase (2013)
Asia	Hong Kong	BEAM Plus	HK-BEAM Society	1996	MCDM	Haase (2013) and HKGBC (2015)
	Korea	GBCC	Korean Institute of Energy Research	1997	MCDM	KGBCC (2015)
	Taiwan	EEWH	ABRI (Architecture and Building Research Institute)	1999	MCDM	EEWH (2015)
	Hong Kong	CEPAS	HK Building Department	2002	MCDM	Haase (2013)
	China	GOBAS	Ministry of Science and Technology	2003	MCDM	Haase (2013), and Borong et al. (2015)
	Japan	CASBEE	Japan Sustainable Building Consort.	2004	MCDM	CASBEE (2015) and Aotake et al. (2005)
	Singapore	Green Mark	Singapore Building & Construction Authority (SBCA)	2005	MCDM	BCA (2015)
	China	ESGB	Ministry of Housing and Urban-Rural Construction	2006	MCDM	Haase (2013) and (Hu (2012)
	Vietnam	LOTUS	Vietnam GBC	2007	MCDM	CEC (2015)
	India	TERI-GRIHA	TERI (The Energy & Research Institute)	2007	MCDM	Haase (2013) and Korkmaz et al. (2009)
	Malaysia	GBI	PAM (Pertubuhan Arkitek Malaysia / Malaysian Institute of Architects) and ACEM (the Association of Consulting Engineers Malaysia)	2008	-	Bahaudin et al. (2014)
	China	DGNB	DGNB China	2009	MCDM	Haase (2013) and DGNB (2015)

	Thiland	DGNB	ARGE - Archimedes Facility - Management GmbH, Bad Oeynhausen & RE / ECC	2010	MCDM	DGNB (2015)
	India	LEED®-	Indian GBC	2011	MCDM	Haase (2013), Korkmaz et al. (2009), and IGBC (2014)
	China	GHEM	China Real Estate Chamber of Commerce	N/A	MCDM	Haase (2013)
Europe	Netherlands	SIMAPRO	Pre Consultants	1990	LCA	Castro et al. (2003)
	United Kingdom	BREEAM	BRE	1990	MCDM	Viitaniemi (2008), BREEAM (2015) and Grace (2000)
	Germany	GABI	IKP University of Stuttgart, PE Product Engineering GmbH	1990	LCA	Viitaniemi (2008)
	France	TEAM™	Ecobilan	1995	LCA	Viitaniemi, (2008) and Rialhe (2000)
		EQUER	Ècole des Mines de Paris, Centre d'Énergétique et Procédés	1995	LCA	Viitaniemi (2008) and Rialhe (2000)
		HQE™ Method	HQE™	1997	MCDM	Haase (2013)
	Netherlands	Økoproifl	SINTEF	1999	MCDM	Pettersen et al. (2000)
	France	ESCALE	CSTB and the University of Savoie	2001	MCDM	Viitaniemi (2008) and Gerard et al. (2000)
	Germany	LEGEP®		2001	LCA	Viitaniemi (2008)
	Denmark	BEAT 2002	SBI	2002	MCDM	Viitaniemi (2008) and Malmborg (2004)
	Netherlands	Eco-Quantum	IVAM	2002	LCA	Viitaniemi (2008)
	United Kingdom	Envest 2	BRE	2003	LCA	Viitaniemi (2008)
	Italy Italia	Protocollo	ITACA iiSBE Italia	2004	MCDM	Haase (2013)
	Portugal	LiderA	Instituto Superior Técnico,	2005	MCDM	Haase (2013)

			Lisbon			
	Finland	PromisE	VTT	2006	MCDM	Haase (2013)
	France	ELODIE	CSTB's Environment Division	2006	LCA	Haase (2013)
	Italy Italia	LEED®	Italy GBC	2006	MCDM	GBC (2015)
	Sweden	EcoEffect	Royal Institute of Technology	2006	LCA	Viitaniemi (2008), Haase, (2013) and Malmborg (2004)
	Spain	VERDE	Spanish GBC	2006	MCDM	Haase (2013)
	Portugal	SBToolPT,	iiSBE Portugal LFTC-UM, ECO CHOICE	2007	MCDM	Braganca (2011)
	Belgium	LEnSE	Belgian Building Research Institute	2008	MCDM	Haase (2013)
	Germany	DGNB	German Sustainable Building Council	2008	MCDM	DGNB (2015)
	Sweden	BREEAM SE	Swedish GBC	2008	MCDM	BREEAM (2015)
	Austria	DGNB	ÖGNI	2009	MCDM	DGNB (2015)
	Bulgaria	DGNB	Bulgarian GBC	2009	MCDM	DGNB (2015)
	Luxembourg	BREEAM LU	DIFNI	2009	MCDM	BREEAM (2015)
	Czech Republic	SBToolCZ	iiSBE International, CIDEAS	2010	MCDM	SBToolCZ (2015)
	Greece	DGNB	DIFNI	2010	MCDM	DGNB (2015)
	Hungary	DGNB	DIFNI	2010	MCDM	DGNB (2015)
	Russia	DGNB	DGNB International	2010	MCDM	DGNB (2015)
	Turkey	DGNB	-	2010	MCDM	DGNB (2015)
	Switzerland	DGNB	SGNI	2010	MCDM	DGNB (2015)
	Netherlands	BREEAM-NL	Dutch GBC	2011	MCDM	Haase (2013), BREEAM (2015) and BREEAM-NL (2015)
	Germany	BREEAM DE	DIFNI	2011	MCDM	BREEAM (2015)

	Denmark	DGNB	Denmark GBC	2011	MCDM	DGNB (2015)
	Czech Republic	DGNB	DIFNI	2011	MCDM	DGNB (2015)
	Spain	DGNB	N/A	2011	MCDM	DGNB (2015)
	Norway	BREEAM-NOR	Norwegian GBC	2012	MCDM	Viitaniemi (2008) and BREEAM (2015)
	Poland	DGNB	DGNB International	2013	MCDM	DGNB (2015)
	France	PAPOOSE	TRIBU Architects	N/A	LCA	Viitaniemi (2008) and Rialhe (2000)
	Finland	BeCost	VTT	N/A	MCDM	Viitaniemi (2008)
	Switzerland	BREEAM CH	DIFNI	N/A	MCDM	BREEAM, (2015)
	Austria	BREEAM AT	DIFNI	N/A	MCDM	BREEAM, (2015)
	Ukraine	DGNB	DGNB International	N/A	MCDM	DGNB (2015) and (EGS--plan)
North America	United States	BEES 4.0	NIST	1998	LCA	Viitaniemi (2008)
		LEED®	United States GBC	1998	MCDM	Viitaniemi (2008) and Haase (2013)
	Canada	GreenGlobes	ECD Canada	2000	MCDM	Haase (2013) and GreenGlobes (2015)
		ATHENA™	ATHENA Sustainable Material Institute	2002	MCDM	Viitaniemi (2008), and Meil (1995)
	United States	GreenGlobes	Green Building Initiative	2004	MCDM	Haase (2013) and GreenGlobes (2015)
	Canada	LEED®-Canada	Canada GBC	2009	MCDM	Haase (2013) and CAGBC (2015)
	Mexico	SICES	Mexico GBC	N/A	MCDM	Haase (2013)
Oceania	Australia	NABERS	NSW Office of Environment and Heritage	2001	MCDM	NABERS (2015) and Cole et al. (2005)
		Green Star	Australian GBC	2003	MCDM	GBCA (2015) and Roderick et al. (2009)
	New Zealand	Green Star NZ	New Zealand GBC	2007	MCDM	NZGBC (2015) and

						Leardini (2011)
South America	Brazil	LEED®-Brazil	Brazil GBC	2007	MCDM	USGBC (2014) and GBCB (2015)
		HQE™	Fundação Vanzolini	2014	MCDM	HQE™ (2015)
	Argentina	LEED®-Argentina	Argentina GBC	N/A	MCDM	(GBC (2015) and Cole (2001)

(Source: Elena et al. (2015))

As can be seen in the above (Table 2.3) a total of 57 SBATs were identified by the authors Elena et al. (2015) by adapting all of them from Haase (2013). To classify them into their respective regions, 2 SBATs from Africa, 14 SBATs from Asia, 45 SBATs from Europe, 7 SBATs from North America, 3 SBATs from Oceania, and 3 SBATs from South America. All of these assessment tools have their assessment categories and criteria which were developed as per their local context (CASBEE, LEED, BREEAM) and may adapt directly from the well-known assessment tools and also be extensively modified for relevant to their actual context (Green Star SA for Mauritius and Kenya). On the other hand, the same assessment tools were used by different countries like DGNB in Austria, Thailand, China, Bulgaria, the Czech Republic, Denmark, Germany, Greece, Hungary, Poland, Russia, Spain, Switzerland, Ukraine, and Turkey.

The most important and internationally predominant SBATs as described by the authors (Saleh (2012); Ali (2009); and Forsberg (2004) are BREEAM, CASBEE, CEPAS, DGNB, GBI, Green Mark-Singapore, Green Star SA, HQE^{TM}-France, LEED and SBTool^{PT}- Portugal.

2.3.1.1. Building Research Establishment Environmental Assessment Methodology (BREEAM)

BREEAM (2011) has explained that BREEAM has established a foundation for best practices in sustainable design leading it to become the most effective scheme around the world for the measurement and description of the environmental performance of a building. As stated by Elena (2017), it is conceived in the UK in 1988 by the Building Research Establishment (BRE), and the Building Research Establishment Environmental Assessment Methodology (BREEAM) was launched in 1990 and utilizes a fixed weighting system. On the other hand, Prior (2019) pointed out that BREEAM is leading the list of sustainability assessments; and between 2013 and 2017, over 10,800 certified assessments were issued at both the design and post-construction stages.

In addition to this, Haroglu (2013) and Cooper (2011) have also said that 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 as described by Lu (2020).

Nowadays, it is being used in approximately 556,600 accredited buildings worldwide, and since its introduction in 1990, more than two million buildings were registered for assessment as depicted by Elena (2017). In addition to this, Elena (2017) illustrated that the BREEAM is composed of ten (10) categories describing sustainability through fifty-one (51) criteria in total, and a percentage-weighting factor is assigned to each category, and the overall number of one hundred twelve (112) available credits is proportionally assigned. The following Table 2.4 shows the BREEAM category and criteria for building assessments.

Table 2.4: BREEAM Category and Criteria for Building assessment (Minimum standards)

S/No.	Category	Criteria
1.	**Management:** The implementation of sustainable and responsible approaches to design, construction, commissioning, transfer, and care is encouraged by this category. This guarantees that solid sustainability goals are established and carried out in the building's operation. This section's issues center on how to integrate sustainability into the crucial phases of design, purchasing, and initial occupation, from the project's early scoping phase through the necessary aftercare service.	Man 01: Project brief and design
		Man 02: Planning for life cycle expenses and service lifetime
		Man 03: Responsible construction practices
		Man 04: Commissioning and handover
		Man 05: Aftercare
2.	**Health and wellbeing:** This category encourages the increased health, well-being, and safety of building users.	Hea 01: Visual comfort
		Hea 02: Indoor air quality
		Hea 03: Safe containment in laboratories
		Hea 04: Thermal comfort
		Hea 05: Acoustic performance
		Hea 06: Security
		Hea 07: Safe and healthy surroundings
3.	**Energy:** This category encourages the specification and design of energy-efficient building solutions, systems, and equipment that support the sustainable use and management of energy during the building's operation. Issues in this section assess measures to improve the inherent energy efficiency of the building,	Ene 01: Energy monitoring
		Ene 02: External lighting
		Ene 03: Low carbon design
		Ene 04: Energy-efficient cold storage
		Ene 05: Energy efficient transportation systems
		Ene 06: Energy efficient

	encourage the reduction of carbon emissions and support efficient management throughout the operational phase of the building's life.	laboratory systems Ene 07: Energy-efficient equipment
4.	**Water:** This category encourages sustainable water use in the operation of the building and its site. Issues in this section focus on identifying means of reducing potable water consumption (internal and external) over the lifetime of the building and minimizing losses through the leakage.	Wat 01: Water consumption Wat 02: Water monitoring Wat 03: Water leak detection Wat 04: Water-efficient equipment
5.	**Material:** This category encourages decisions that reduce the environmental and social impact of construction products used on a project. The issue focuses on construction product efficiency, environmental impact, responsible sourcing, and product durability.	Mat 01: Assessment of the environmental effects of construction items and buildings (LCA) Mat 02: Construction product environmental effects - Environmental Product Declarations (EPD) Mat 03: Responsible sourcing of construction products Mat 04: Insulation Mat 05: Designing for durability and resilience Mat 06: Material efficiency
6.	**Waste:** This section encourages the reduction of waste from construction and throughout the lifetime of the building. During construction, it supports sustainable behaviors such as trash reporting, minimization, and landfill diversion while also rewarding sustainable waste management. In addition to this, it encourages waste minimization through optimized design methods, which consider current and future needs, and respond to functional requirements and climate change adaptation.	Wst 01: Construction waste management Wst 02: Use of recycled and sustainably sourced aggregates Wst 03: Operational waste Wst 04: Speculative finishes (Offices only) Wst 05: Adaptation to climate change Wst 06: Design for disassembly and adaptability
7.	**Transport:** This category encourages the	Tra 01: Transport assessment

	provision of improved access to local amenities and to sustainable means of transport, i.e. for building users, public transportation, and other alternative transportation options.	and travel plan
		Tra 02: Sustainable transport measures
8.	**Land Use and Ecology:** This category encourages sustainable land use, habitat protection and creation, and improvement of long-term biodiversity for the building's site and surrounding land. Issues in this section relate to the reuse of brownfield sites or those of low ecological value, mitigation and enhancement of ecology, and long-term biodiversity management.	LE 01: Site selection
		LE 02: Ecological risks and opportunities
		LE 03: Managing impacts on ecology
		LE 04: Ecological change and enhancement
		LE 05: Long-term ecological management and maintenance
9.	**Pollution:** This area deals with the prevention and management of surface water runoff and pollution caused by the building's use and location. By addressing issues like light pollution, noise, flooding, and emissions to the air, land, and water, this section hopes to lessen the building's negative effects on the communities and environments in the area.	Pol 01: Impact of refrigerants
		Pol 02: Local air quality
		Pol 03: Flood and surface water management
		Pol 04: Reduction of nighttime light pollution
		Pol 05: Reduction of noise pollution
10.	**Innovation:** The innovation category provides opportunities for exemplary performance and innovation to be recognized that are not included within, or go beyond, the requirements of the credit criteria.	Inn 01: Innovation

(Source: BREEAM UK New Construction Non-Domestic Buildings (United Kingdom) Technical Manual SD5078: BREEAM New Construction 2018 3.0)

A BREEAM assessment uses recognized measures of performance, which are set against established benchmarks, to evaluate a building's specification, design, construction, and use Basnet (2017).

As evidenced by BREEAM (2011a), the BREEAM ratings and grading are displayed in (Table 4.5).

Table 2.5: BREEAM rating benchmarks

Assessment Level	Scoring Scale
Outstanding	X ≥ 85
Excellent	70 ≤ X < 85
Very Good	55 ≤ X < 70
Good	30 ≤ X < 55
Pass	X < 30

(Source: BREEAM (2011a)

The BREEAM rating tools have certified different types of buildings (Education & Healthcare, Industrial, Mixed Use & Other Buildings and Offices – In-Use) based on the assessment category and criteria.

2.3.1.2. Comprehensive Assessment System for Built Environment Efficiency (CASBEE)

A method for assessing and ranking the environmental performance of buildings and the built environment is called the Comprehensive Assessment System for Built Environment Efficiency (CASBEE). It's a thorough evaluation of a building's quality, considering environmentally friendly practices such as using resources and machinery that minimize environmental loads or conserve energy, as well as aspects like interior comfort and scenic aesthetics.

The goal of CASBEE is to improve people's quality of life while lowering environmental loads and life-cycle resource consumption related to the physical environment, from a single house to an entire city. As a result, numerous CASBEE programs are being implemented throughout Japan with assistance from both the federal and local governments. Construction (dwellings and buildings), urban (urban developments), and urban management assessment tools are all part of CASBEE. These tools are collectively known as the CASBEE Family CASBEE (2021).

CASBEE for New Construction (NC) was the first assessment tool, published in 2003. There is now a range of rating tools available, covering: houses, new construction, existing buildings, renovation and temporary construction, heat island relaxation, schools, urban development, and cities. Based on the concept of CASBEE as noted by CASBEE (2021), the following three guiding concepts are served as the foundation for the creation of the CASBEE evaluation tools:

- Thorough evaluation throughout the building's life;

- The assessment of the built environment's load and quality; and
- Using the recently introduced Built Environment Efficiency (BEE) metrics for assessment.

The authors Muhammad (2019) have elaborated that CASBEE has been widely used in Japan via various scales of assessment tools CASBEE-Buildings for individual buildings, since 2011, more than 1,500 Japanese cities have participated in the CASBEE-Urban Development for urban compounds and the CASBEE-City for cities and municipalities. The authors Murakami (2011) have also explained that the basic concept of CASBEE applies "a unique assessment framework that takes into account the concept of environmental efficiency which is different from a simple summation of points or credits awarded in all performance areas".

In addition to this, the authors Muhammad (2019) and Cole (2005) said that this type of environmental efficiency assessment framework provides a different insight into the built environment performance assessment compared with conventional assessment methods. By dividing the increase in Quality of Life (Q) indicators by the decrease in carbon emission or load (L) emitted outside of the city's boundary, CASBEE calculates the comprehensiveness of Built Environment Efficiency (BEE), which is how it takes into account the efficiency improvement of the built environment. As noted CASBEE (2021), the success of CASBEE-City in Japan, has brought the expansion of the assessment for worldwide city use. CASBEE-City worldwide version was developed in 2015 and its assessment indicators comprise international indicators developed from the Sustainable Development Goals (SDGs) and ISO 37120:2014 Sustainable Developments of Communities (ISO) by the United Nations (UN).

Environmental Labeling Using Building Environmental Efficiency (BEE)

As in CASBEE (2004), the BEE (Building Environmental Efficiency), using Q and L as the two assessment categories, is the core concept of CASBEE. BEE, as used here, is an indicator calculated from Q (building environmental quality and performance) as the numerator and L (building environmental loadings) as the denominator.

$$Building\ Environmental\ Efficiency\ (BEE) = \frac{\text{Q (Building environmental quality and performance)}}{\text{L (building environmental loadings)}} \ldots\ldots(2.1)$$

Buildings are evaluated using CASBEE, which takes into account interior comfort, landscape consideration, and environmental consciousness (utilize energy-saving materials and equipment, or those that cause smaller environmental loads).

The CASBEE (2004) has remarked that the BEE is ranked in five grades Poor (C), Fairly Poor (B-), Good (B+), Very Good (A), and Excellent (S) which is shown in Table 2.6 and Figure 2.5 below.

Table 2.6: The rating/grading system of CASBEE

Assessment Level	**Scoring Scale (BEE)**
Excellent	$X > 3.0^a$
Very Good	$1.5 \le X < 3.0$ OR $X > 3.0^b$
Good	$1.0 \le X < 1.5$
Fairly Poor	$0.5 \le X < 1.0$
Poor	$X < 0.5$

a and $Q \ge 50$, b and $Q < 50$
(Source: CASBEE (2004))

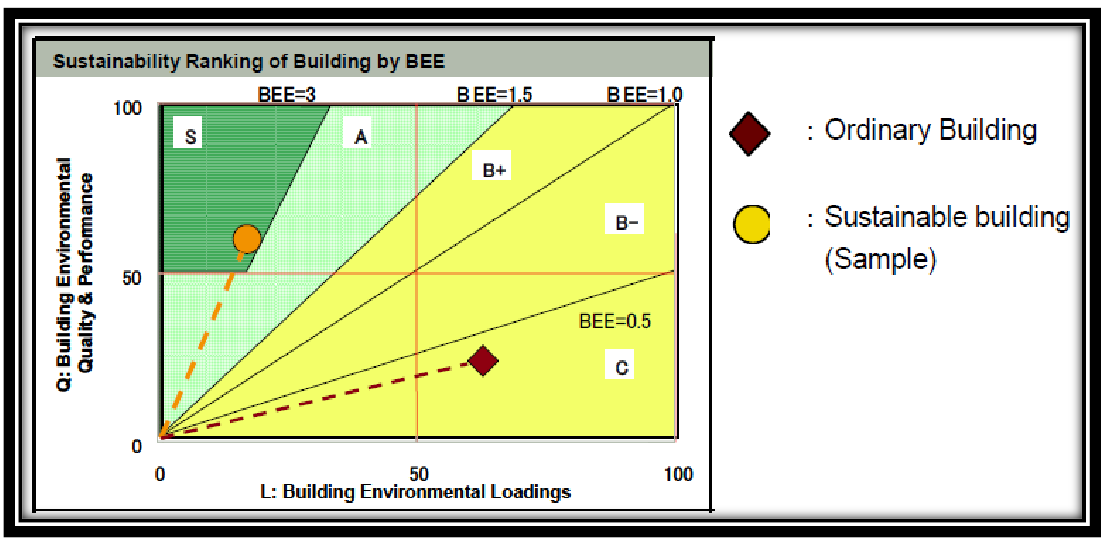

Table 2.5: Environmental labeling based on Building Environmental Efficiency (BEE)

(Source: CASBEE (2004))

Assessment Criteria of CASBEE

According to CASBEE (2004) there are two key assessment categories for the built environment: Quality (Q), the built environment's quality and performance, and Load (L), the built environment's load. The improvement in living amenities for building residents "inside the imagined enclosed space (the private property)" is measured by the built environment quality, or quality (Q). On the other hand, the built environment load looks at "negative aspects of environmental damage which reach beyond the hypothetical enclosed space to the outside (the public property)."

Additionally; the other authors Wan Zahari (2014) have explained in detail that CASBEE evaluates the environmental efficiency of the building by considering two spaces divided by the virtual boundary of the premises borders of the building and uses the letter Q to denote the efficiency and quality of the environment inside the border, i.e. inside the building and on the property, with L for Loading used for environmental obligations that extend beyond the boundary. However, CASBEE is also functioning following the evaluation standard viz. indoor environment, quality of services, outdoor environment on-site, energy, resources, and materials, reuse, and reusability. As shown in Figure 2.6 below, the CASBEE has six (6) assessment criteria under the two (2) categories mentioned above CASBEE (2009).

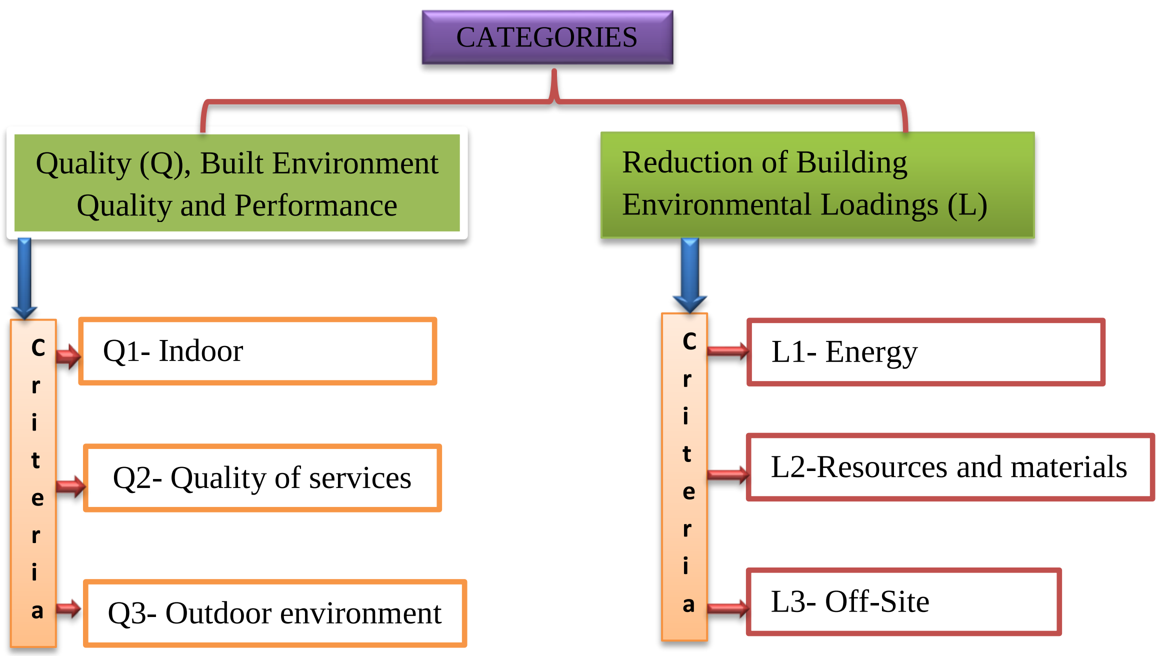

Figure 2.6: CASBEE assessment criteria

(Source: CASBEE (2009))

The CASBEE assessment categories and criteria have been identified by CASBEE (2004), and they are clearly shown in Table 2.7 below.

Table 2.7: CASBEE main category, sub-category, main criteria, and sub-criteria for Building assessments for existing building

Main-Category	Sub-Category	Main-Criteria	Sub- criteria
Quality (Q), Built Environment Quality and Performance	Q1. Indoor Environment	1. Noise and Acoustics	1.1. Noise
			1.2. Sound insulation
			1.3. Sound absorption
		2. Thermal Comfort	2.1. Room temperature control
			2.2. Humidity control
			2.3. Type of air conditioning system
		3. Lighting and Illumination	3.1. Daylighting
			3.2. Anti-glare measures
			3.3. Illuminance level
			3.4. Lighting controllability
		4. Air Quality	4.1. Source control
			4.2. Ventilation
			4.3. Operation plan
	Q2. Quality of Service	1. Service Ability	1.1. Functionality and usability
			1.2. Amenity
		2. Durability and Reliability	2.1. Earthquake-resistance
			2.2. Service life of components
			2.3. Reliability
		3. Flexibility and Adaptability	3.1. Spatial margin
			3.2. Floor load margin
			3.3. Adaptability of facilities
	Q3. Outdoor Environment on Site	1. Preservation and Creation of Biotope	
		2. Townscape and Landscape	-
		3. Local Characteristics and Outdoor Amenity	3.1. Attention to local character and improvement of

			comfort
			3.2. Improvement of the thermal environment on site
LR: Reduction of Building Environmental Loadings	LR1. Energy	1. Building thermal load	-
		2. Natural energy utilization	2.1. Direct use of natural energy
			2.2. Converted use of renewable energy
		3. Efficiency in the building service system	3.1. HVAC system
			3.2. Ventilation system
			3.3. Lighting system
			3.4. Hot water supply system
			3.5. Elevators
			3.6. Equipment for improving energy efficiency
		4. Efficient operation	4.1. Monitoring
			4.2. Operational management system
	LR2. Resources and Materials	1. Water resources	1.1. Water saving
			1.2. Rainwater and gray water
		2. Materials of low environmental load	2.1. Recycled materials
			2.2. Timber for sustainable forestry
			2.3. Materials with low health risks
			2.4. Reuse of existing building structure, etc.
			2.5. Reusability of components and Materials
			2.6. Use of CFCs and halons
	LR3. Off-site Environment	1. Air pollution	-
		2. Noise, vibration,	2.1. Noise & vibration

		and odor	2.2. Odors
		3. Wind damage and sunlight obstruction	-
		4. Light pollution	-
		5. Heat island effect	-
		6. Load on local infrastructure	-

(Source: CASBEE (2004))

2.3.1.3. Comprehensive Environmental Performance Assessment Scheme (CEPAS)

To develop a system for designating green buildings, Hong Kong launched the Comprehensive Environmental Performance Assessment Scheme (CEPAS) in accordance with the 2001 Government Policy Objectives. In 2007, the tool became publicly available for self-assessment as noted Alimalk (2007).

According to CEPAS (2021), CEPAS is devised to provide a measure to evaluate the environmental performance of all building types in Hong Kong. The overarching objective of CEPAS is to advance the existing ecological performance of buildings in Hong Kong and to adhere to the worldwide shift to sustainable building.

Pre-design, design, construction, and operation are the four main stages of the building life cycle that the CEPAS framework provides building environmental performance evaluation for. The CEPAS (2021) has identified eight (8) categories and twenty (20) criteria, and twenty-four (24) sub-criteria as shown in Table 2.8 below. The eight categories include indoor environmental quality, building amenities, resources use, loadings, site amenities, neighborhood amenities, site impacts, and neighborhood impacts. Although there isn't a specific category for sustainability, CEPAS mostly handles the problem in the resource-use and building amenities categories. CEPAS examines water conservation and preservation in several methods, including facilities that reduce pollution, the amount of recycled water used in buildings, and the source of the water. It calculates what percentage of the building materials comes from environmentally preferred sources and when various provisions are in place to encourage energy efficiencies, such as design consideration and shading devices. CEPAS also assesses the long-term sustainability of the building by looking for optimization of utilities, building management and reusability, pollution, and site location Alimalk (2007).

The building is examined from its features and design to its cultural influence, administration, and contribution to the neighborhood and local ecosystem. Each category has prerequisites as well as a weighting scheme that takes into account the particular requirements and values of Hong Kong. As the authors Alimalk (2007) remarked that the scope of CEPAS, however, might work against encouraging sustainable design methods. In Hong Kong, CEPAS is not yet widely used or well-known, and no buildings have received certification.

Table 2.8: The CEPAS assessment category, criteria, and sub-criteria for existing buildings

S/No.	Category	Criteria	Sub-Criteria
1.	Indoor Environmental Quality (IEQ)	IEQ1: Health and Hygiene	IEQ1.1: Health and Hygiene
		IEQ2: Indoor Air Quality	IEQ2.1: Indoor Air Quality Strategies
		IEQ3: Lighting Environment	IEQ3.1: Visual Quality and Comfort
2.	Building Amenities (BA)	BA1: Safety	
		BA2: Management	BA2.1: Building Management
3.	Resources Use (RE)	RE1: Energy Efficiency	RE1.1: Energy Efficiency
		RE2: Water Conservation	RE2.1: Water Conservation Strategies
		RE3: Timber Use	RE3.1: Timber for Temporary Use
			RE3.2: Minimization of Timber Use
		RE4: Material Use	RE4.1: Recycled Material Use
			RE4.2: Construction Waste Recycling
			RE4.3: Demolition Waste Recycling
			RE4.4: Environmentally-Friendly Materials
4.	Loadings (LD)	LD1: Pollution	LD1.1: Air Pollution
			LD1.2: Water Pollution
			LD1.3: Noise Pollution
		LD2: Waste Management	LD2.1: C and D Waste Management
5.	Site Amenities (SA)	SA1: Landscape	SA1.1: Tree Preservation
		SA2: Security	SA2.1: Security
6.	Neighborhood Amenities (NA)	NA1: Environmental Economics	NA1.1: Environmental Economics
7.	Site Impacts (SI)	SI1: Nature Conservation	SI1.1: Natural Conservation
		SI2: Heritage Conservation	SI2.1: Heritage Conservation
		SI3: Buildability	SI 3.1: Buildability
8.	Neighborhood Impacts (NI)	NI1: Environment Impact Assessment	
		NI2: Environmental Interactions	NI 2.1: Environmental Nuisance
		NI3: Impact on communities	NI 3.1: Impact on communities

(Source: CEPAS (2021))

2.3.1.4. The Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB)

The authors Pombinho (2013) and Schmidt (2012) have pointed out that the DGNB system was developed by the German Sustainable Building Council (DGNB) together with the Federal Ministry of Transport, Building and Urban Affairs (FMoTBUA) to be used as a tool for the planning and evaluation of buildings with a comprehensive perspective on quality.

The other authors Pombinho (2013); Kibert (2012) and Araújo (2008) have also identified that the purpose of the DGNB was to create a second-generation certification system, which emphasizes an integrated view over the whole life-cycle of the building and with focus on the following main groups of criteria that affect the evaluation: ecological, economic, sociocultural, and functional subjects, methods, procedures, and settings.

On the other hand, Pombinho (2013) and DGNB (2009) has stipulated that the DGNB is an arranged and easy-to-understand rating system, covering all the relevant topics of sustainable construction and awards outstanding buildings in the categories with bronze, silver, and gold.

In addition to this, Pombinho (2013) and Kibert (2012) have identified that the DGNB certification system was initially developed for new office and administration buildings, in 2008. This version emerged from the pilot phase of the system and the sustainability of office and administration buildings was evaluated based on forty-two (42) assessment criteria. The author Kibert (2012) has also pointed out that the current version considers a total of sixty-three (63) criteria but only uses forty-eight (48), because of the scientific principles fifteen (15) criteria are currently being developed. This shows that the DGNB system is very flexible as different buildings have different characteristics and requirements that need to be taken into account.

The objective of the DGNB assessment is to identify built environment solutions that are environmentally friendly, resource-efficient, and economically optimized, which therefore integrate the ecological, economic, and social dimensions of sustainable building.

The DGNB scoring and rating system are based on the performance of six (6) evaluation areas, the topics, with fixed relative importance as mentioned by Araújo (2008). These topics are weighted in the following way: Ecological Quality: 22.5%; Economical Quality: 22.5%; Socio-cultural and functional Quality: 22.5%; Technical Quality: 22.5%; Quality of the Process: 10%; and Quality of the Location: this topic is not included in the final grade but presented separately.

Depending on the degree of compliance, the author Araújo (2008) suggested that the evaluated buildings are awarded the gold, silver, or bronze certification as shown in Table 2.9 below.

Table 2.9: DGNB rating scale and performance

S/No.	Scoring Scale	Assessment Level
1	65 < X ≤ 80%	Gold
2	50 < X ≤ 65%	Silver
3	35 < X ≤ 50%	Bronze
4	X = 35%	Certified

(Source: Araújo (2008))

The authors Pombinho (2013); Kibert (2012); and Araújo (2008) have clearly stated that the grades are given for the overall performance of the building as well as for the individual topics. The following Table 2.10 illustrates the DGNB building assessment categories and criteria Pombinho (2013).

Table 2.10: DGNB building assessment categories and criteria

S/No.	Category	Criteria
1.	Ecological Quality	Global warming potential
		Ozone depletion potential
		Photochemical ozone creation potential
		Acidification potential
		Eutrophication potential
		Risks to the regional environment
		Other impacts on the global environment
		Microclimate
		Non-renewable primary energy demands
		Total primary energy demands and proportion of renewable primary energy
		Potable water consumption and sewage generation
		Surface area usage
2.	Economical Quality	Building-related life cycle costs
		Value stability
3.	Socio-Cultural and Functional Quality	Thermal Comfort in winter
		Thermal Comfort in summer
		Indoor Hygiene
		Acoustical Comfort
		Visual Comfort
		Influences by users
		Roof design

		Safety and risks of failure
		Barrier-free accessibility
		Area efficiency
		Feasibility of conversion
		Accessibility
		Bicycle comfort
		Guarantees of design excellence and urban development for competition
		Art within Architecture
4.	Technical Quality	Fire protection
		Noise protection
		The building's shell's energetic and moisture-proofing qualities
		Ease of Cleaning and Maintenance of the Structure
		Ease of deconstruction, recycling, and dismantling
5.	Quality of the Process	Quality of the project's preparation
		Integrated planning
		Optimization and complexity of the approach to planning
		Proof that sustainability was taken into account while inviting and selecting the winning bid
		Establishment of preconditions for optimized use and operation
		Construction site, construction phase
		Quality of executing companies, pre-qualifications
		Quality assurance of the construction activities
		Systematic commissioning

(Source: Pombinho (2013))

Advantages of the DGNB Certification Systems

The DGNB certification system has a set of advantages as demonstrated by the authors Pombinho (2013); Kibert (2012) and Farias (2010). These are: the certificate demonstrates the positive effects of a building on the environment and society; the certification provides, in an early stage, a high degree of certainty that the goals, in terms of the performance of the building, can be achieved at the time of completion; as the system is present in all stages of the construction, it leads to more transparency and well-defined processes, minimizing the risks during construction, operation, renovation, and removal; the certificate supports owners and designers in a globally oriented way for the development of sustainable/green buildings; it is based on the life cycle of a building; the German certificate is not only about the ecological aspects but also the economic performance, as well as socio-cultural and functional aspects of buildings and the certificate system can flexibly be updated which is simply flexible to technical, social, and international improvements.

2.3.1.5. The Green Building Index (GBI)-Malaysia

According to the GBI (2011), Green Building Index is defined as an environmental rating system for buildings developed by PAM (Pertubuhan Arkitek Malaysia/ Malaysian Institute of Architects) and ACEM (the Association of Consulting Engineers Malaysia) and is officially launched on August 2008. The authors Saifudin (2014) have clearly stated that the GBI Non-Residential Rating tool evaluates the sustainable aspects of buildings that are commercial, institutional, and industrial and includes factories, offices, hospitals, universities, colleges, hotels, and shopping complexes. The GBI is Malaysia's first comprehensive rating system for evaluating the environmental design and performance of Malaysian buildings based on the six (6) main categories of Energy Efficiency, Indoor Environment Quality, Sustainable Site Planning and Management, Materials and Resources, Water Efficiency, and Innovation.

Additionally, this GBI initiative also pointed out that the GBI is fundamentally derived from existing rating tools, including the Singapore Green Mark and the Australian Green Star system, but heavily altered to be relevant to the tropical climate, environmental surroundings, and cultural, and social needs of Malaysia. Moreover; this GBI environmental rating system was created for the following reasons as noted by the GBI initiative: define green building by establishing a common language and standard of measurement; promote integrated, whole-building design; recognize and reward environmental leadership; transform the built environment to reduce the environmental impact of development; and ensure new buildings remain relevant in the future and existing buildings are refurbished and thereafter sustained properly to remain relevant.

Assessment category and criteria for the GBI

The GBI sustainable building assessment categories are listed in Table 2.11 below, along with the maximum points allotted for each category GBI (2011).

Table 2.11: Assessment category and maximum allocated points

S/No.	Category	Maximum allocated Points
1.	Energy Efficiency	38
2.	Indoor Environmental Quality	21
3.	Sustainable Site Planning and Management	10

4.	Material and Resources	9
5.	Water Efficiency	12
6.	Innovation	10
	Total Score	**100**

(Source: GBI (2011))

The GBI initiative has also developed six (6) categories, seventeen (17) criteria, and forty-five (45) indicators for the assessment of the buildings from the sustainability points of view as shown in Table 2.12 below GBI (2011).

Table 2.12: The GBI categories, criteria, and indicators for building assessments

S/No.	Category	Criteria	Indicators
1.	EE: Energy Efficiency	EE1: Design and Performance	EE11: Minimum EE Performance
			EE12: Lighting Zoning
			EE13: Electrical sub-metering and Tenant sub-metering
			EE14: Renewable Energy
			EE15: Advanced or Improved EE Performance
		EE2: Commissioning	EE21: Enhanced Commissioning of Building Energy Systems
			EE22: Post Occupancy Commissioning
		EE3: Monitoring, Improvement, and Maintenance	EE31: EE Monitoring & Improvement
			EE32: Sustainable Maintenance
2.	IEQ: Indoor Environmental Quality	IEQ 1: Air Quality	IEQ 11: Minimum IAQ Performance
			IEQ 12: Environmental Tobacco Smoke (ETS) Control
			IEQ 13: Carbon Dioxide Monitoring and Control
			IEQ 14: Indoor Air Pollutants
			IEQ 15: Mould Prevention
		IEQ 2: Thermal Comfort	IEQ 21: Thermal Comfort: Controllability of Systems
			IEQ 22: Air Change Effectiveness
		IEQ 3: Lighting, Visual, and Acoustic Comfort	IEQ 31: Daylighting
			IEQ 32: Daylight Glare Control
			IEQ 33: Electric Lighting Levels
			IEQ 34: High-Frequency Ballasts
			IEQ 35: External Views

			IEQ 36: Internal Noise Levels
		IEQ 4: Verification	IEQ 41: IAQ Before/During Occupancy
			IEQ 42: Occupancy Comfort Survey: Verification
3.	SSPM: Sustainable Site Planning and Management	SSPM 1: Facility Management	SSPM 11: GBI-Rated Design and Construction
			SSPM 12: Building Exterior Management
			SSPM 13: Integrated Pest Management, Erosion Control, and Landscape Management
		SSPM 2: Transportation	SSPM 21: Green Vehicle Priority - Low Emitting and Fuel-Efficient Vehicles
			SSPM 22: Parking Capacity
		SSPM 3: Reduce Heat Island Effect	SSPM 31: Greenery and Roof
			SSPM 32: Building User Manual
4.	MR: Materials and Resources	MR1: Reused and Recycled Materials	MR11: Materials Reuse and Selection
			MR12: Recycled Content Materials
		MR2: Sustainable Materials and Resources and Policy	MR21: Sustainable Timber
			MR22: Sustainable Purchasing Policy
		MR3: Waste Management	MR31: Storage, Collection, and Disposal of Recyclables
			MR32: Construction waste management
		MR4: Green Products	MR41: Refrigerants & Clean Agents
5.	WE: Water Efficiency	WE1: Water Harvesting and Recycling	WE11: Rainwater Harvesting
			WE12: Water Recycling
		WE2: Increased Efficiency	WE21: Water Efficient - Irrigation/Landscaping
			WE22: Water-Efficient Fittings
			WE23: Metering and Leak Detection System
6.	IN: Innovation	IN1: Innovation	IN11: Innovation and Environmental Initiatives
			IN12: Green Building Index Facilitator

(Source: GBI (2011))

As can be seen in (Table 2.13) below, the GBI initiative has developed the buildings rating classifications based on the assessment categories, criteria, and indicators described in (Table 2.12) above that buildings scored GBI (2011).

Table 2.13: The GBI assessment points and ratings

S/No.	Scoring Scale	Assessment Level
1.	$85 < X \leq 100$	Platinum
2.	$75 < X \leq 85$	Gold
3.	$66 < X \leq 75$	Silver
4.	$50 < X \leq 65$	Certified

(Source: GBI (2011))

2.3.1.6. The Green Mark- Singapore

The BCA (2015) identified that the “Green Mark” scheme was launched in January 2005 to encourage the construction of more environmentally friendly buildings by the Singapore industry. The National Environment Agency (NEA) is one of the ministerial organizations in Singapore that has accepted and sponsored the "Green Mark." According to the Building Construction Agency BCA (2015), it offers a thorough framework for evaluating the entire environmental performance of both new and existing buildings to advance environmentally friendly building design, construction, and operating methods. Its goal is to advance the built environment's sustainability and increase environmental consciousness among project developers, consultants, and contractors both before and during construction.

Various energy-efficient and ecologically responsible techniques and elements that may be incorporated into construction works and projects are given points under the scheme's assessment system. These characteristics have to be more environmentally friendly than what is often used in ordinary constructions.

The authors Chieh (2011) noted that there are four (4) different ratings of GM certification: Green Mark Certified (GMC), Green Mark Gold (GMG), Green Mark Gold Plus (GMGP), and Green Mark Platinum (GMPL). The building that is evaluated under this scheme (after an application to that effect has been made) is based on a maximum of one hundred fifty-five (155) points awarded in each of the five (5) categories as shown in Table 4.14 and a score is also given as per the points earned as specified in Table 4.15.

Table 2.14: GM-Buildings evaluation categories, criteria, and point allocations

S/No.	Category	Criteria	Point Allocations
1.	Energy Efficiency	1.1. Thermal Performance Building Envelope	15
		1.2. Naturally Ventilated Design and Air-Conditioning System	22
		1.3. Daylighting	6
		1.4. Artificial Lighting	10
		1.5. Ventilation in Car Parks	6
		1.6. Lifts	1
		1.6. Energy-Efficient Features	7
		1.7. Renewable Energy	20
		Category Score	**87**
2.	Water Efficiency	2.1. Water-Efficient Fittings	10
		2.2. Water Usage Monitoring	1
		2.3. Irrigation System and Landscaping	3
		Category Score	**14**
3.	Environmental Protection	3.1. Sustainable Construction	10
		3.2. Sustainable Products	8
		3.3. Greenery Provision	8
		3.4. Environmental Management Practice	8
		3.5. Green Transport	4
		3.6. Storm Water Management	3
		Category Score	**41**
4.	Indoor Environmental Quality	4.1. Sound Level	1
		4.2. Interior Air Contaminants	2
		4.3. Leftover Removal	1
		4.4. Interior Air Eminence in Wet Spaces	2
		Category Score	**6**
5.	Other Green Features	5.1. Green Structures & Inventions	7
		Category Score	**7**
Green Mark Score			**155**

(Source: Chieh (2011))

Table 2.15: Green Mark Scores and Ratings

S/No.	Scoring Scale	Assessment Level
1.	$X \geq 90$	Green Mark Platinum
2.	$85 \leq X < 90$	Green Mark Gold Plus
3.	$75 \leq X < 85$	Green Mark Gold
4.	$50 \leq X < 75$	Green Mark Certified

(Source: Chieh (2011))

2.3.1.7. Green Star SA (South Africa)

A proactive sustainability rating system called Green Star SA assesses how environmentally friendly a building's design and construction are. Green Star SA tools were developed in 2013 to provide the property industry with an objective measurement for green buildings and to recognize and reward environmental leadership in the property industry Mauritius (2017).

The Green Building Council of Australia (GBCA) has granted the Green Building Council of South Africa (GBCSA) permission to use the Green Star SA grading tools for certification only in South Africa, Ghana, Namibia, Uganda, Nigeria, Kenya, Mauritius, and Rwanda Mauritius (2017).

A natural connection point for green construction initiatives and authorities in other parts of Africa is the Green Star SA rating system. Working along with newly formed sustainable building councils across Africa, the GBCSA permits the adoption of the Green Star SA methods for accreditation in the aforementioned nations Mauritius (2017).

The objectives of the Green Star SA building rating tools include: establishing a common language and standard of measurement for green buildings; promoting integrated, whole-building design; raising awareness of green building benefits; reducing the environmental impact of development; and recognizing environmental leadership.

The GBCSA (2012) and Mauritius (2017) have identified that Green Star SA consists of nine (9) separate environmental impact categories under which specific key ninety-four (94) criteria are grouped and assessed as shown in Table 4.16 below. These nine (9) categories are management, indoor environment quality (IEQ), energy, transport, water, materials, land use and ecology, emissions, and innovation.

Table 2.16: Green Star SA category and Criteria

S/No.	Category	Criteria
	Management (Man)	Man-01: Green Star SA accredited professional
		Man-02: Commissioning clauses
		Man-03: Building tuning
		Man-04: Independent commissioning agent
		Man-05: Building user’s guide

		Man-06: Environmental management
		Man-07: Waste management
		Man-08: Airtightness testing
		Man-09: Waste recycling management plan
		Man-10: Building management system
		Man-11: Green lease
		Man-12: Common property rules
		Man-13: Learning resources
		Man-14: Life cycle costing
		Man-15: Maintainability
	Indoor Environmental Quality (IEQ)	IEQ-01: Ventilation rates
		IEQ-02: Air change effectiveness
		IEQ-03: Carbon dioxide monitoring and control
		IEQ-04: Daylight
		IEQ-05: Daylight glare control
		IEQ-06: High-frequency ballasts
		IEQ-07: Electric lighting levels
		IEQ-08: External views
		IEQ-09: Thermal comfort
		IEQ-10: Individual comfort control
		IEQ-11: Hazardous materials
		IEQ-12: Internal noise levels
		IEQ-13: Volatile organic compounds
		IEQ-14: Formaldehyde minimization
		IEQ-15: Mould prevention
		IEQ-16: Tenant exhaust riser
		IEQ-17: Environmental Tobacco Smoke (ETS) avoidance
		IEQ-18: Places of respite and connection to nature
		IEQ-19: Private outdoor space
		IEQ-20: Universal access
		IEQ-21: Stairs
	Energy (Ene)	Ene-0: Conditional requirement
		Ene-01: Greenhouse gas emissions
		Ene-02: Energy sub-metering
		Ene-03: Lighting power density
		Ene-04: Lighting zoning
		Ene-05: Peak energy demand reduction
		Ene-06: Thermal energy sub-metering
		Ene-07: Hot water energy use

		Ene-08: Common property energy use
		Ene-09: Low-emission energy generation
		Ene-10: Energy-efficient appliances
		Ene-11: Unoccupied spaces
	Transport (Tra)	Tra-01: Provision of car parking
		Tra-02: Fuel-efficient transport
		Tra-03: Cyclist facilities
		Tra-04: Commuting mass transport
		Tra-05: Local connectivity
		Tra-06: Trip reduction – mixed-use
		Tra-07: Vehicle operating emissions
	Water (Wat)	Wat-01: Occupant amenity water
		Wat-02: Water meters
		Wat-03: Landscape irrigation
		Wat-04: Heat rejection water
		Wat-05: Fire system water consumption
		Wat-06: Potable water-efficient appliances
	Materials (Mat)	Mat-01: Recycling waste storage
		Mat-02: Building reuse
		Mat-03: Reused materials
		Mat-04: Shell and core or integrated fit-out
		Mat-05: Concrete
		Mat-06: Steel
		Mat-07: PVC minimization
		Mat-08: Sustainable timber
		Mat-09: Design for disassembly
		Mat-10: Dematerialisation
		Mat-11: Local sourcing
		Mat-12: Efficient dwelling size
		Mat-13: Masonry
	Land Use and Ecology (Eco)	Eco-: Conditional requirement
		Eco-01: Topsoil
		Eco-02: Reuse of land
		Eco-03: Reclaimed contaminated land
		Eco-04: Change of ecological value
		Eco-05: Urban heat island
		Eco-06: Outdoor communal facilities
		Eco-07: Urban consolidation
		Eco-08: Community facilities

	Emissions (EMI)	Emi-01: Refrigerants/gaseous ozone-depleting potential (ODP)
		Emi-02: Refrigerants/gaseous global warming potential (GWP)
		Emi-03: Refrigerant leaks
		Emi-04: Insulant ODP
		Emi-05: Watercourse pollution
		Emi-06: Discharge to sewer
		Emi-07: Light pollution
		Emi-8: Legionella
		Emi-9: Boiler and generator emissions
		Emi-10: Kitchen exhaust emissions
	Innovation	Innovation

(Source: GBCSA (2012) and Mauritius (2017)

Accreditation is given for 4-Star, 5-Star, and 6-Star Green Star SA assessments. For all projects, the following Green Star SA certification ratings are available. These are the Weighted Score: of 45 to 59; for the 4 Star Green Star SA Certified Rating which is Best Practice and acknowledged; the Weighted Score of 60 to 74 for the 5 Star Green Star SA Certified Rating which is South African Excellence and recognized; and Weighted Score: 75 to 100 for the 6 Star Green Star SA Certified Rating which is Global Leadership and acknowledges.

A 1-3 Star rating can also be obtained and granted for the Green Star SA - existing building performance tool only, acknowledging that existing buildings have a long road to go before being green while occupied and in use.

2.3.1.8. Haute Qualité Environnementale (HQE™)

The Haute Qualité Environnementale standard, referred to by its acronym HQE™, was developed in 1994 in France by the HQE™ Association. This association supports stakeholders, designers, partners, developers, and users during the phases of the project, aiming to guarantee a high environmental quality of buildings. The HQE™ Association has developed a large number of schemes, exploitable both in France and outside France HQE™ (2015).

HQE™ 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

HQE™ evaluation implements a Multi-Criteria Decision Making (MCDM) approach and requires that a qualified professional called the “Référent" assist the assessment process HQE™ (2015).

HQE™ is an environmental assessment system, which is made of several assessment schemes. They are organized in one international scheme and three systems dedicated to France and addressed to non-residential buildings, residential buildings, and detached houses HQE™ (2015).

A healthy and welcoming indoor environment for their clientele is made possible by HQE®, which supports contracting authorities, architects, manufacturers, and business owners. Investors and real estate developers can use it as a metric to keep track of a building's or a portfolio's financial success.

The authors Bernardi (2015) have identified that the environmental performance requirements of the HQE™ are organized into four (4) categories and fourteen (14) criteria. These categories are quite the same for all building types instead the criteria are arranged differently for residential buildings or non-residential buildings as shown in (Table 2.17) below.

Table 2.17: HQE™ assessment category, and criteria for building assessments

S/No.	Category	Criteria
1.	Environment	Building's relationship with its immediate environment
		Quality of components
		Sustainable worksite
		Waste management
2.	Energy and Savings	Energy management
		Water management
		Maintenance management
3.	Comfort	Hygrothermal comfort
		Acoustic comfort
		Visual Comfort
		Olfactory comfort
4.	Health and Safety	Quality of spaces
		Air quality and health
		Water quality and health

(Source: Bernardi (2015))

The author Bernardi (2015) has clearly articulated that the evaluation rating performance scale is expressed in the number of stars, and the global performance level reached by the buildings is calculated based on the total number of stars obtained in each issue as shown in Table 2.18 below.

Table 2.18: HQE™ rating scale and minimum levels to achieve

S/No.	Assessment Level	Scoring scale (stars)
1.	HQE™ Exceptional	$X \geq 12^c$
2.	HQE™ Excellent	$9 \leq X \leq 11$
3.	HQE™ Very Good	$5 \leq X \leq 8$
4.	HQE™ Good	$1 \leq X \leq 4$
5.	HQE™ Pass	0^d

c with at least 3 stars for the energy theme
d but all pre-requirements have been successfully met

(Source: Bernardi (2015))

2.3.1.9. Leadership in Energy and Environmental Design (LEED)

Using strategies to improve performance across all the metrics that matter most—energy savings, water efficiency, CO_2 emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts—a building or community was designed and built using LEED, an internationally recognized green building certification system. The author Baharuddin (2012) has explained that LEED is a green building rating system developed by the United States Green Building Council (USGBC) to hasten the implementation of green building techniques.

The USGBC (2009a) has notified that as of June 2009, there were 3,111 certified and 24,769 registered projects worldwide. In addition to this, Baharuddin (2012) has also addressed that these figures exclude the use of adapted LEED systems i.e. LEED Canada and LEED India. Moreover; Baharuddin (2012) pointed out that in Canada and India, LEED rating systems have been adapted to accommodate local conditions, but of course, the main parts are still following the US system. In other countries such as China, Taiwan, Hong Kong, and Singapore, LEED rating systems have been adopted in their original form which means the same as the system applied in the U.S. practice as noted Baharuddin (2012).

The other authors Florez (2020) have explained that the USGBC created the LEED in 1998. After establishing a solid reputation among specialists, LEED has become the most widely used and respected rating system in the United States (US). It is frequently utilized by designers, engineers, and architects who aspire to receive LEED certification. The authors Florez (2020) have also said that since its creation as a voluntary standard measure, the LEED system has become an appropriate tool for the assessment of green buildings, being a model for such design, building, and management of sustainable buildings outside of the US.

In addition, the World Green Building Council (WGBC) states that adaptations of the LEED system have been developed or are in the process of implementation in Central and South America, Asia, the Middle East, and India among others. During the year 2018, LEED has issued over 78,000 certifications in more than 150 countries and it is considered the world's most widely adopted rating system based on the number of countries that have adopted it. Moreover; Florez (2020) depicted that LEED is a multi-attribute rating and certification system, which assesses different building types such as new construction, existing buildings, commercial interiors, core and shell, schools, retail, healthcare, homes, and neighborhood development. LEED also has mandatory prerequisites like minimum energy and water-use reduction, recycling collection, and tobacco smoke control. If the prerequisites are achieved, then a project can earn points in eight categories: sustainable site, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, location and transportation, regional priority, and innovation in design as shown in Table 2.19 below. Within each category, some credits pertain to specific strategies for sustainability, for instance, the use of low-emitting products, reduced water consumption, energy efficiency, access to public transportation, recycled content, renewable energy, and daylighting. Such credit uses a prescriptive and feature-oriented approach rather than a performance approach.

The author Florez (2020) has pointed out that even though all the sustainability criteria are assessed by LEED, the environmental factors are predominant within the eight categories and additionally, various economic aspects are indeed taken into account and are crucial to the categories.

The importance of LEED certification

Meeting the highest performance standards resulted in a LEED rating, this show a commitment to sustainability. Florez (2020) has described that LEED-certified buildings have the following benefits: use key resources more efficiently; contribute to a healthier work environment, higher productivity, and comfort; enhance asset value over time; encourage innovation of new technologies, products, materials, and equipment; establish national leadership in the building industry and marketplace; validate achievement through third party review process; qualify for a growing array of state and local government incentives; and contribute to growing green building knowledge base.

The design of LEED-accredited buildings makes them more resource-efficient as compared to conventional buildings that are just constructed to code.

Evaluation category, criteria, and certification level

The assessment categories and the criteria of LEED certification for existing buildings are described by LEED (2008) in detail as shown in Table 2.19 below.

Table 2.19: LEED category, and criteria for building assessments for existing buildings

S/No.	Category	Criteria
	Sustainable Sites (SS)	SS Credit 1: LEED-certified design and construction
		SS Credit 2: Hardscape and exterior building management plan
		SS Credit 3: Landscape management plan, erosion prevention, and pest and disease management
		SS Credit 4.1 – 4.4: Alternative commuting transportation
		SS Credit 5: Protection or restoration of open space with less site disruption
		SS Credit 6: Stormwater management
		SS Credit 7.1: Heat island reduction: Non-roof
		SS Credit 7.2: Heat island reduction: Roof
		SS Credit 8: Light pollution reduction
	Water Efficiency (WE)	WE Prerequisite 1: Minimum indoor plumbing fixture and fitting efficiency
		WE Credit 1.1 and 1.2: Water performance measurement
		WE Credit 2.1–2.3: Additional indoor plumbing fixture and fitting efficiency
		WE Credit 3.1–3.3: Water-efficient landscaping
		WE Credit 4.1 and 4.2: Control of central cooling water
	Energy and Atmosphere (EA)	EA Prerequisite 1: Energy efficiency best management practices: planning, documentation, and opportunity assessment
		EA Prerequisite 2: Minimum energy efficiency performance

		EA Prerequisite 3: Refrigerant management: Ozone protection
		EA Credit 1: Optimize energy efficiency performance
		EA Credit 2.1: Accreditation of existing buildings: research and analysis
		EA Credit 2.2: Existing building commissioning: Implementation
		EA Credit 2.3: Existing building commissioning: Ongoing commissioning
		EA Credit 3.1: Performance measurement: Building automation system
		EA Credit 3.2 and 3.3: Performance measurement: System-level measuring
		EA Credit 4.1 – 4.4: On-site and off-site renewable energy
		EA Credit 5: Refrigerant management
		EA Credit 6: Emissions reduction reporting
	Materials and Resources (MR)	MR Prerequisite 1: Sustainable purchasing policy
		MR Prerequisite 2: Solid waste management policy
		MR Credit 1.1–1.3: Sustainable purchasing: Ongoing consumables
		MR Credit 2.1–2.2: Sustainable purchasing: Durable goods
		MR Credit 3: Facility modifications and new features: Responsible procurement
		MR Credit 4: Sustainability in purchasing: Mercury-free lamps
		MR Credit 5: Sustainable purchasing: Food
		MR Credit 6: Waste stream audit in solid waste management
		MR Credit 7.1 and 7.2: Management of solid waste: Continual consumables
		MR Credit 8: Solid waste management: Durable goods
		MR Credit 9: Facility modifications and additions related to solid waste management
	Indoor Environmental Quality (IEQ)	IEQ Prerequisite 1: Outdoor air introduction and exhaust systems
		IEQ Prerequisite 2: Environmental tobacco smoke (ETS) Control
		IEQ Prerequisite 3: Green cleaning policy
		IEQ Credit 1.1: IAQ management program: IAQ best management practices
		IEQ Credit 1.2: IAQ best management practices: Monitoring outdoor air delivery

		IEQ Credit 1.3: Improved ventilation among IAQ Best management practices
		IEQ Credit 1.4: Eliminate particulate matter in air circulation: IAQ best management practices
		IEQ Credit 1.5: IAQ best management practices: Managing changes and additions to facilities
		IEQ Credit 2.1: Occupant comfort: Occupant survey
		IEQ Credit 2.2: Occupant comfort: Occupant-controlled lighting
		IEQ Credit 2.3: Occupant comfort: Thermal comfort monitoring
		IEQ Credit 2.4 and 2.5: Occupant comfort: Daylight and views
		IEQ Credit 3.1: High-efficiency cleansing method for green cleansing
		IEQ Credit 3.2 and 3.3: Green cleaning: Custodial effectiveness assessment
		IEQ Credit 3.4 and 3.6: Purchasing environmentally friendly cleaning supplies and equipment
		IEQ Credit 3.7: Green cleaning: Sustainable cleaning equipment
		EQ Credit 3.8: Green cleaning: Entryway systems
	Innovations in Operations	Innovation Credit 1.1 – 1.4: Innovation in operations
		Innovation Credit 2: LEED® accredited professional
		Innovation Credit 3: Documenting sustainable building cost impacts
	Location & Transportation (LT)	LT Credit 1: LEED for neighborhood development location
		LT Credit 2: Sensitive land protection
		LT Credit 3: High-priority site
		LT Credit 4: Surrounding density and diverse uses
		LT Credit 5: Access to quality transit
		LT Credit 6: Bicycle facilities
		LT Credit 7: Reduced parking footprint
		LT Credit 8: Green vehicles
	Regional Priority (RP)	RP Credit 1: Regional Priority

(Source: LEED (2008))

The LEED (2008) confirmed that the LEED certification can be achieved via a point system based on the above-mentioned Table 2.19 eight (8) key classification categories, sixty-six (66) criteria, and the values of weighting and the available credits for each assessment category has been listed in the Table 2.20 below.

Table 2.20: LEED for environmental weighting and credits for existing buildings

S/No.	Category	Credits available
1.	Sustainable Sites	9
2.	Water Efficiency	4-10
3.	Indoor Environmental Quality	16-20
4.	Material and Resources	9-14
5.	Energy and Atmosphere	13-30
6.	Location and Transportation	16
7.	Innovation in Operations	4-7
8.	Regional Priority	4
	Total	75-110

(Source: LEED (2008))

In LEED certification, existing buildings can qualify for four (4) levels of certification based on the evaluation criteria (the assigned credits/points that the buildings get) and the sum of the credits as shown in (Table 2.21) below LEED (2008).

Table 2.21: LEED for environmental weightings and credits/points for existing buildings

S/No.	Assessment Level	Scoring Scale
1.	Platinum	$X \geq 80$
2.	Gold	$60 \leq X \leq 79$
3.	Silver	$50 \leq X \leq 59$
4.	Certified	$40 \leq X \leq 49$

(Source: LEED (2008))

2.3.1.10. Sustainable Building Tool (SBTool)

SBTool is a software version of the Green Building Challenge (GBC) international assessment method, which has been under development since 1996 by the International Initiative for a Sustainable Built Environment (iiSBE). The system is based in Canada and includes teams from more than twenty-five countries as noted Alimal (2016).

As noted in the iiSBE (2007), the SBTool is defined as the GBC assessment method for rating the sustainable performance of buildings and projects. The iiSBE, (2007) and Larsson (2007) have pointed out that the SBTool covers a wide range of sustainable building concepts, and not just green buildings; it reflects socio-economic issues as well. The SBTool for buildings assesses a building's sustainability against seven (7) factors, the mandatory factors being energy and resource use, environmental loadings, and interior environmental stewardship. These include local climate, material use, and construction practices and techniques. The system is therefore a very useful international benchmarking tool, one that provides signals to local industry on the state of performance in the region, while also providing data for international comparisons.

Site selection, project planning and development, environmental loadings, energy and resource use, indoor environmental quality, functionality, long-term performance, and social and economic aspects are just a few of the categories that are covered by SBTool, as can be seen in Table 2.22 below. Buildings can receive a score of -1 if their performance falls below average practice, 0 for the least permissible level, or +3 to +5, which denotes good to extremely high performance, when evaluating criteria using scales based on local benchmarks of "typical" practices. A thorough evaluation of the building is provided through the scoring of each criterion.

The sponsoring organization establishes benchmarks of usual practice and weightings of criteria to reflect national, regional, or local laws, policies, settings, circumstances, and priorities. SBTool has evolved and has been tested by participating countries, with results presented at a series of international conferences.

In Portugal, a building sustainability assessment method has been developed i.e. SBTool^{PT} as depicted by the authors Bragança (2011). The authors Bragança (2011) have stated that the Portuguese version of SBTool - is the result of the work performed both at the University of Minho and the International Initiative for a Sustainable Built Environment (iiSBE) Portugal, whose aim was to develop and propose a generic procedure to evaluate the sustainability of existing, new and renewed buildings in built-up areas, explicitly in the Portuguese setting. They also pointed out that all three dimensions of sustainable development are considered and the final rating of a building depends on the comparison of its performance with two benchmarks: conventional practice and best practice.

The authors Bragança (2011) have also put-forwarded that the priorities that were defined in the development of SBTool^{PT}, are: to develop a list of parameters wide enough to be meaningful and to comprise the most relevant building impacts, and, at the same time, limited enough for practical use; to develop a building-level assessment method based upon existing state-of-the-art of methodologies and taking into account ongoing standardization; to establish an appropriate balance between all different dimensions of sustainable development (environmental, social and economic); to limit or exclude the subjective and/or qualitative indicators that are hard to validate (e.g. aesthetics and technical innovation); to improve reliability through the use of accepted life cycle assessment (LCA) methods for environmental performance assessment; and to produce an assessment output and certification label that is easy for building users to interpret and understand and equally easy for clients and designers to work with.

This SBTool^{PT} encompasses nine (9) categories, and twenty-six (26) indicators beneath the scope of the key sustainability magnitudes like environment, society, and economy as shown in Table 2.22 below, and each category is defined by several indicators. The authors Bragança (2011) have also defined a category as it is a global indicator that summarizes the performance of a building at the level of a key-sustainability aspect.

The list of indicators is based on the commonly accepted LCA methods, the main indicators used in several building sustainability assessment systems in different countries (mainly in the international SBTool method), and the ongoing work at the CEN TC350 standardization body as noted by CEN (2005).

As Larsson (2015) said the approach used for scoring criteria is the additive improved weighted scoring approach and the ratings of the SBTool are -1 = unsatisfactory; 0 =minimum acceptable performance; 5 = best practice; 1–4 = intermediate performance levels; 2 = normal default. Table 2.22 below indicates the list of categories and sustainability indicators for the SBTool^{PT}. The author Larsson (2015) has also depicted that such an assessment tool is widely used to assess almost any type of building and is highly flexible while using it throughout the world.

Table 2.22: List of category and sustainability indicators for the SBTool

Dimensions	**Categories**	**ID**	**Sustainability indicators**
Environment	C1-Climate change and outdoor air quality	I1	Construction materials' embodied environmental impact
		I2	Heat-island effect
	C2-Land use and biodiversity	I3	Urban density
		I4	Water permeability of the

			development
		I5	Use of pre-developed land
		I6	Use of local flora
		I7	Heat-island effect
	C3-Energy efficiency	I8	Primary energy
		I9	In-situ energy production from renewable sources
	C4-Materials and waste management	I10	Materials and products reused
		I11	Use of materials with recycled content
		I12	Use of certified organic materials
		I13	Use of cement substitutes in concrete
		I14	Waste management during the operation
	C5-Water efficiency	I15	Fresh water consumption
		I16	Reuse of grey and rainwater
Society	C6-Occupant's health and comfort	I17	Natural ventilation efficiency
		I18	Toxicity of finishing
		I19	Thermal comfort
		I20	Lighting comfort
		I21	Acoustic comfort
	C7-Accessibilities	I22	Accessibility to public transportation
		I23	Accessibility to urban amenities
	C8-Education and awareness of sustainability	I24	Education of occupants
Economy	C9-Life-cycle costs	I25	Capital cost
		I26	Operation cost

(Source: Mateus (2011))

The following Table 2.23 presents the pros and cons of the mentioned 10 SBAT

Table 2.23: The pros and cons of the chosen 10 SBATs

No.	Name of SBATs	Pros	Cons	References
1.	BREEAM	• Robust • Detailed • Well Known • Easy to Specify • Independent • Tailored to each building type	• Complicated • Inflexible • Poorly Understood • Often Poorly Specified • Extra Cost	Grace and MacFayden, (2006)
2.	CASBEE	• Comprehensive Assessment: • Regional Adaptation • Life Cycle Approach • User-Focused Assessment • Certification and Recognition • Continuous Improvement	• Complexity • Resource Intensive • Regional Variations • Limited International Recognition • Evolving System	CASBEE, (2021)
3.	LEED	• LEED's research-backed standards give Green Design credibility. • LEED's standards focus on the life cycle evaluation of a building and prioritize long term environmental benefits. • LEED legitimized/mainstreamed Green Design as a business investment, jumping the mental hurdles of high initial cost and green building as a "pseudo-science" • LEED's cachet as a status symbol often ensures follow-through of Green building practices • The governing organization of LEED, the United States Green Building Council (USGBC), is receptive to change	• The unweighted system encourages project teams to "game the system" by going after easy points at the expense of actual environmental benefits. • LEED is difficult and expensive for individual homeowners and smaller non- commercial projects. • LEED ignores context and performance. • The closer LEED gets to becoming a mandate, the more blindly it will be followed • LEED does not inspire, encourage, or recognize innovations	Thomas (2022) and LEED (2008)
4.	GBI-Malaysia	• Minimize the toxic substances' emission during its life cycle, • Save resources and energy and recycle materials, • Capable of sustaining and improving the quality of human life • Reserving the ecosystem's • Utilize resources efficiently, they have significant operational savings and lead to workplace productivity enhancement.	• High initial costs • Green construction is not a magic pill • Energy supply may depend on weather conditions • Unclear long-term effects	Frank Gehry, (2019); and Saleh and Faieza (2018)

			• Technology problems • Indoor air temperature may greatly vary over time	
5.	SBTool[PT]-Portugal	• Lays out a thorough methodology for evaluating the environmental performance of both new and existing buildings. • Able to sustain and enhance the quality of human life, by conserving resources, and • Use less energy, and recycling materials.	• Resource-Intensive, • Difficult to Maintain, and • Regional Variations	Bragança (2011)
6.	Green Mark-Singapore	• It places greater emphasis on energy efficiency; • It has been tailored for a tropical climate with the cooling of inner spaces using air-conditioning as a key consideration; • It has higher standards of measurement and verification, using more precise instruments to monitor equipment performance; and • Provides a comprehensive framework for assessing the overall environmental performance of new and existing buildings	• Technology problems, • Maintenance may be difficult; and • Regional Variations. •	Vidushini , Thomas, and Mansi (2017)
7.	Green Star-South Africa	• wide range of government set targets to address greenhouse gas emission; • most adoptive tools, • professional accreditation method employed, and • the award system promotes competition for the use of green products	• The lack of compatibility between the tool and the existing policies, • more problematic with the next generation tools • High initial costs •	
8.	HQE[TM]-France	• covers buildings throughout their life cycle (Focus on sustainability) • environmental performance requirements are highly promoted • the targets are arranged differently for residential buildings and nonresidential building	• High initial Cost • Unclear long-term effects •	Umberto Berardi (2017)
9.	CEPAS- Hon Kong	• Lower Maintenance Cost • Improves Indoor Environment • Sustainable • Prevent Water Wastage • Enhances Health of Occupants	• High Initial Investment • Getting the Right Materials • Long Time to Build • Selecting Right Location • Finding Right Laborers	Olivia (2023)
10.	DGNB	• High consideration of regional conditions, • Promote a uniformly high quality of buildings, quarters or interiors, • Contributes to a high degree of future security for construction projects, and • Ensure transparent quality control for the assessed buildings	• Difficult to Control Indoor Air Temperature • High Initial Investment • Energy supply may depend on weather conditions •	Pombinho (2013) and DGNB (2009)

(Source: Compiled by the researcher, 2023)

In conclusion, the mentioned 10 SBATs resulted in the identification of a total of three-hundred-seventy-four (374) criteria, and sixty-nine (69) categories, as illustrated in Table 2.24 below.

Table 2.24: Lists of the 10 SBATs, number of assessment categories, and criteria

S/No.	**Name of SBATs**	**No. of Categories**	**No. of Criteria**	**References**
1.	BREEAM - United Kingdom	10	49	BREEAM (2011a)
2.	CASBEE - Japan	6	22	CASBEE (2004)
3.	CEPAS – Hong Kong	8	20	CEPAS (2021)
4.	DGNB - Germany	5	43	Pombinho (2013)
5.	GBI - Malaysia	6	17	GBI (2011))
6.	Green Mark - Singapore	5	22	Chieh (2011))
7.	Green Star – South Africa	8	94	GBCSA (2012) and Mauritius (2017
8.	HQE™ - France	4	14	Bernardi (2015))
9.	LEED – United States of America	8	67	LEED (2008))
10.	SBToolPT - Portugal	9	26	Mateus (2011)
	Total	**69**	**374**	

(Source: Compiled by the researcher, 2022)

To rate and evaluate buildings of various types, these assessment methods indicated in Table 2.4 above used a wide range of categories and criteria depending on the local conditions of the various countries. Based on their local environment, all other SBATs have their assessment categories and criteria as depicted in the Table 2.24 above. Different kinds of analysis and grading systems were used for each of these SBATs in their national settings. The grading systems employed by a few well-known sustainable building assessment tools are further described in Table 2.25 below.

Table 2.25: The rating/grading systems of the SBATs

BREEAM BREEAM (2011a)		**CASBEE CASBEE (2004)**		**DGNB Araújo (2008)**		**GBI-Malaysia GBI (2011)**	
Assessment Level	**Scoring Scale (%)**	**Assessment Level**	**Scoring Scale (BEE)**	**Assessment level**	**Scoring Scale (%)**	**Assessment level**	**Scoring Scale (points)**
Outstanding	$X \geq 85$	Excellent	$X > 3.0^{a}$	Gold	$65 < X \leq 80$	Platinum	$85 < X \leq 100$
Excellent	$70 \leq X < 85$	Very Good	$1.5 \leq X < 3.0$ OR $X > 3.0^{b}$	Silver	$50 < X \leq 65$	Gold	$75 < X \leq 85$
Very Good	$55 \leq X < 70$	Good	$1.0 \leq X < 1.5$	Bronze	$35 < X \leq 50$	Silver	$66 < X \leq 75$
Good	$30 \leq X < 55$	Fairly Poor	$0.5 \leq X < 1.0$	Certified	$X = 35$	Certified	$50 < X \leq 65$
Pass	$X < 30$	Poor	$X < 0.5$	-	-	-	-

a and $Q \geq 50$, b and $Q < 50$

Cont...

Green Mark- Singapore Chieh (2011)		**Green Star-SA GBCSA (2012) and Maurtius (2017)**		**HQE™ -France Bernardi (2015)**		**LEED-USA LEED (2008)**	
Assessment Level	**Scoring Scale (%)**	**Assessment level**	**Scoring Scale (points)**	**Assessment level**	**Scoring Scale (stars)**	**Assessment level**	**Scoring Scale (points)**
Green Mark Platinum	$X \geq 90$	6 Star Global Leadership and acknowledges	$75 \leq X \leq 100$	Exceptional	$X \geq 12^{c}$	Platinum	$X \geq 80$
Green Mark Gold Plus	$85 \leq X < 90$	5 Star Excellence and recognized	$60 \leq X \leq 74$	Excellent	$9 \leq X \leq 11$	Gold	$60 \leq X \leq 79$
Green Mark Gold	$75 \leq X < 85$	4 Star Best Practice and acknowledged	$45 \leq X \leq 59$	Very good	$5 \leq X \leq 8$	Silver	$50 \leq X \leq 59$
Green Mark Certified	$50 \leq X < 75$	-	-	Good	$1 \leq X \leq 4$	Certified	$40 \leq X \leq 49$
-	-	-	-	Pass	0^{d}	-	-

c with at least 3 stars for the energy theme
d but all pre-requirements have been successfully met

(Source: compiled by the researcher, 2020)

As shown in Table 2.3, most of the SBATs like Green Star SA, CEPAS, CASBEE, Green Mark, DGNB, BREEAM, GBCC, GOBAS, TERI-GRIHA, GBI, HQE™ Method, ESCALE, SBToolPT, LEnSE, and LEED® are used the MCDM method for the assessment of buildings. Whereas the other SBATs such as GABI, TEAM™, EQUER, LEGEP®, Eco-Quantum, Envest 2, ELODIE, EcoEffect, PAPOOSE, and BEES 4.0 are employed the LCA analysis methods for the assessment of the buildings. The pros and cons of these assessment methods (MCDM) and (LCA) are briefly discussed below.

2.3.2. Multiple-Criteria Decision-Making (MCDM)

Multiple-Criteria Decision-Making (MCDM) is one of the main decision-making problems which aim to determine the best alternative by considering more than one criterion in the selection process. It has manifold tools and methods that can be applied in different fields from finance to engineering design.

In the context of sustainability research, MCDMs are the most often used methods for assessing building-integrated green technologies and prioritizing the related criteria and sub-criteria Kumar, et al. (2017). It can also be used to determine the relative importance of complex problem aspects and the extent to which they influence one another Misra et al. (2012). In addition to this, the economic, social, and environmental practices (sustainability issues) are all included in the Multiple-Criteria Decision-Making (MCDM) approach used in sustainable building assessment tools Kumar, et al. (2017).

The MCDM analysis method has the following merits (pros): used for everyday problems in human lives in dealing with structuring, decision-making, and planning steps when the domain possesses manifold criteria to reach an optimum solution based on the deciders' preferences Kumar, et al. (2017); used for considering decisions' disproportionate and contradictory impacts; applicable in different disciplines and areas ranging from economics and finance to engineering design and medicine so that it is one of the most common decision-making methods. Kumar, et al. (2017); assess the relative importance of the assessment categories and criteria; easy to calculate; Non-compensatory; comprehensible logic of calculations; and Robust to outliers Indre et al. (2021). On the other hand; the demerits (cons) of the MCDM includes: the generated solutions are a compromise among several goals and this leads to not obtaining the optimal point due to the nature of the problems for verification of the analyzed, result additional analysis is required; and it requires subjective assumptions Indre et al. (2021) and Hajduk, S. (2021).

2.3.3. Life Cycle Assessment (LCA)

Life Cycle Assessment (LCA) aims to quantify the environmental impacts that arise from material inputs and outputs, such as energy use or air emissions, over a product's entire life cycle to assist consumers in making decisions that will benefit the environment noted by Pérez et al. (2008). It is also known as life cycle analysis, which is a methodology for assessing environmental impacts associated with all the stages of the life cycle of buildings. It studies the environmental aspects and potential impacts throughout a product's life cycle (i.e., cradle-to-grave) from raw materials acquisition through production, use and disposal as stated by Crawley (2015).

It is an effective way to help make informed investment decisions during the early building design stages. As it is described in ISO (2011), it is an analytical methodology for a systematic evaluation of the environmental impacts of a product or service system through all stages of its life cycle. LCA evaluations include potential environmental impacts from raw material acquisition to production, use, and disposal where it takes into account all costs of constructing, owning, and disposing of a building or building system. Given the fact that different projects have various objectives of analysis, builders, architects, and engineers, should define the expected results and details of interest for their projects before starting life-cycle analyses in order to choose the right tool.

LCA tools for buildings measure the economic costs and environmental performance of building products and systems by using the life-cycle assessment approach. Without LCA, a decision maker is likely to ignore the benefit of these improvements and only focus on the initial costs. Moreover, LCA is especially useful when project alternatives that perform the same function, but differ with respect to the initial costs and operating costs, are to be compared in order to select the one that maximizes net savings Pérez et al. (2008).

The LCA analysis method has the following merits (pros)**:** a simple and effective design tool in use, detailed and flexible, directly accounts for environmental impacts including scarcity and toxicity, used readily available data which is frequently updated, easy to calculate, easily to comprehensible, and it provides credible data for policymakers to identify and quantify the specific stage of a process to intervene and the connections between elements. On the other hand; the demerits (cons) of the LCA includes: requires value judgment on environmental priority, does not directly incorporate environmental data, it is very specific and often cannot be applied to other processes of a similar nature, compiling data can be time-consuming and expensive, it may need to be utilized as a part of a more thorough investigation because it may not always establish which procedure or product performs best or is the most cost-effective, and it has been challenged as an expensive approach and requires deep knowledge and value judgment to make an inference.

2.3.4. Analytical Hierarchy Process (AHP) Technique

AHP technique is one of the MCDM analysis methods used in this study because it is easy to use and faces issues due to the interdependence between assessment categories and criteria for prioritizing and weightings.

Analytical Hierarchy Process (AHP) has been the commonly used MCDM method in examining building-related green technologies Siti et al. (2018) and Zarghami et al. (2018).

It is one of the techniques employed in the Multiple-Criteria Decision Making (MCDM) for the assessment of sustainable buildings by using categories and criteria. The major characteristic of the AHP method is the use of pair-wise comparisons, which are used both to compare the alternatives with respect to the various criteria and to estimate criteria weights Siti et al. (2018). It is also one of the more popular methods of MCDM and has many advantages, as well as disadvantages Saaty (2008, p. 83). One of its advantages is its ease of use. Its use of pairwise comparisons can allow decision makers to weight coefficients and compare alternatives with relative ease. It is scalable, and can easily adjust in size to accommodate decision making problems due to its hierarchical structure.

Even though the AHP requires enough data to properly perform pairwise comparisons, the method has experienced problems of interdependence between criteria and alternatives. Due to the approach of pairwise comparisons, it can also be subject to inconsistencies in judgment and ranking criteria and it does not allow [individuals] to grade one instrument in isolation, but in comparison with the rest, without identifying weaknesses and strengths Konidari and Mavrakis, 2007, p. 6238). One of its biggest criticisms is that the general form of AHP is susceptible to rank reversal. Due to the nature of comparisons for rankings, the addition of alternatives at the end of the process could cause the final rankings to flip or reverse.

The authors Siti et al. (2018) and Saaty (2005) clearly depicted that this technique is used for effective decision-making on complex issues by simplifying and speeding up the decision-making process by solving the problem into its parts, arranging these parts or criteria in a hierarchical order, assigning numerical values to subjective considerations about the importance of each criteria and synthesize these various considerations to determine the most important variable which is acting to affect how the situation turns out.

In addition to this, the AHP technique helps solve complex problems by structuring a hierarchy of criteria, participants of results, and by drawing various considerations to develop weight or priorities as discussed by Siti et al. (2018) and Salgado et al. (2012). Moreover; the authors Siti et al. (2018), Salgado et al. (2012) and Salomon (2012) have identified that this technique combines the strengths of the feelings and logic concerned on various issues, and then synthesizes various considerations into the results that match the authors' estimates intuitively as presented in the consideration already made.

Additionally, the AHP has numerous uses in a variety of contexts, including decision-making, rank ordering, prioritization, and resource allocation. Moreover; AHP helps quantify the weight of the appraised criteria in the form of numeric basis. Other authors like Olomolaiye (2012) have identified that the criteria weight of each element determines its relative importance with the other elements of the hierarchy and it facilitates the decision-makers to identify and prioritize significant factors. Another notable aspect of AHP is the determination of the inconsistency index. According to Siti et al. (2018), Saaty (1980) and Saaty (1990), there are three principles in solving the problem with AHP, namely, compose the hierarchy (Decomposition), the principle of prioritizing (Comparative Judgment), and the logical consistency principle (Logical Consistency). The AHP in question is a hierarchy of problems that will be solved to consider the criteria or components that support the achievement of goals as demonstrated by the authors Siti et al. (2018) and Salomon (2012). In selecting the criteria for each decision-making issue it is necessary to consider the following criteria: The criteria should be complete so that it covers all important aspects utilized in decisions making for attaining goals; actions are in the wisdom in which both of these criteria must need the connotation for the decision-makers, so that they can really appreciate the existing alternatives; avoid any criteria that essentially contain the same meaning, so create criteria based on the goal of focus; and simplify the problem in the analysis as noted by the authors Siti et al. (2018), Salomon (2012) and Kalic (2014).

The AHP technique is also important in compiling the hierarchy which depends on the type of decision to take. If the tricky is to choose an alternative, it is possible to start from the first level by dragging all those alternatives. The next level should consist of categories or criteria to consider the various alternatives. And the top level should be one element only which is the goal/purpose of the study, example focus or overall purpose as described by the author Siti et al. (2018) and Salomon (2012). There can be compared to the importance of each individual's contribution. For the AHP technique, the comparative judgment is very crucial in order to reach the weightings and rankings of the proposed categories and criteria. The comparative judgment means making judgments about the relative importance of two elements at a certain level in relation to the levels above. This comparative judgment also used for the assessment which is the core of AHP, as it will affect the priority criteria of the criteria. The results of this assessment will be placed in a matrix called the pairwise comparison matrix as noted by Siti et al. (2018), Salomon (2012), and Kalic (2014).

2.4. Research Gap

Nowadays the sustainability issues are the core discussion agenda in every parts of the world and the developed nations propagate it for the implementation of sustainable development goals. To attain sustainable/green building construction, the following points were highly incorporated during the processes: designing of the buildings to be integrated with the natural environment; integrating the building with the site; conserving energy and providing high-energy efficiency; concerning about the climate; using locally available and non-toxic building materials; respecting the users; and taking advantages of the traditional local building technique and experience. But the developing world did not consider the above mentioned points in order to construct buildings used for different purposes.

Even though the notion of sustainability is recognized in developing nations, they did not focus on it in the building construction processes. Moreover; the amount of money outlaid for the construction of such buildings are too much but they are not sustained for longer period of time since there are some physically observed problems like cracking, installation and provision problems of various infrastructures (electricity lines, water supply lines, sanitary lines, drainage lines, etc.), waste management system problems, usage of poor quality construction materials and others. These show that the sustainable building constructions are not the prior concern for these developing countries.

There are different types of sustainable/green buildings observed in developed nations which are evaluated and certified by different SBATs like Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Methodology (BREEAM), Comprehensive Assessment System for Built Environment Efficiency (CASBEE), Comprehensive Environmental Performance Assessment Scheme (CEPAS), Sustainable Building Tool (SB-Tool), Green Star SA, Green Mark, Green Building Index, etc. There are also sustainable/green buildings assessment categories, criteria and indicators to evaluate and certify both the existing and new buildings for these tools like sustainable sites; water efficiency; energy efficiency; location and transportation; land use and ecology; materials and resources; indoor environmental quality; innovations and others. However; most developing nations are not pay due attentions to the concepts and principles of sustainable/green buildings and the issues of sustainability while designing and construction of buildings for different purposes.

If we take the country, Ethiopia, the scenario is the same. For instance, most of the buildings are not users-friendly and this can be manifested by the lack of sufficient water supply, poor drainage systems, poor waste management systems, not considering the disability issues, disturbing the natural ecosystems and others. So it could be said that the sustainability concerns for sustainable/green buildings are paid insignificant attention.

Generally speaking, even if there are SBATs categories and criteria to be considered in building construction sectors at the international level, there is no such SBATs used for the evaluation and certification of both existing and new buildings which in turn create gaps in the use of sustainable building construction processes for attaining the minimum SBAT with the identified category and criteria /requirements in developing nations like Ethiopia. Therefore; this study is trying to fill this research gaps.

2.5. The study variables

The word varies, which denotes change, is the root of the term variable. Thus, to put it simply, variables are things that can vary. The accepted definition of a variable in research is one that may be supported or refuted by experimentation or observation. The relationship between one variable item and variation in another is of interest to researchers. The emphasis is on the factor of cause and effect which officially is known as causal relationship. The figure 2.7 below depicts the relationships between the independent variables (cause) and the dependent variables (effect).

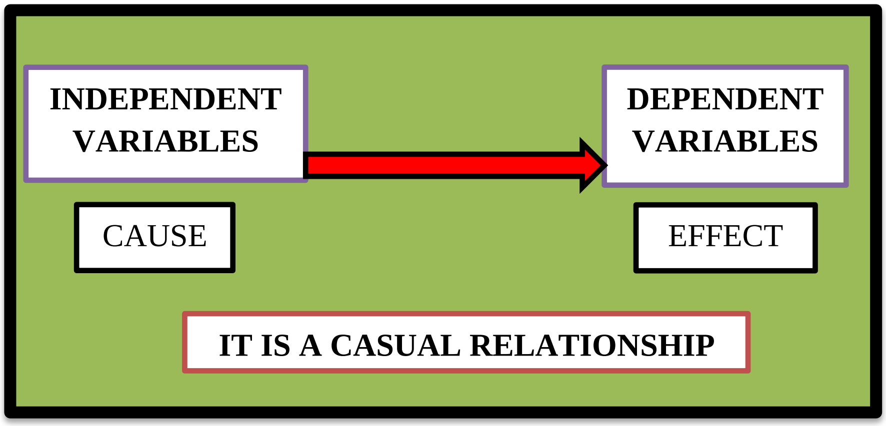

Figure 2.7: The casual relationship of variables

(Source: Developed by the researcher, 2020)

As it is known that there are two types of variables, namely independent and dependent, existing in any research.

The independent variable is the variable in which it can be changed and controlled in an experiment/study. It is called independent because its value does not depend on and is not affected by the state of any other variable in the experiment/study and sometimes it can be called the "controlled variable" because it is the one that is changed.

The dependent variable is the variable in which it can be measured in an experiment. The researcher will assess how it responds to a change in the independent variable, so it can be thought as depending on the independent variable. Sometimes the dependent variable is called the "responding variable."

In this study there is one dependent variable namely, a sustainable building assessment tool (SBAT) appropriate for Ethiopia.

The independent variables for the development of a sustainable building assessment tool appropriate for Ethiopia are building resources and materials, environmentally sound sites, indoor environmental quality, energy and water efficiency, building economic values, management systems, and accessibility (closeness to various facilities and services). The variables used in this study are depicted in figure 2.8 below.

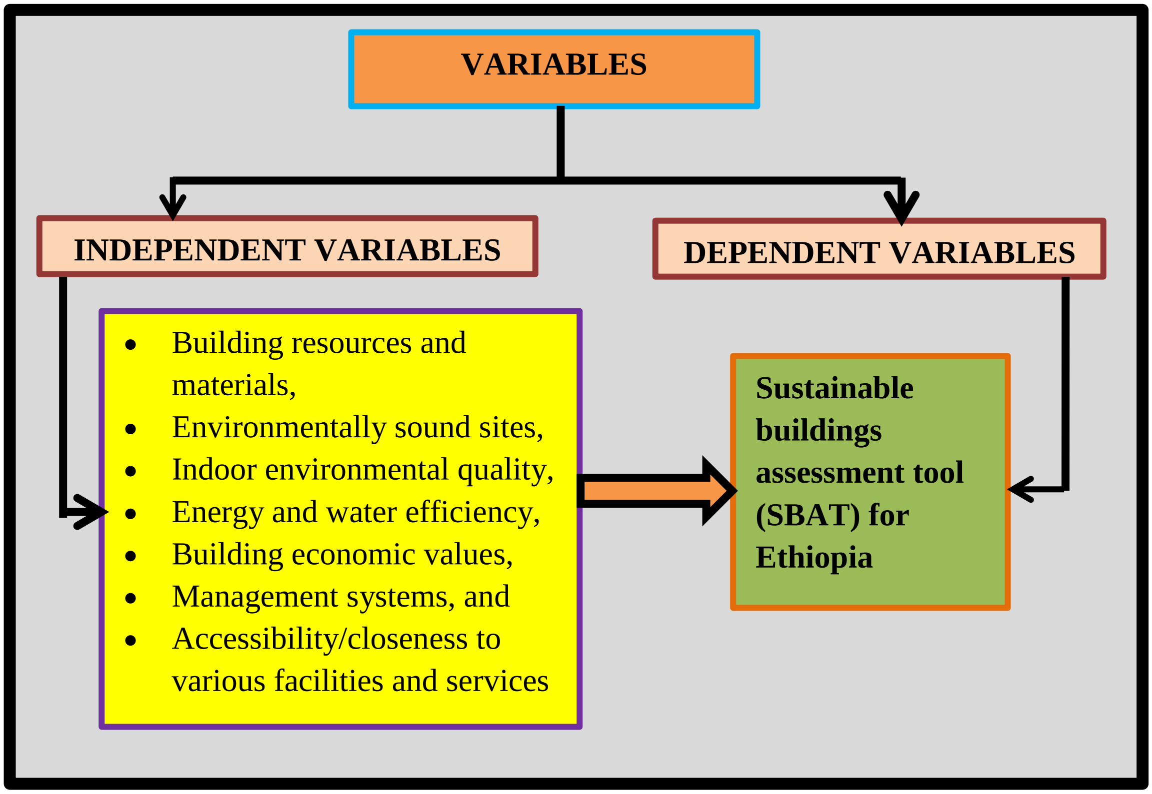

Figure 2.8: The dependent and independent variables of the study

(Source: Developed by the researcher, 2020)

The independent variables that are thought to be the cause and the dependent variable likewise thought to be the effect, as is stated in this part (Section 2.5 of the study variables) of Figure 2.2. It is well known that there is an effect observed for every cause of action. The Sustainable Buildings Assessment Tool (SBAT) for Ethiopia is the dependent variable in this study, which is accompanied by a number of independent variables, as shown in Figure 2.8.

The development of the sustainable building assessment tool (SBAT) to the Ethiopian context which is a dependent variable and in this study considered as an effect, is directly related to some independent variables known as the causes, such as building resources and materials, environmentally sound sites, indoor environmental quality, energy and water efficiency, building economic values, management systems, and location and transportation.

These independent variables are composed of different criteria to assess/ evaluate the buildings from the perspective of sustainability. The independent variable like building resources and materials is composed of criteria like use of materials of low environmental impact, use of non-renewable-virgin materials, use of locally available materials, use of materials with recycled content, and use of finishing materials. Similarly, the independent variable energy and water efficiency contains some assessment criteria like use of energy monitoring /management system, use of energy-efficient equipment, use of natural energy resources/ renewable energy, regular water leak detection and monitoring, use of rainwater harvesting, regular water usage monitoring, recycling of wastewater, and use of water-efficient fittings and equipment. In addition to this, the independent variables building economic values has the criteria such as operation and maintenance cost of buildings, life cycle cost (LCC) of buildings, investment risk, and construction cost for the buildings. The location and transportation variable is also incorporates the assessment criteria like availability of alternative modes of transportation, accessibility to public transportation, and provision of the car parking area and parking capacity. Each mentioned and others independent variables are playing significant roles with the dependent variables in this study for the development SBAT.

Buildings are evaluated for their being sustainable/green by taking into account the mentioned categories and criteria as per the context of the given countries which have the assessment/evaluation points. These points were added up to determine whether or not the assessed/evaluated buildings were awarded as sustainable/green. This showed that the cause-and-effect relationship could be seen clearly. According to LEED (2008), for instance, the LEED evaluation tool has eight assessment categories, in this case the cause, and also has prizes labeled as platinum for $X \geq 80$ points, gold for $60 \leq X \leq 79$ points, silver for $50 \leq X \leq 59$ points, and certified for $40 \leq X \leq 49$ points. The labeling of the evaluated/assessed buildings is considered as the effect. By considering the variables (dependent and independent) mentioned above, the researcher has identified that this study has a cause-and-effect relationship.

CHAPTER THREE

3. The Research Methodology

3.1.1. The Research Approach

A research approach is a detailed sequence of events that directs ideas and actions, allowing the carrying out of research methodically and on time to yield high-quality outcomes. This study recognized research as a process of systematic inquiry that entails the collection of data; documentation of critical information; and analysis and interpretation of that data/information, in conformity with appropriate techniques established by particular academic and professional areas. It is also a way of critical investigation for examining the various aspects of the problem under consideration; understanding and formulating guiding principles to govern the research procedure; and putting hypotheses to the test or inventing new ones to improve the current condition, status, or procedure.

As it is quoted in Wubishet (2004), research can then either be theory-based (deductive), a problem initiated for theory contribution (inductive), or a mixed approach to research., Robert (2000) also acknowledged that research is a systematic investigation to find answers to a problem, and Kumar (1999) was also placed research as a process for collecting, analyzing and interpreting information to provide solutions to queries.

The research approach of this study starts with the development of research problems accompanied by both research objectives and questions which needs to be achieved and answered at the end of the study by using various scientific procedures (sampling techniques, samples, data types, source of data, data collection tools, data analysis tools). Following this, the review of research frameworks like conceptual, methodological, and contextual is taken into account with respect to the study topic as discussed in the Literature Review section. Finally, the findings of the study contributes to the development of the sustainable building assessment tool in order to evaluate and certify the buildings by referring the allocated points that are given for each assessment criteria suitable to the country's context. Therefore; the research approach is considered an inductive technique.

For further elaboration, as indicated in Figure 3.1 below, the philosophical premises were formed throughout the research process and methodologically based on the bottom-up approach, that is, from the problem definition to knowledge contribution. As a result, the ontological and epistemological perspective of this study was developed up to the point at which the themes for the analysis became obvious as shown in Figure 3.1 below. Epistemology is defined as the philosophy and knowledge behind the belief which is investigated by making use of a research method, or methodology. On the other hand, ontology is "the science of being" and it is also a statement of fact without explanation.

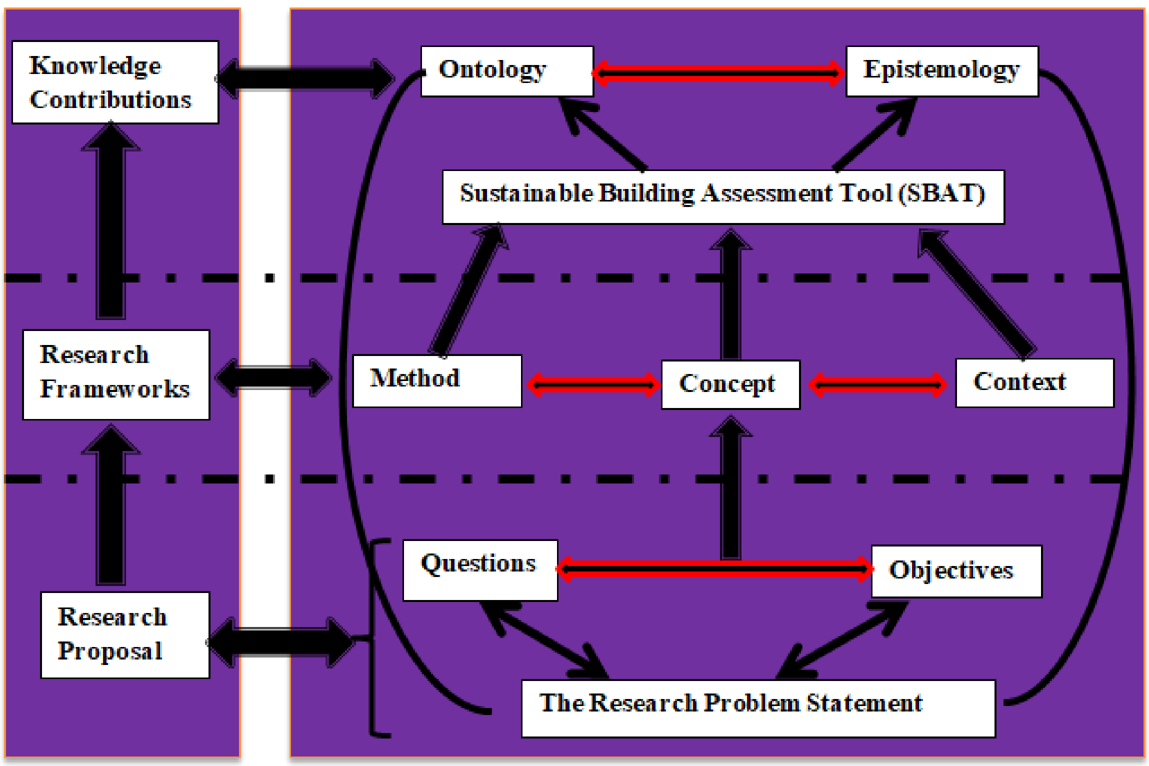

Figure 3.1: The research approach of the study

(Source: Developed by the researcher, 2020)

This study together with the research approaches develop the following categories of stakeholders, which are used as the basis for the study population and as a source of data.

From these stakeholders, the researcher takes the most appropriate key expertise as well that are directly or indirectly resourceful with the topic of the study. These are:

1. Experts from the Government (Ministry of Urban and Infrastructure (MoUI), Ethiopian Construction Authority (ECAA), Addis Ababa City Administration Construction Bureau (AACACB) and Addis Ababa City Administration Housing Development Corporation (AACAHDC)),
2. Contractors and consultants,
3. Senior experts (reputable professionals), and
4. Academia.

The research methodology incorporates the various stages used throughout the research processes and these stages, in turn, develop their typical methodologies which are used to enrich and build the whole process. The stages are strategy, research instrument, data collection, and analysis.

As Grove (2001) identified that designing a study helps the researcher to plan and implement the study in a way to obtain intended results, raising the likelihood of learning something that might be related to the actual circumstance.

The study combined a mixed method to data collecting and analysis with a case study strategy for inquiry. Figure 3.2, which follow, illustrate how this study's research was conducted.

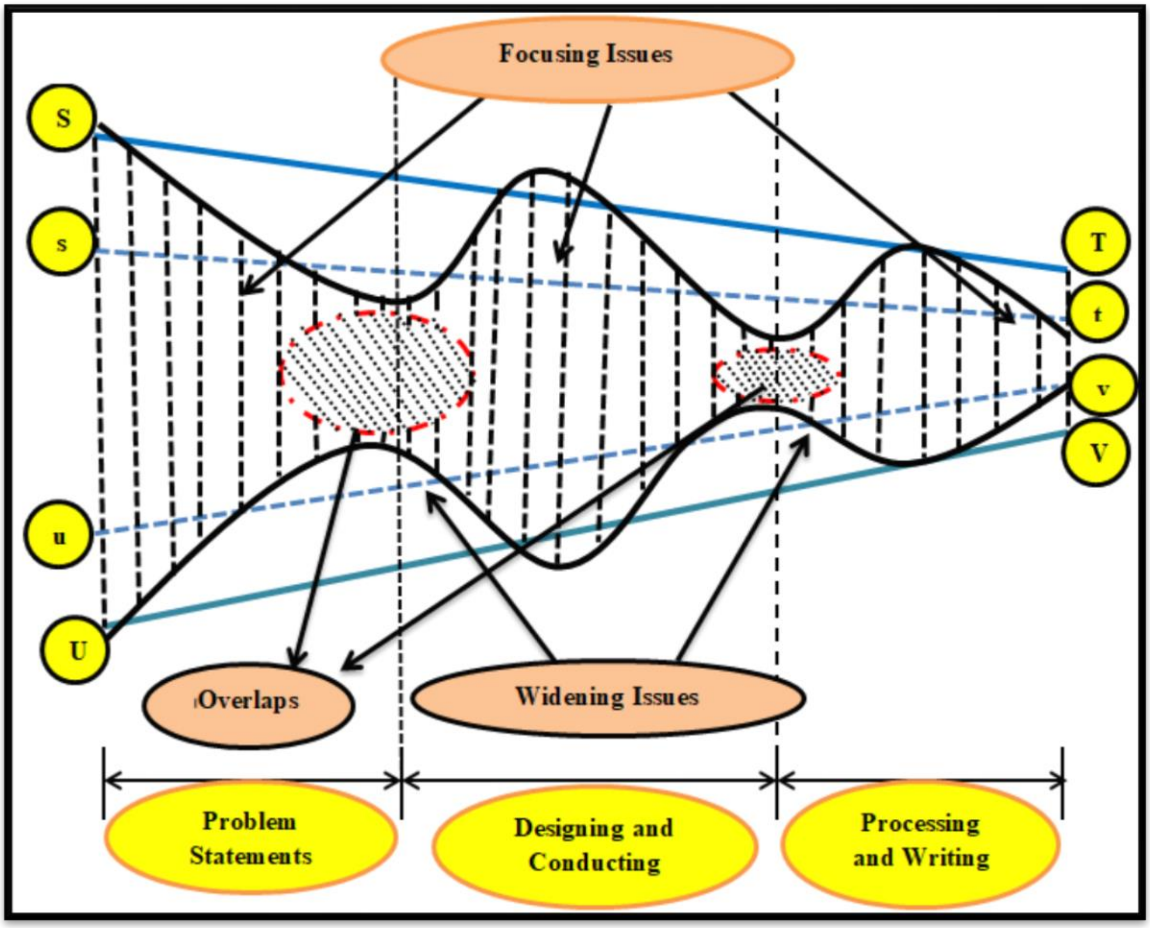

Figure 3.2: The research process of the study

(Source: Developed by the researcher, 2020)

The study's paths were depicted in Figure 3.2 above along three twisting procedures. The lines ST and UV demonstrated the general inductive methodology. The flowing curves between each of the two lines, ST and UV, as well as the broken lines st and uv between ST and UV, are used to illustrate the research process. This diagram shows how the three main stages of the study's development shaped the study's focus. The formulation of the problem statement, the designing and conducting phase of the study, and the processing and writing phase of the study are the three main stages for focus demarcation that more or less correspond to the three well-known research techniques employed here. These processes were discovered to be synergistic and overlapping rather than sequential. Also, because this study was carried out in Ethiopia, one of the least developed nations, some of the context-building turned into a separate study. As a consequence, the conceptual and contextual developments of the research contributed to the establishment of the frame of reference for the research. Hence, the case study and desk research components were both included in the context developments.

Although the study problem was congruent and based on a practical conceptualization Creswell (2003) it has qualified for a cognitive approach nonetheless. This came as a result of the researcher's decision to handle the issue holistically rather than by removing context. In other words, both literature reviews and my personal experiences raised my consciousness of the significant effects that the study context has on developing countries. After that, causal links and strategies were established with the conviction that reality was seen as a field of contextual knowledge and realms of metaphorical conversation. That is, rather than simply looking at causally linked associations, the idea of causal links that are functional through strong but likely associations, meaning that variables are associated in a required way, was given more weight.

As opposed to using questionnaires to conduct a survey, case study research is not constrained to a single source of data. In reality, having a variety of sources of information is advantageous for effective case studies. Direct observations, interviews, archival records, documents, and participant observation may be used in any combination, as well as related sources like focus groups (an alternative to interviews), depending on what is available and pertinent for examining the identified case. These lists are typical sources of evidence (s).

The study characteristics: It is the logic that links the conclusions drawn and the data collected to the initial questions of the study as confirmed by the authors Yin (1994 & 2003) and Miles (2002). Yin (1994 & 2003) has further provided five components of study characteristics but only four of them were used in this study: the research questions, units of analysis, logic linking of collected data to the research questions and criteria for interpreting the findings. Therefore, the choice of the study design is based on four fundamental perspectives: the nature of the investigation; the reference period of the study; the nature of variables because of different data collection instruments; and using of multiple evidences and the number of contacts within the study population Wubishet (2004) and Kumar (1999).

Considering the nature of the investigation, conditions such as the types of research questions, the researcher's extent of control over the actual circumstances, the degree of focus adopted on contemporary events, the type of data to be collected, and their availability (access and documentation), and the time and cost constraints of the study has been recommended by Yin (1994 & 2003) for the research design.

For each research/study population, the unit of analysis is employed. The thing being studied, described, or analyzed is the subject of the analysis. This may include individual people, groups of people, or organizations/institutions. The importance of using the unit of analysis in this research is to help in finding data sources, data collection, and building the analysis and discussion subjects for improving the reliability of the pieces of evidence and validity of the research findings.

The following two features served as the foundation for this study. First, the qualities of the investigation were taken into account, including control, rigor and systematic, validity and reliability, and empirical and critical thinking. Second, it was thought about how different study types were categorized based on their application, objectives, and the kind of information they looked for. As a result, the following is a summary of how these qualities and the many kinds of these well-known research classifications were taken into account in this study.

The objectives of the research were to investigate the relationships between variables for the development of sustainable building assessment tools by taking into account a number of categories and criteria appropriate to the local context. Furthermore, it was believed that these connections between causes and effects were likely. So, several relationships can play a role in an occurrence, according to a widely held notion.

The occurrence relationships between independent and dependent variables can display an intricate series of occurrences and this is specifically the case for assessment researches that explain program links or describe involvements in real-world contexts.

As a result, a number of issues had an impact on the creation of techniques for evaluating sustainable buildings. Because of this, the problem of control in the literary meaning of the post-positivist scientific research could not be relevant to this study's findings; it was instead managed by putting the emphasis on the study directly.

In order to increase the validity and reliability of this study, complementary relationships and possible source between the research questions, the evidence, and the conclusions were regarded essential. These chains and complementarities are listed in Table 3.1 below. Responses at all levels demonstrated the thorough appraisal of the steps taken to reduce difficulties and the logical connection between the approach used and the study topics. As stated in Table 3.1 below, the research process, the findings and conclusions were determined to be complementary to one another and ensured their extraction from diverse evidences acquired utilizing four separate study instruments.

Table 3.1: The research methodology

Stages	Methodology	Motives	Research Objectives	Data collection tools	Data analysis	Validation
Strategy	Qualitative and quantitative surveys	Research questions, context influences, & contemporary events	Research Objectives 1 and 2	Survey Questionnaire, Observation, Discussion with key informants, and Interviews	SPSS, AHP, and reliability analysis	Sampling Validity
Research Instrument	Multiple evidences	Construct validity using triangulation	Research Objectives 1 and 2	Survey Questionnaire, Observation, document analysis and Interviews	SPSS, AHP, descriptive statistics and reliability analysis	Construct Validity
Data Collection	Study samples	Contemporary research, accessibility; and reliability & external validity	Research Objectives 1 and 2	Survey Questionnaire, Discussion with key informants, and Interviews	SPSS, AHP, descriptive statistics and reliability analysis	Reliability & external validity
Analysis	Pattern matching & explanation building	Internal and construct validity	Research Objectives 1 and 2	Survey Questionnaire, document analysis and Interviews	AHP, descriptive statistics and reliability analysis	Internal and construct validity

(Source: Developed by the researcher, 2021)

Recurrence of findings according to three criteria (respondents, study populations or investigators, and simultaneously multiple evidences) were established to demonstrate importance among factors identified for the development of sustainable building assessment tool. Such qualities assisted the investigator in strengthening the validity, reliability, and empirical quality of the study.

The research types: The research types are classified into three based on the application, objectives, and available information.

Under the application, there are basic and applied researches are considered where this research tends to be more on applied rather than basic; under the objectives which include both descriptive and explanatory research types, it inclines to both descriptive and explanatory; and under the availability of information which consists of qualitative and quantitative research types, it is likely to be more qualitative even though the researcher uses the quantitative types. Because of all these, mixed approach types are employed. Most authors are increasingly recognizing that mixed approaches are important Creswell (2003) and Teddlie (1998) for a successful study (evaluation) of research Yin (1994 & 2003) and Hughes (1992). Therefore; the researcher employed the mixed research approach type.

3.1.2. The Research Design

The research questions had been examined by the research design. Other considerations include adopting criteria to interpret the results and logically connecting the data to the study objectives. The purpose of a research design is to provide a plan of study that permits an accurate assessment of cause-and-effect relationships between independent and dependent variables. The research design process is a systematic and structured approach to conducting research. The research design is composed of the study populations, sampling design, the sampling techniques, and the sample size determination, the sources of data, the data types, method of data collection, method of data analysis, and methods of data presentation.

3.1.2.1. The Study Population

The authors Hungler (1999) have described the research/study population as an aggregate or totality of all the objects, subjects, or members that conform to a set of specifications. The determination of the study populations, the purpose of the study, the delimitation of the study, and the limitation of the study are taken into account.

As mentioned in chapter one, the objective of the study is to develop sustainable building assessment tool (SBAT); its scope is to focus on the economic, social and environmental significance as well as reviews the theoretical and the definitions of the various SBATs, categories and criteria; and the limitations are absence of available data on sustainable building evaluation and certification from the sustainability perspective. So, identification of the study populations based on this is very crucial.

The study populations were identified based on their significance for delivering/providing essential data/information needed for this study. Based on their involvement for various goals, the study population was divided into five categories such as senior experts from the government, contractors and consultants, reputable professionals, and academia.

The study population who are directly related to the development of SBAT are architects, engineers (civil, mechanical, electrical, hydraulics, sanitary), urban planners, urban designers, and construction managers. This implies that the populations are diverse. It is well known, that these populations are involved in the construction sectors like road, bridge, water, dam, and buildings. Since the study is focusing on buildings, the populations are engaged in the plan/design preparation, construction of the buildings, consultation for the overall construction process, contract administration, and construction supervision.

Reputable professionals are those who specialized in their fields and have high profiles (experiences) in the construction sectors as stated above. These professionals include construction managers, architects, engineers, urban planners, and designers. They have worked as project managers, project coordinators, architects, and construction managers in this sector for more than fifteen years as shown in the Table 3.2 below.

Table 3.2: The lists of reputable professionals involved in the study as a study population

No.	Professions	Position	Experiences (Years)
1.	Architect	Architect	20
2.	Architect	Project Manager	27
3.	Architect	Architect	25
4.	Civil Engineer	Project Manager	24
5.	Civil Engineer	Project Coordinator	27
6.	Urban Planner	Project Coordinator	19
7.	Civil Engineer	Project Manager	26
8.	Civil Engineer	Project Coordinator	24
9.	Architect	Architect	27
10.	Construction Management	Construction Manager	23
11.	Architect	Project Manager	20

(Source: collected by the researcher, 2022)

Like that reputable professionals, senior experts are experts in their fields and have high experiences in the construction sectors. These professionals include construction managers, architects, engineers, and urban planners. They have worked as project managers, project coordinators, architects, team leader, contract administrator, electrical engineer, project evaluator, and construction supervision officer in this sector for more than ten years as shown in the Table 3.3 below.

Table 3.3: The lists of senior experts involved in the study as a study population

No.	Professions	Position	Experiences (Years)
1.	Architect	Architect	11
2.	Architect	Architect	12
3.	Civil Engineer	Team Leader	17
4.	Construction Manager	Construction Supervision Officer	12
5.	Construction Manager	Contract Administrator	13
6.	Electrical Engineer	Electrical Engineer	10
7.	Mechanical Engineer	Lift Technician	11
8.	Sanitary Engineer	Sanitary Engineer	13
9.	Urban Planner	Urban Planner	19
10.	Architect	Architect	15
11.	Civil Engineer	Program Coordinator	22
12.	Civil Engineer	Project Evaluator	17
13.	Civil Engineer	Project Manager	30
14.	Architect	Architect	15
15.	Architect	Architect	12

(Source: collected by the researcher, 2022)

Academia is also professionals engaged in the higher education sectors (in this case the University Lecturers). This academia is teaching their students of various disciplines (Engineering, Architecture, Urban Planning and designing, and Construction Management). In addition to teaching, they involved in the consulting services in the University with respect to their specialty. The following Table 3.4 displays the list of academia.

Table 3.4: The lists of academia involved in the study as a study population

No.	Professions	Position	Experiences (Years)
1.	Hydraulics Engineer	Lecturer	10
2.	Hydraulics Engineer	Lecturer	12
3.	Urban Designer	Lecturer	15
4.	Civil Engineer	Lecturer	9
5.	Construction Manager	Lecturer	13
6.	Environmental Engineer	Lecturer	16
7.	Construction Manager	Lecturer	8
8.	Sanitary Engineer	Lecturer	17
9.	Urban Planner	Lecturer	12
10.	Urban Designer	Lecturer	16
11.	Civil Engineer	Lecturer	20
12.	Construction Manager	Lecturer	17
13.	Civil Engineer	Lecturer	12
14.	Architect	Lecturer	9
15.	Architect	Lecturer	12
16.	Urban Planner	Lecturer	16
17.	Hydraulics Engineer	Lecturer	11
18.	Hydraulics Engineer	Lecturer	18
19.	Architect	Lecturer	10
20.	Hydraulics Engineer	Lecturer	9

(Source: collected by the researcher, 2022)

The key informants are individuals who are directly involved in the building construction sector and have also had a rich experience like that of reputable professionals in the mentioned disciplines. The following Table 3.5 shows the list of key informants

Table 3.5: The lists of key informants involved in the study as a study population

No.	Professions	Position	Experiences (Years)
1.	Civil Engineer	Deputy Director of AACACB	19
2.	Urban Planner	Planning Department Head	16
3.	Civil Engineer	Project Manager	23
4.	Architect	Team Leader	17
5.	Construction Manager	Construction Department Head	20
6.	Civil Engineer	Contract Administrator	16
7.	Architect	Design Team Leader	12

(Source: collected by the researcher, 2022)

The following Table 3.6 shows the list of contractors and consultants considered as a study population in this study. All contractors and consultants are grade 1 and 2 and mostly involved in the building construction sectors.

Table 3.6: The lists of contractors and consultants involved in the study as a study population

S/No.	Professions	Position	Experiences (Years)	Remark
1.	Civil Engineer	Project Coordinator	16	Consultants
2.	Civil Engineer	Project Coordinator	12	Consultants
3.	Civil Engineer	Resident Engineer	10	Consultants
4	Architect	Project Coordinator	13	Consultants
5.	Civil Engineer	Resident Engineer	17	Consultants
6.	Architect	Project Coordinator	20	Consultants
7.	Architect	Project Manager	15	Consultants
	Civil Engineer	Contract Administrator	13	Consultants
8.	Architect	Architect	8	Consultants
9.	Architect	Architect	12	Consultants
10.	Civil Engineer	Team Leader	17	Consultants
11.	Construction Manager	Construction Supervision Officer	10	Consultants
12.	Construction Manager	Contract Administrator	13	Consultants
13.	Electrical Engineer	Electrical Engineer	10	Contractors
14.	Mechanical Engineer	Lift Technician	9	Contractors
15.	Sanitary Engineer	Sanitary Engineer	13	Contractors
16.	Urban Planner	Urban Planner	19	Contractors
17.	Architect	Architect	15	Contractors

18.	Civil Engineer	Program Coordinator	22	Contractors
19.	Urban Designer	Designer	17	Contractors
20.	Civil Engineer	Project Manager	30	Contractors
21.	Civil Engineer	Site Engineer	9	Contractors
22.	Construction Manager	Project Manager	11	Contractors
23.	Civil Engineer	Project Manager	16	Contractors
24.	Civil Engineer	Office Engineer	13	Contractors
25.	Civil Engineer	Project Coordinator	20	Contractors
26.	Civil Engineer	Project Manager	23	Contractors
27.	Construction Manager	Manager	25	Contractors
28.	Civil Engineer	Site Engineer	13	Contractors
29.	Construction Manager	Project Manager	18	Contractors
30.	Civil Engineer	Project Coordinator	20	Contractors
31.	Urban Designer	Designer	16	Contractors
32.	Urban Planner	Project Coordinator	15	Consultants
33.	Civil Engineer	Project Manager	13	Contractors
34.	Construction Manager	Project Manager	19	Contractors
35.	Civil Engineer	Office Engineer	17	Contractors
36.	Architect	Architect	20	Contractors
37.	Urban Designer	Project Manager	27	Contractors
38.	Architect	Architect	20	Contractors
39.	Construction Manager	Project Manager	27	Contractors
40.	Architect	Architect	9	Contractors
41.	Civil Engineer	Project Manager	24	Consultants
42.	Civil Engineer	Project Coordinator	13	Consultants
43.	Urban Planner	Planner	8	Consultants
44.	Civil Engineer	Project Manager	15	Consultants
45.	Civil Engineer	Project Coordinator	24	Consultants
46.	Urban Planner	Planner	10	Consultants
47.	Architect	Project Manager	13	Consultants

(Source: collected by the researcher, 2022)

Due to the large sizes and disciplines of populations involved in the study, the researcher cannot test every individual in the population because it is too expensive and time consuming, as well as the overlap of time frames for the research period, the knowledge contribution rather than generalization and inferences of the study's purpose, as well as the study's unfamiliarity in the study area and myself as a researcher, forced me to choose the specified number (100) of study populations comprising experts, academia, consultants, contractors, and reputable professionals in order to obtain reliable data/information for the development of SBAT.

3.1.2.2. Sampling Design

A sampling design is a comprehensive approach for choosing a sample from a certain population. It alludes to the method or practices the researcher would use when choosing the items for the sample. The sample size, or the number of objects that will be included in the sample, may also be specified in the sample design. Before data are gathered, the sample design is decided. A researcher can select from a variety of sample designs. Some designs are easier to implement and more precise than others. The sample design that the researcher chooses or creates must be trustworthy and acceptable for his research topic Nahla (2020).

The researcher must carefully select a small number of population members, thoroughly study them, and make findings that can be applied to the entire population without the danger of applying a sampling design. A critical step in the procedure is selecting the sample. The sample size, methodology, and test should all be decided by the researcher Yin (2011). Purposive sampling was used by the researcher to gather information from study participants for the development of the SBAT to Ethiopian context. It requires the researcher to have prior knowledge about the purpose of the study that can accurately choose and approach eligible participants. This is collected according to the requirements of the test, survey, or research that it will be used for.

Purposive sampling is employed in this study because:

- The characteristic of the study is only on the buildings.
- The study populations have well experienced in the subject matter of the study.
- There are diverse disciplines/professions involved in the construction sector and it is very difficult to access and involve all these professionals in the study. So that using purposive sampling is preferable

- For getting suitable response/ answer to the research questions, purposive sampling is preferable.
- The researcher can select an accurate and cost-effective sample by selecting respondents based on their knowledge.
- There is little room for error. As the respondents are chosen based on the right criteria, the sample selection is precise and effective.
- Using purposive samples can create a substantial result in real-time, as the study population has specific knowledge about the research.

3.1.2.3. The Sampling Techniques

A sampling technique is the name or other identification of the specific process by which the entities of the sample have been selected.

As mentioned in the sample design section 3.1.2.2, for the development of SBAT, a purposive sampling technique was employed to select the experts, academia, and reputable professionals from the study populations.

3.1.2.4. The Sample Size Determination

Sample size determination is the procedure of choosing the number of observations to embrace in a sample. Every research or investigation in which the goal is to arrange the population from a sample must consider the sample size. The sample sizes to be used in a study are determined based on the cost of data collection and sufficient statistical power. In the more multifaceted study, several sample sizes could be utilized. For instance, in a surveying sample with stratified sampling, if the population is heterogeneous, there might be different sample sizes for each population.

For the development of SBAT suitable to the Ethiopian context, the researcher is also conducting survey questionnaires for the experts of various stakeholders from the Government (Ministry of Urban and Infrastructure (MoUI), Ethiopian Construction Authority (ECA), Addis Ababa City Administration Construction Bureau (AACACB) and Addis Ababa City Administration Housing Development Corporation (AACAHDA)), Contractors and consultants, senior experts (reputable professionals) and

Academia. For all this, as mentioned in the study population section 3.1.2.1 above, a total of 100 populations (Architects (25), Engineers (48), Urban Designers (5), Urban Planners (8), and Construction Managers (14)) are selected purposely by the researcher because these study populations have good working experience as well as actively engaged in the construction sector like design preparation; construction of the buildings; teaching and learning about the designing and construction of buildings; consulting in the design, supervision, and contract administration of the construction; and monitoring, controlling, regulating and evaluation of the overall building construction processes.

3.1.2.5. The Sources of Data

The sources of data are classified into primary and secondary. In this study, three fundamental documents were created using the data sources. Documents from the respondents, observations and pictures/artifacts, as well as document analysis, made up this group. Documents from respondents were gathered utilizing surveys, interviews, and meetings/discussions with key informants. The key informant interviews served as a tool for both identifying archive items whose relevance was assessed afterwards and those respondents believed their responses were heavily influenced by such papers. Documents essential for contextual analysis were included in the archival records like publications, rules, regulations, strategies, and guidelines related to building constructions and similar studies. The sources of data gathered for this research and the links connecting them to the study's design and assumptions based on its established research questions. This aided the researcher in strengthening the research's validity and reliability. The following Figure 3.3 showed the sources for data collections of this study.

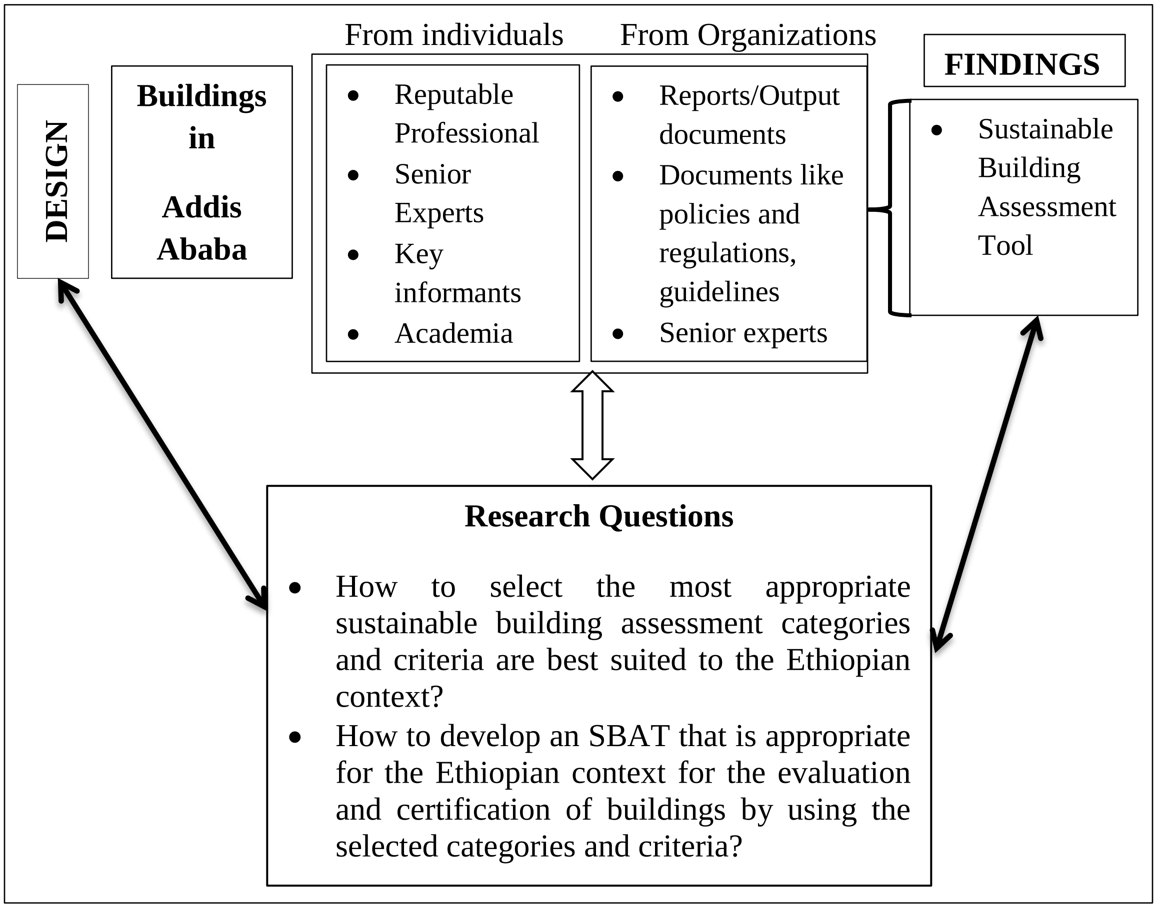

Figure 3.3: Design-Data collection sources-Findings integrated to Research Questions (Source: Based on Yin (1994 & 2003)

3.1.2.6. The Data Types

Depending on the level of standardization, data may be categorized as quantitative or qualitative. Raw data from interviews, focus groups, observations, documents, or multimedia content often makes up qualitative data. Since data from observations and interviews can be recorded as field notes or written transcriptions, most qualitative data are presented as text. There are fewer requirements for organizing before data analysis because of the in-depth focus on qualitative techniques. Combining the categories of analysis and categorization is a common practice.

A high level of uniformity characterizes quantitative data. For instance, closed-ended questionnaires and quantitative content analyses can be used to collect this kind of data. The raw data are classified into quantifiable categories and numerical scales for this purpose. The process of developing categories and quantifiable structures, as well as the coding procedure itself, is frequently based on a qualitative evaluation. The following Figure 3.4 shows the different types of data.

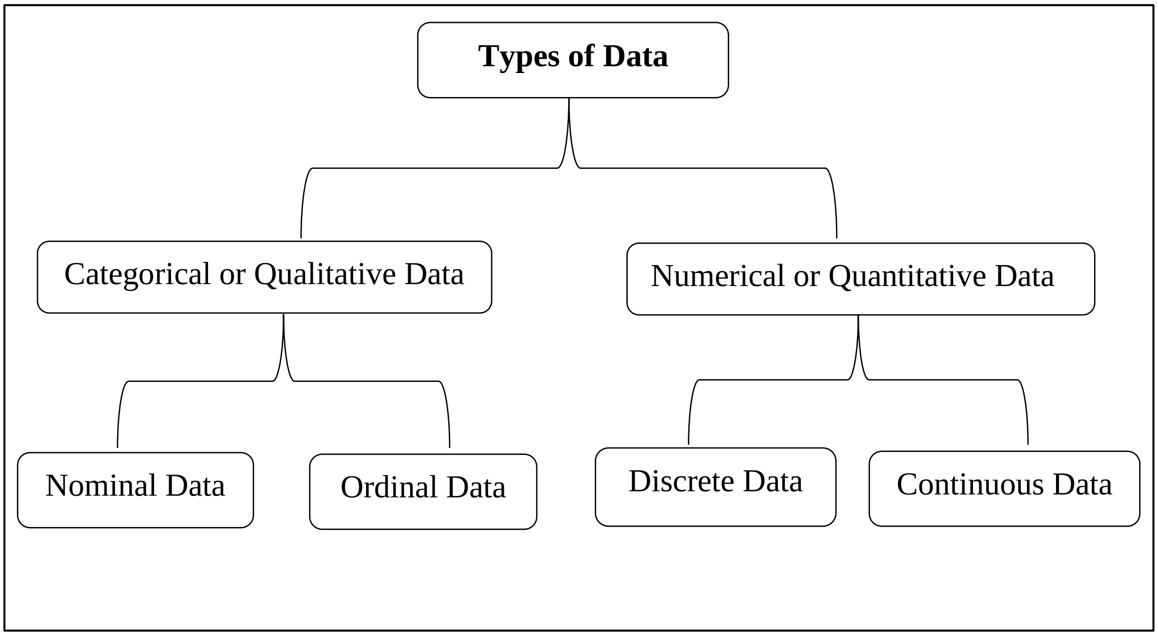

Figure 3.4: The types of data

(Source: Developed by the researcher, 2020)

Each of these data types is discussed below.

Qualitative or Categorical Data

The data that falls into categories is referred to as qualitative data, also known as categorical data. Data with a qualitative component lack numbers. Categorical variables that describe characteristics like a person's gender or town are included in the categorical information. Categorical data can occasionally contain numerical values (quantitative values), although those values don't always make sense mathematically.

One category of qualitative information that aids in labeling variables without providing a numerical value is nominal data. It cannot be measured or ordered. Examples of numeric variables include word, letters, symbols, and genders, among others. The numerical data are analyzed using the clustering approach. The frequency or percentage of the data can then be determined using this method, which groups the data into categories. The pie charts are used to visually portray these facts Yin (2011).

A type of data is called an ordinal variable or data follows a natural order. Numeric is significant since there is no recognized difference between the datasets. Most frequently, this factor can be found in surveys, monetary and economic assessments, and other situations of a similar nature. A bar chart is a frequent visual representation of ordinal data. Numerous visualization tools are used to explore and comprehend these data. Tables can be used to convey the data, with each row displaying a different category Yin (2011).

Quantitative or Numerical Data

Quantitative data is also known as numerical data because it reflects a numerical score (i.e., how much, how often, how many). Quantitative data provides details about the quantities of a particular thing. The following are some samples of numerical data: height, length, size, weight, etc. Based on the data sets, the quantitative data can be divided into two categories: discrete data and continuous data Yin (2011).

Only discrete values are possible for discrete data. These ideals cannot be meaningfully differentiated. Calculable data is continuous data. There are an infinite number of possible numbers that can be selected within a given range.

For this research, various data were collected from different sources as mentioned in sub-section 3.2.3.6 above, and methods of data presentation as described in section 3.2.3.9 below. Based on these, the researcher employed mixed types of data i.e. both qualitative/categorical and quantitative/numerical data because the analyzed data can be presented in different forms like tables, pie charts, bar charts, and others.

3.1.2.7. Method of Data Collection

The research instruments are measurement tools (for example, questionnaires or scales) designed to obtain data on a topic of interest from research subjects. Since the different methods are used for the collection of data that are sensitive to the circumstances, their applicability and suitability are evaluated against their problems and limitations. The research instruments like questionnaires, interviews, observations, discussions with key informants, and document analysis are employed.

In comparison to other tools, the questionnaires are highly affordable, suitable, and cover a large geographic area, allowing access to many participants (samples) depending on the number of study populations. It may manifest in various ways, including a limited ability to obtain detailed information and a low response rate. In addition to questionnaires, interviews are used in this study to gather in-depth data on stakeholders' opinions, experiences, views, and beliefs since they are focused and informative, despite some drawbacks such as incompleteness and prejudice from the tools/ instruments and the respondents. On the other hand, both observations and key informant interviews are the most and best reliable data collection tools because they give researchers real data that is focused and touches the contextual coverage of the study. However, behavioral shifts and some observer bias may be noted, making this instrument's data incomplete. Another tool for gathering data is document analysis, which covers a wide range of analysis topics and can be stable because it is gleaned from archives. But, accuracy, availability to data, and clear partiality of the report are some of the challenges this tool faces in comparison to other data collection methods.

Triangulation, which can be defined as crosschecking of collected data using multiple data sources and using two or more methods of data collection, is also employed to check whether the collected data are talking about the same issues or not. Therefore; the reliability and validity of the data to be collected by using the different research instruments play a significant role in the success of the study and due attention are given to data collection. This led to the adoption of the use of numerous evidences (research instruments) based on the amalgamation of both primary and secondary sources as depicted in Figure 3.5 below for this study.

This study was modified to fit this research based on the following underlying issues Yin (1994 & 2003), Kumar (1999) & Burns (2000) principles for building the research instruments. Some of the issues to be considered for this study are: the research problem, the objectives and the research questions should clearly be addressed; the theories and situation developments related to the research problem, the objectives and the research questions should clearly be identified, defined and integrated; the analyses approaches to be used; the accessibility of data and constraints (time, cost and study area); and the issue of reliability and validity of the research instruments.

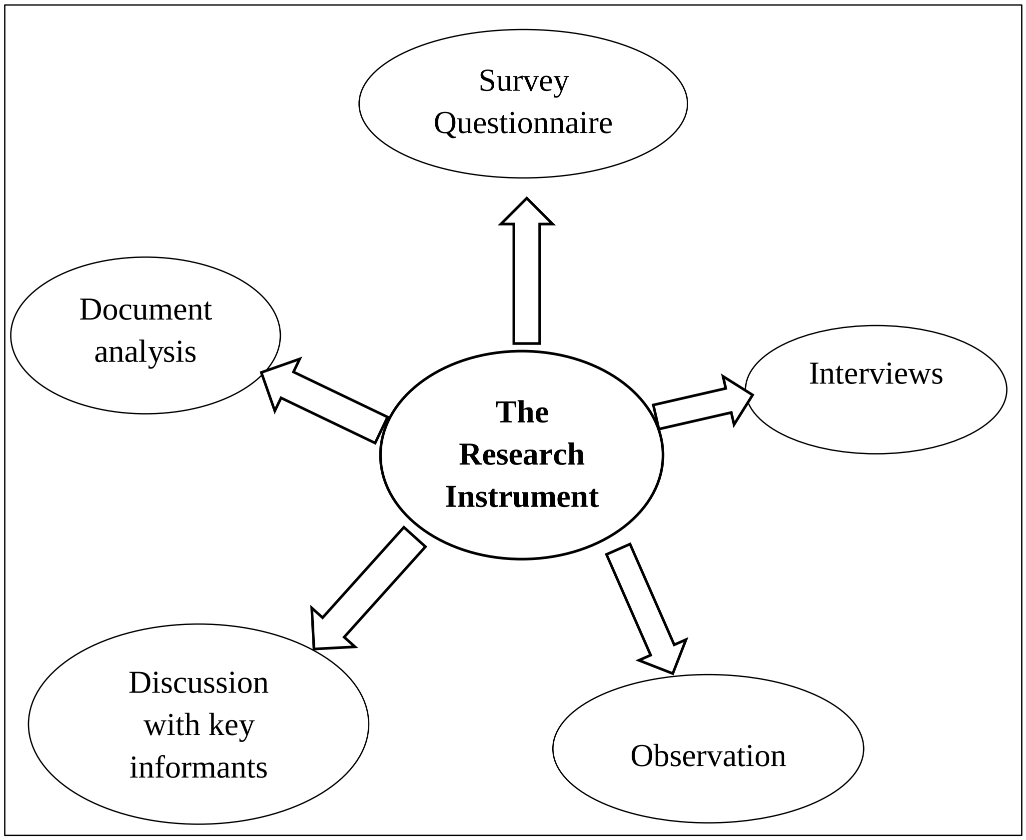

Figure 3.5: Data collection instruments/tools
(Source: Formulated by the researcher, 2020)

The following Table 3.7 shows the matrix of the relationships among different data sources, data types, research questions, and respondents.

Table 3.7: Matrix shows the relationship among research questions, the respondents, data collection instruments, and sources of data

Research Questions	Respondents of the study	Data Collection Instruments	Source of Data	Remark
➢ How to select the most appropriate sustainable building assessment categories and criteria are best suited to the Ethiopian context?	Experts from (MoUI, AACAHDC, and ECA), reputable professionals, and academia	Questionnaires and Interviews	Primary	Document Analysis (Secondary Source) also used as a data collection instrument and source of data
➢ How to develop an SBAT that is appropriate for the Ethiopian context for the evaluation and certification of buildings by using the selected categories and criteria?	Experts from (MoUI, AACAHDC, ECA) and experts, Contractors and consultants, academia, and reputable professionals.	Questionnaires and Interviews	Primary	Discussion with key informants (Primary source) and Document Analysis (Secondary Source) was also used as data collection instruments and sources of data

(Source: Formulated by Researcher, 2020)

3.1.2.8. Method of Data Analysis

The method of examining, purifying, manipulating, and modeling data to find relevant information, support inferences, and help decision-making is considered as data analysis.

The author Wilkinson (2010) has defined data analysis as - several closely related operations that are performed to summarize the collected data and organize these in such a method that they will provide responses to the research objectives or offer other questions if no such queries or assumptions had been used to launch the investigation.

The data analysis process involves evaluating, classifying, tallying, validating, or otherwise merging mixed evidence to solve the study's initial problem statement as noted by Wubishet (2004), and Yin (1994 & 2003).

The authors Wubishet (2004) and Grove (2001) have also indicated that organizing, abstracting, synthesizing, and integrating followed by continual revisions to form conceptual categories or themes is vital in analyzing the study.

For the analysis of the data, Statistical Package for Social Sciences (SPSS) Version 25 for Windows® and the MS-Excel data analysis tools were employed. Under this SPSS Version 25 for Windows®, both descriptive statistics and reliability analysis were used. Descriptive statistics help to describe and understand the features of a specific data set by giving short summaries about the sample and measures of the data. For the reliability analysis, Cronbach's alpha was considered and it is the most common measure of internal consistency ("reliability") as well as most commonly used when multiple Likert questions are used in surveys and questionnaires to create scales and assess the reliability of those scales. In this study, the Reliability Analysis was used for the analysis of the Relative Importance Index and level of importance. In addition to this, the Analytical Hierarchy Process (AHP) technique was used for weighting and rankings to select the appropriate sustainable building assessment categories and criteria. The authors Saaty (2005) noted that the main steps required in the formulation of the AHP framework comprise hierarchy construction, pairwise comparisons, deriving relative weights, consistency checking, and synthesizing results.

3.1.2.9. Methods of Data Presentation

As Chilisa (2012) said, once the data has been processed and analyzed, the final step required in the research process is an interpretation of the data. It can be difficult to distinguish between analysis and interpretation. Chilisa (2012) has also discussed that through interpretation one understands what the given research findings mean and what the underlying generalization is manifested through the data collected. This can be descriptive or analytical or theoretical. The data is interpreted from the point of the research questions and hypothesis tested. While interpretation is being done, generalizations are drawn. Thus, interpretation consists of conclusions that the researcher has reached after the data has been processed and analyzed. The analyzed data are presented in the form of tables, graphs, charts, and reports.

3.2. Validation and Reliability

Concepts like validity and reliability are used to assess the quality of research. They show how well a technique, approach, or test gauges things. While reliability is focused with a measure's consistency, validity involves with a measure's accuracy. Validity and reliability have various definitions, notwithstanding their close relationship. Even though a measurement is unreliable, it can nevertheless be valid. However, a measurement is typically reliable if it is valid Middleton (2019).

Particularly in quantitative research, reliability and validity should be taken into account while developing the study design, selecting methodology, and summarizing findings. Failure to do so may result in many forms of research bias and negatively impact the work.

How consistently a method assesses something is referred to as its reliability. The measurement is regarded as reliable if the same result can be consistently obtained by applying the same techniques under the same conditions. Validity is the degree to which a method actually measures what it is intended to measure. When a study's findings are highly valid, it means that they accurately reflect the genuine features, traits, and variations in the physical or social reality Middleton (2019).

It is clear from the methodology used for this research's sampling processes/techniques (Sub-section 3.2.3.3. entitled "The Sampling Techniques"), characterization of the study population (Sub-section 3.2.3.1. entitled "The Study Population"), and sample size determination (Sub-section 3.2.3.4. entitled as “The Sample Size Determination”) that it is both valid and reliable. This is supported by the use of diverse data gathering techniques like survey questionnaires, field observations, and document analysis (section 3.2.3.7. entitled "Method of Data Collection"), as well as distinct data analysis like SPSS, MS-Excel, and AHP (section 3.2.3.8. entitled as “Method of Data Analysis”) and presentation approaches like Charts, Tables, Graphs, and Maps (section 3.2.3.9 entitled as “Methods of Data Presentation”). Multiple data-gathering tools were used, depending on the research questions. This ensures the data's reliability while also being utilized to triangulate the data's validity.

CHAPTER FOUR

4. Data Analysis, Results, and Discussion

The definition of data analysis given by Wilkinson (2010) in the methodology section of this study's (sub-section 3.2.3.8 of Method of Data Analysis) is as follows: Data analysis is defined as several closely related operations that are carried out to condense the gathered data and arrange these in a way that will produce answers to the research questions or provide hypotheses or questions if the study hadn't been launched by such inquiries or hypotheses. The authors Wubishet (2004) and Yin (1994 & 2003) stipulated in the same sub-section that the analysis of data entails examining, categorizing, tabulating, testing, or otherwise combining mixed pieces of evidence to meet the initial problem statement of the study. In addition, it has been noted Wubishet (2004) and Grove (2001) that organizing, abstracting, integrating, and then continuing changes to build conceptual categories or themes are essential steps in the analysis of the study.

The two primary sources of information used in this study's analysis are drawn from the research methodology framework outlined in (Figure 4.1). These are:

1) Choosing eight (8) categories and sixty-nine (69) criteria for the development of sustainable building assessment tools that are the most popular and frequently applied in Ethiopian contexts, and
2) Comparing the assessment categories and criteria for sustainable buildings based on surveys, and using SPSS Version 25 for Windows® to analyze the Prioritizing, Weighting, and Ranking of these assessment categories and criteria.

It is crucial to determine the validity and reliability of the data acquired before undertaking a detailed analysis of these fundamental sources of information since these two aspects will largely determine whether the analysis will be conducted at all.

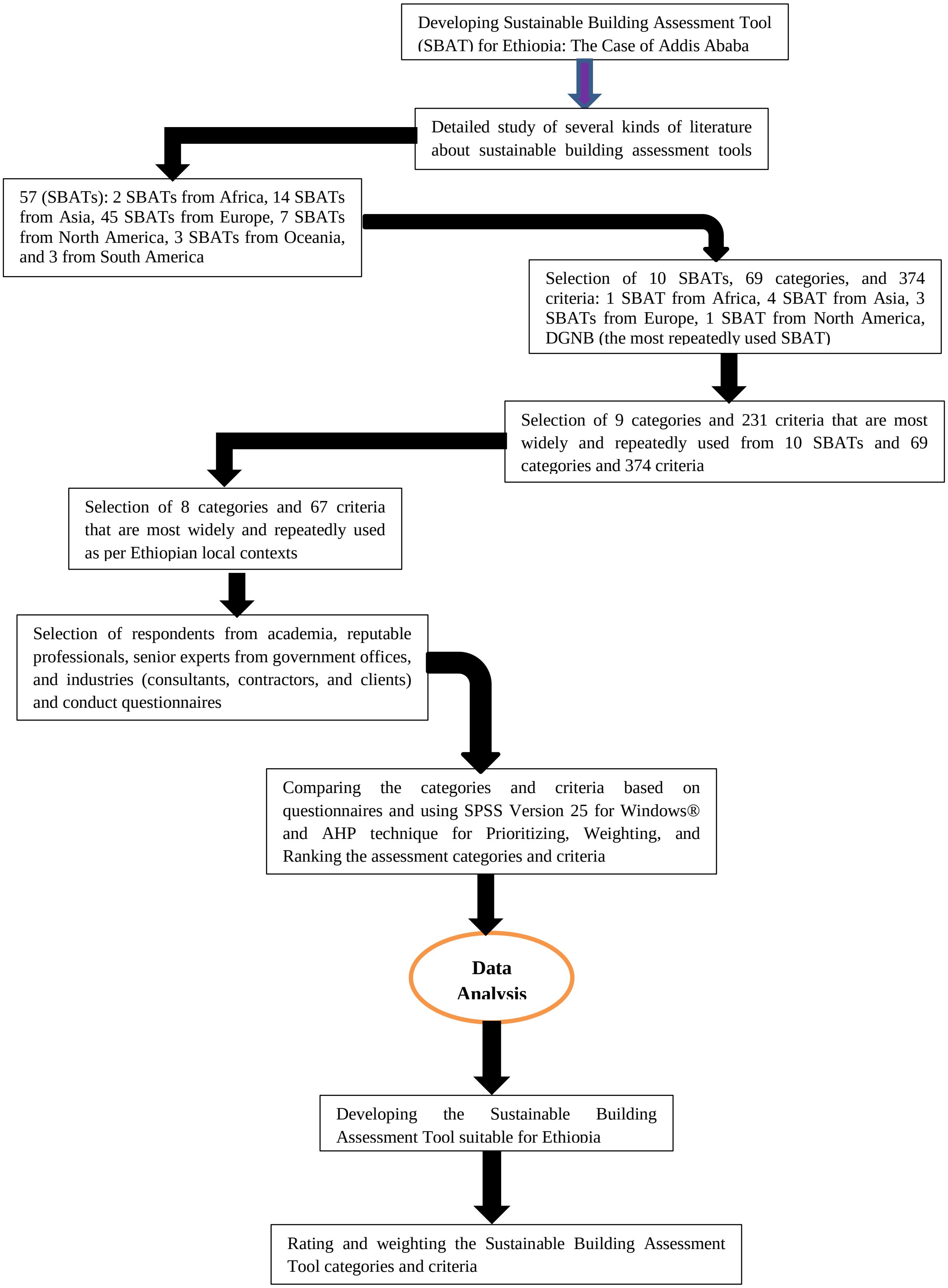

Figure 4.1: The Research Methodological Framework

(Source: Developed by the researcher, 2021)

Validity of the study

Validity is a measure of the level of cogency or the validity of a research instrument, and it also relates to the appropriateness of conclusions drawn regarding assessment outcomes.

Before beginning the actual data collection procedure, a thorough examination of the pertinent literature is conducted to create a sample questionnaire. Eight (8) participants who are knowledgeable about the research topic were used in a pilot study based on these sample questionnaires to identify the most relevant assessment categories and criteria/components for developing (SBAT) and evaluate their validity and reliability. This confirms the clarity, thoroughness, and application of the surveys.

4.1. The selection of the most appropriate sustainable building assessment categories and criteria are best suited to the Ethiopian context

Research Question 1: How to select the most appropriate sustainable building assessment categories and criteria are best suited to the Ethiopian context?

By considering the various types of categories from the 10 SBATs, which are discussed in the chapter two of Methodological Framework of 2.3 of section 2.3.1 and the summary of Table 2.24, there are 69 categories and 374 criteria. Out of the 69 assessment categories, seventeen (17) were selected by the researcher after thorough research into the most frequently utilized categories, as shown in Table 4.1 below. The duplication of these assessment categories in more than one of each of the ten (10) SBATs that were chosen served as the selection criterion.

Table 4.1: The 10 selected SBATs' most frequently recurring categories

S/ No.	Categories	The selected 10 Sustainable Building Assessment Tools									
		BREEAM-UK	CASBEE-Japan	CEPAS-Hong Kong	DGNB	GBI-Malaysia	Green Mark Singapore	Green Star-South Africa	HQE^{TM}- 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, (2021) The highlighted categories like management (in 3 SBATs), material (in 3 SBATs), waste (in 3 SBATs), off-site environment (in 4 SBATs), pollution (in 5 SBATs), quality service (in 4 SBATs), comfort (in 5 SBATs), and regional priority (in 3 SBATs) shown in Table 4.24 above as being the least frequently used SBATs, while the most frequently used categories are health and well-being (in 9 SBATs), energy (in 10 SBATs), water (in 10 SBATs), transport (in 7 SBATs), land use and ecology (in 9 SBATs), innovation (in 6 SBATs), indoor environmental quality (in 10 SBATs), resources and materials (in 10 SBATs), and sustainable site planning and management (in 9 SBATs). As a result, prior consideration must be given to these categories (most frequently repeated once) in the development of the new SBATs, and some categories may be added in light of the Ethiopian context.

There are various criteria available for each of the SBATs' selected categories, as stated in Table 4.2 below. As discussed in the Literature Review Chapter of section 2.3.1, the criteria found in one SBAT may also be present in other SBATs with similar category names or subtle variations on those category names, such as “Health and Well-being” in the BREEAM SBAT (Table 2.4) whereas "Occupant's Health and Comfort" in the SBTool SBAT (Table 2.22) and "Health and Safety" in the HQE™ SBAT (Table 2.17). Other categories names include "Energy" in the BREEAM (Table 2.4), CASBEE (Table 2.7), and Green Star SA SBAT (Table 2.16); "Energy Efficiency" in the GBI (Table 2.12), Green Mark (Singapore) (Table 2.154), and SBTool SBAT (Table 2.22); "Energy and Savings" in the HEQ™ SBAT (Table 2.17); and "Energy and Atmosphere" in the LEED SBAT (Table 2.19).

The category "Water" in the BREEAM and Green Star SA SBATs is comparable to and slightly different from "Water Efficiency" in the GBI, Green Mark (Singapore), LEED, and SBTool SBATs. In addition to this, the category names vary depending on the SBAT, such as "Land Use and Ecology" in BREEAM and Green Star SA versus "Land Use and Biodiversity" in SBTool. For example, under the category name "Health and Well-being," criterion like "Visual Comfort" in the BREEAM SBAT is also found in the HQE™. These direct similarities and slight changes in category names have several criteria with similar names (duplication of similar names) and a slight change of its name.

The assessment criteria for "Thermal Comfort" can also be found in the BREEAM SBAT under the "Health and Well-being" category, in the CASBEE SBAT under the "Indoor Environment" category, in the GBI and Green Star-SA SBATs under the "Indoor Environmental Quality" category, and in the SBTool SBAT under the "Occupant's Health and Comfort" category.

The CEPAS SBAT (Table 2.8) lists the "Waste Management" evaluation criterion under the "Loadings" category, the GBI SBAT under the "Materials and Resources" category, the Green Star SA SBAT under the "Management" category, the HQE^{TM} SBAT under the "Environment" category, and the LEED SBAT under the "Resources and Materials" category. The fact that the same criteria are used for many types of SBATs demonstrates how nations have adapted the criteria to their local context and directly adopted previously produced criteria from SBATs like BREEAM, LEED, CASBEE, SBTool, and others. When all the subcategories of the chosen 10 SBATs are taken into account, there are 231 assessment criteria, some of which are repeated across numerous SBAT categories, as was already mentioned.

For further analysis, the researcher selected nine (9) of the non-highlighted sustainable building assessment categories that are presented in Table 4.1 above as they are repeatedly used in more than five (5) times. The associated evaluation criteria for these non-highlighted categories that were identified in the chosen ten (10) SBATs are shown in Table 4.2 below.

Table 4.2: Lists of the criteria for each of the 10 selected SBATs' 9 categories

S/No.	Category	Criteria
Health and Well-being		
1.		Visual Comfort
2.		Indoor air quality
3.		Safe containment in laboratories
4.		Thermal comfort
5.		Acoustic performance
6.		Security
7.		Safe and healthy surroundings
8.		Quality of spaces
9.		Air quality and health

10.		Water quality and health
11.		Natural ventilation efficiency
12.		Toxicity of finishing
13.		Thermal comfort
14.		Lighting comfort
15.		Acoustic comfort
16.		Visual Comfort
Energy		
1		Reduction of energy use and carbon emissions
2		Energy monitoring
3		External lighting
4		Low carbon design
5		Energy-efficient cold storage
6		Energy-efficient transportation systems
7		Energy-efficient laboratory systems
8		Energy-efficient equipment
9		Building thermal load
10		Natural energy utilization
11		Efficiency in the building service system
12		Efficient operation
13		Energy efficiency
14		Design and performance
15		Commissioning
16		Monitoring, improvement, and maintenance
17		Thermal performance building envelope
18		Naturally ventilated design and air-conditioning system
19		Daylighting
20		Artificial lighting
21		Ventilation in car parks
22		Lifts
23		Energy-efficient features
24		Renewable energy
25		Conditional requirement
26		Greenhouse gas emissions
27		Energy sub-metering
28		Lighting power density
29		Lighting zoning
30		Peak energy demand reduction
31		Thermal energy sub-metering

32		Hot water energy use
33		Common property energy use
34		Low-emission energy generation
35		Energy-efficient appliances
36		Unoccupied spaces
37		Energy management
38		Water management
39		Maintenance management
40		Energy efficiency best management practices: Planning, documentation and opportunity assessment
41		Minimum energy efficiency performance
42		Refrigerant management: Ozone protection
43		Optimize energy efficiency performance
44		Existing building commissioning: Investigation and analysis
45		Existing building commissioning: Implementation
46		Existing building commissioning: Ongoing commissioning
47		Performance measurement: Building automation system
48		Performance measurement: System-level measuring
49		On-site and off-site renewable energy
50		Refrigerant management
51		Emissions reduction reporting
52		Primary energy
53		In-situ energy production from renewable sources
Water		
1		Water consumption
2		Water monitoring
3		Water leak detection
4		Water efficient equipment
5		Water harvesting and recycling
6		Increased efficiency
7		Water efficient fittings
8		Water usage monitoring
9		Irrigation system and landscaping
10		Recycling waste storage
11		Minimum indoor plumbing fixture and fitting efficiency
12		Water performance measurement
13		Additional indoor plumbing fixture and fitting efficiency

14		Water efficient landscaping
15		Cooling tower water management
16		Fresh water consumption
17		Reuse of grey and rainwater
Location and Transport		
1		Transport assessment and travel plan
2		Sustainable transport measures
3		Transportation
4		Provision of car parking
5		Fuel-efficient transport
6		Cyclist facilities
7		Commuting mass transport
8		Local connectivity
9		Trip reduction – Mixed use
10		Vehicle operating emissions
11		LEED for neighborhood development location
12		Sensitive land protection
13		High priority site
14		Surrounding density and diverse uses
15		Access to quality transit
16		Bicycle facilities
17		Reduced parking footprint
18		Green vehicles
19		Accessibility to public transportation
Land use and Ecology		
1		Site selection
2		Ecological risks and opportunities
3		Managing impacts on ecology
4		Ecological change and enhancement
5		Long-term ecological management and maintenance
6		Global warming potential
7		Ozone depletion potential
8		Photochemical ozone creation potential
9		Acidification potential
10		Eutrophication potential
11		Risks to the regional environment
12		Other impacts on the global environment
13		Microclimate
14		Non-renewable primary energy demands

15		Total primary energy demands and proportion of renewable primary energy
16		Potable water consumption and sewage generation
17		Surface area usage
18		Conditional requirement
19		Topsoil
20		Reuse of land
21		Reclaimed contaminated land
22		Change of ecological value
23		Urban heat island
24		Outdoor communal facilities
25		Urban consolidation
26		Community facilities
27		Urban density
28		Water permeability of the development
29		Use of pre-developed land
30		Use of local flora
31		Heat-island effect
Innovation		
1		Innovation
2		Innovation in operations
3		LEED® accredited professional
4		Documenting sustainable building cost impacts
Indoor Environmental Quality		
1		Noise and acoustics
2		Thermal comfort
3		Lighting and illumination
4		Air quality
5		Health and hygiene
6		Indoor air quality
7		Lighting environment
8		Indoor air quality
9		Indoor hygiene
10		Air quality
11		Thermal comfort
12		Lighting, visual and acoustic comfort
13		Verification
14		Noise level
15		Indoor air pollutants

16		Waste disposal
17		Indoor air quality in wet areas
18		Ventilation rates
19		Air change effectiveness
20		Carbon dioxide monitoring and control
21		Daylight
22		Daylight glare control
23		High-frequency ballasts
24		Electric lighting levels
25		External views
26		Thermal comfort
27		Individual comfort control
28		Hazardous materials
29		Internal noise levels
30		Volatile organic compounds
31		Formaldehyde minimization
32		Mould prevention
33		Tenant exhaust riser
34		Environmental tobacco smoke (ETS) avoidance
35		Places of respite and connection to nature
36		Private outdoor space
37		Universal access
38		Stairs
39		Outdoor air introduction and exhaust systems
40		Environmental tobacco smoke (ETS) Control
41		Green cleaning policy
42		IAQ best management practices: IAQ management program
43		IAQ best management practices: Outdoor air delivery monitoring
44		IAQ best management practices: Increased ventilation
Resources and Materials		
1		Water resources
2		Materials of low environmental load
3		Energy efficiency
4		Water conservation
5		Timber use
6		Material use
7		Reused and recycled materials

8		Sustainable materials and resources and policy
9		Waste management
10		Green products
11		Sustainable purchasing policy
12		Solid waste management policy
13		Sustainable [purchasing: Ongoing consumables
14		Sustainable purchasing: Durable goods
15		Sustainable purchasing: Facility alterations and additions
16		Sustainable purchasing: Reduced mercury in lamps
17		Sustainable purchasing: Food
18		Solid waste management: Waste stream audit
19		Solid waste management: Ongoing consumables
20		Solid waste management: Durable goods
21		Solid waste management: Facility alterations and additions
22		Materials and products reused
23		Use of materials with recycled content
24		Use of certified organic materials
25		Use of cement substitutes in concrete
26		Waste management during the operation
Sustainable sites planning and Management		
1		Nature conservation
2		Heritage conservation
3		Buildability
4		Facility management
5		Transportation
6		Reduce the heat island effect
7		Sustainable construction
8		Sustainable products
9		Stormwater management
10		Environmental management practice
11		Sustainable worksite
12		LEED-certified design and construction
13		Building exterior and hardscape management plan
14		Integrated pest management, erosion control, and landscape management plan
15		Alternative commuting transportation
16		Reduced site disturbance: Protect or restore open space
17		Stormwater management

18		Heat island reduction: Non-roof
19		Heat island reduction: Roof
20		Light pollution reduction
21		Heat-island effect

(Source: Extracted from the selected 10 SBATs and 9 assessment categories by the researcher, 2021)

According to the above Table 4.2, a total of 231 criteria have been identified from the selected and most frequently used 9 categories of the 10 selected SBATs shown in Table 4.2 and it is very difficult to manage if we use them as sustainable building assessment criteria for the given country.

As shown in Table 4.2 above, some criteria are repeatedly used in different categories like "Thermal Comfort" (in the categories of "Health and Well-being", "Indoor Environment", "Indoor Environmental Quality", and "Occupant's Health and Comfort"), "Visual Comfort" (in the category of “Health and Well-being”, “Socio-Cultural and Functional Quality”, and “Comfort”) as well as "Waste Management" (in the categories of "Loadings", "Materials and Resources", “Environment”, and “Materials and Waste Management”). Because of this, it would be impossible to use all of the criteria for evaluating sustainable buildings. This is because the chosen SBATs use all the criteria based on their local context, adapting (their country's familiarization with the criteria) or adoption (their acceptance and implementation of the already developed SBATs without taking into account their context).

From the nine (9) selected assessment categories shown in Table 4.3, eight (8) categories are selected based on the considering the local context; the categories used by the LEED-USGBC to award the HoA-REC green building; renaming (Water and Energy categories to Water Efficiency and Energy Efficiency categories), rearranging (Land use and Ecology and Sustainable sites planning and Management to Sustainable Sites end Ecology and Management) or merging some categories; and adding new category like economic aspects SBAT.

From the two hundred thirty one (231) assessment criteria mentioned in the Table 2.2 above, sixty seven (67) criteria were selected based on the considering the local context;

the criteria used for the assessment of the HoA-REC green building by the LEED-USGBC; and considering the repeatedly used criteria.

As shown in Table 4.3 below, the following factors are therefore taken into account when developing new SBATs: Repeated criteria were consolidated; some criteria were dropped since they didn't apply to Ethiopia; some new category like economic aspects, were added; and some criteria were kept if they were appropriate.

Table 4.3: The selected assessment categories and criteria for the Ethiopian context

S/No.	Category	Criteria
Economic Aspects		
1.		Building's affordability concerning the distance of facilities of transportation
2.		Building's affordability concerning the distance of getting shops/marketplaces
3.		Building's affordability concerning the distance of getting health services
4.		Building's affordability concerning the distance of getting education services
5.		Building's affordability concerning the distance of the workplace
6.		Building's affordability concerning rental for residential
7.		Costs for maintenance and operation
8.		Costs of buildings' life cycle
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 Transport		
1.		Availability of alternative modes of transportation
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
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
Indoor Environmental Quality		
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 and illumination for lighting controllability
8.		Lighting and illumination for the view out
9.		Lighting and 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
Resources and Materials		
1.		Use of Materials with 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)
Management		
1.		Facility management
2.		Commissioning
3.		Consultation
4.		Construction process planning and management
5.		Waste management during construction and operation
6.		Security

(Source: Extracted from the 231 sustainable building assessment criteria by the researcher, 2021)

According to Table 4.3 above, the revised and most appropriate sustainable building assessment categories and criteria for the Ethiopian setting were identified. These categories include economic aspects, energy efficiency, water efficiency, location and transport, sustainable sites and ecology, indoor environmental quality, resources and materials, and management. The following Table 4.4 presents the 10 SBATs that were chosen, the eight sustainable building evaluation categories, and the 67 criteria that were utilized to design the SBAT for Ethiopia.

Table 4.4: The sustainable building assessment criteria of the 8 categories used by the selected 10 SBATs

S/ No.	**Sustainable building assessment criteria**	**The selected 10 Sustainable Building Assessment Tools (SBATs)**									
		BREEAM-UK	CASBEE-Japan	CEPAS-HK	DGNB	GBI-Malaysia	Green Mark-Singapore	Green Star-SA	HQE™-France	LEED-USA	SBTool^{PT}-Portugal
Economic Aspects											
1.	Building's affordability concerning the distance of facilities of transportation	●		●	●	●	●	●		●	●
2.	Building's affordability concerning the distance of getting shops/marketplaces			●	●					●	●
3.	Building's affordability concerning the distance of getting health services		●	●	●						●
4.	Building's affordability concerning the distance of getting education services			●	●						●
5.	Building's affordability concerning the distance of the workplace										●
6.	Building's affordability concerning rental for residential										●
7.	Costs for maintenance and operation			●						●	●
8.	Costs of buildings' life cycle	●	●	●	●			●			●
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									●	
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	●	●						●	●	●
Indoor Environmental Quality											
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	●	●				●	●	●	●	●
Resources and Materials											
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)	●	●		●	●		●	●	●	●
Management											
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)

The following also explains how each selected category of the sustainable building assessment is discussed.

The **economic aspect (EA)**, one of the eight sustainable building assessment categories, is significant regardless of whether the facility is owned or rented. Economically sustainable buildings have an advantage over those that are not, as is well recognized. In addition to other factors, non-sustainable buildings produce more waste and emissions, require more energy and water, are uncomfortable for occupants, and ineffectively control the quality of the indoor environment. In Ethiopia, this category is essential for evaluating buildings by taking into account a variety of assessment criteria, such as the building's affordability concerning distances to transportation facilities, work locations, health services, education services, shops/markets, and rental of the building for residential purposes, as well as the construction costs and the operation and maintenance costs.

The **efficient utilization of energy (energy-efficient (EE))** is essential for national economic development, especially in developing nations such as Ethiopia. The majority of developing nations are currently seeing an increase in building construction; however, because of the price and market for energy, few efficient solutions are being used. The requirement to improve energy capacity to meet its rising energy demand base is one of Ethiopia's primary challenges and a crucial developmental aim for most developing nations. According to Behnam (2017), sustainable buildings can save 36% of total energy use and 65% of electricity consumption. This suggests that if energy sources are being used efficiently, having sustainable buildings for countries can contribute to rapid, sustainable economic growth. Therefore, it is crucial to evaluate buildings from the perspective of efficient energy use by taking into account several assessment criteria, such as the use of energy monitoring and management systems, energy for internal and external lighting, energy-efficient equipment, the use of renewable and natural resources, the use of hot water and steam, HVAC systems, and energy savings.

Water is one of the most important natural resources, and the construction industry uses a large quantity of it. **Water efficiency (WE)** is one of the primary sustainability categories included in all of the existing SBATs since it helps reduce the number of water resources used in buildings. Since it is a fundamental human requirement, one of the crucial sustainability categories is water. Throughout a building's lifespan, access to and quality of water are essential. The application of water strategies and practices such as those mandated by such criteria is suggested in the literature to have a major impact on water conservation as well as other environmental benefits, as discussed by the authors Yasutoshi (2013). In addition to other factors, such as energy efficiency and carbon reduction, experts have thoroughly studied buildings' water efficiency Cheng (2016). Water efficiency is one of the assessment categories used to assess buildings from the viewpoint of sustainable building, and it has several assessment criteria listed within it. Water consumption, regular water leak detection, and monitoring, rainwater harvesting, the use of water-efficient fixtures and equipment, regular monitoring of water usage, wastewater recycling, and groundwater recharge are some of the assessment criteria that were chosen.

Because the environmental performance of the building and its occupants is influenced by how people and commodities get to and from a site, location is an essential aspect of sustainable building techniques. A location-efficient site is well-connected to the surrounding area and adjacent to resources, including job hubs, retail establishments, dining options, educational institutions, healthcare centers, and other services. Businesses seeking quicker access to customers and workers, as well as locals seeking easier access to additional employment opportunities, may be attracted to a location with good transit links to other places. Therefore, selecting a location that has access to transportation options and a variety of nearby destinations has benefits, such as preserving open space, urban agriculture, and natural lands by building on or close to already developed sites; saving money and resources by utilizing existing infrastructure, and protecting air and water quality by reducing the distance people must drive. Under the assessment category of **location and transportation (LT)**, the assessment criteria are the availability of alternative modes of transportation, provision of the car parking area and parking capacity, community/local connectivity, density development location, sensitive land protection, surrounding density, and diverse uses, and accessibility to public transportation Cheng (2016).

Preserving the wider ecosystem by reducing the influence of the built environment is one of the primary priorities of sustainable buildings and landscapes. The authors Osman (2018) pointed out that **sustainable site and ecology (SE)** addresses problems in the area around the building, including the neighborhood and the land being developed. The sustainable sites and ecology category assessment takes into account criteria such as site selection and protection, reuse of land, ecological/land value, reclaimed contaminated land, enhanced site ecology, use of local /indigenous plants/flora, protection and restores open space, and the existence of open space, green area, playground area, and public space.

The term **"indoor environmental quality" (IEQ)** refers to all of the factors that affect a building's occupants or residents, including air quality, lighting, temperature, and ergonomics. IEQ can be addressed by methods that enhance the quality of life, safeguard human health, and decrease stress and potential harm. A better indoor environment can also improve inhabitants' quality of life, raise the property's resale value, and decrease the building owners' liability. The authors Osman (2018) have also identified that the IEQ deals with materials and systems inside the building that affect the health and comfort of the occupants and construction workers. Among the chosen sustainable building evaluation criteria for this category are noise level; sound insulation; sound absorption; thermal comfort concerning cooling control and comfort; thermal comfort concerning heating control and comfort; thermal comfort concerning humidity control and comfort; lighting & illumination concerning lighting controllability; lighting & illumination concerning view out; lighting & illumination concerning glare measure and control; indoor air quality; visual comfort; the existence of natural ventilation; availability of ventilation system; and air purification, supply of fresh air.

Sustainable building **materials and resources (MR)**, also known as eco-friendly materials, are those used in constructions that have little impact on the environment. Instead of nonrenewable resources, they are made of renewable ones. Throughout the lifetime of the building, this category affects the environment of the materials. The infrastructure that brings people to and from the buildings, the things we use to fill them and the activities that take place inside of them are all built based on materials and resources. It is simple to ignore the histories and expenses connected with manufacturing, transportation, consumption, and disposal, given the pervasiveness of materials and resources. The assessment criteria for the category of materials and resources cover the responsible selection of sustainable materials and resources, which include the use of materials of low environmental impact, use of nonrenewable virgin materials, reuse of structural frame materials, use of locally available materials, use of materials with recycled content, use of finishing materials, and material efficiency over its life cycle Osman (2018).

To address concerns of incommensurability and complexity related to environmental regulations and legislation, sustainable building **management** requires proper and acceptable assessment techniques and procedures Yasutoshi (2013). The management category's chosen assessment criteria for the assessment of sustainable buildings include facility management, commissioning, consultation, construction process planning, and management, waste management during construction and operation, and security.

4.1.1. Analytical tools appropriate for the assessment of selected categories and criteria

The term "data analysis" is defined as follows by (Wilkinson, 2010) in the methodology part of subsection 3.8 (Methods of Data Analysis) of this study: To condense the collected data and arrange it in a way that would result in answers to the research questions, or generate hypotheses or questions if no such questions or hypothesis had initially motivated the investigation, so that data analysis is described as a set of closely connected activities. In the same subsection, the authors Wubishet (2004) and Yin (1994 & 2003) specified that the analysis of data comprises looking at, classifying, tabulating, testing, or otherwise combining mixed evidence to address the study's initial problem statement. The steps of organizing, abstracting, integrating, and then continuing alterations to develop conceptual categories or themes have also been emphasized by Wubishet (2004) and Grove (2001) as being crucial to the analysis of the study.

In the methodological framework of the Literature Review of sub-section 2.3.2 of this study, it is stated that the Analytical Hierarchy Process (AHP) is a fundamental method for weighting, ranking, and prioritizing the various categories and criteria based on the comparative evaluations of the study's participants/samples who are the respondents to the survey questionnaires. The weightings, rankings, and prioritization used in this study ultimately lead to the development of new SBATs that are appropriate for the Ethiopian setting.

The Analytical Hierarchy Process (AHP) technique was used for data analysis under the data analysis tools of sub-section 3.8 of the study in addition to the literature section of sub-section 2.3.2 to weigh and rank the data to select the appropriate sustainable building assessment categories and criteria. The author Saaty (2005) observed that the hierarchy construction, pairwise comparisons, deriving relative weights, consistency checking, and synthesizing results are the primary phases necessary in the formulation of the AHP framework.

Eight (8) categories and sixty-seven (67) criteria have been identified by Research Question 1 for the development of SBAT that are suitable for the Ethiopian setting, as shown in Table 4.4.

A researcher conducted survey questionnaires for the respondents from various offices in Addis Ababa. As stated in the Methodology part of Study Design of section 3.1.2.1-3.1.2.4 (The Study Population to Sample Size Determination Techniques), 100 professionals from different disciplines, such as architects, engineers, designers, urban planners, and construction managers, were selected based on the mentioned purposive sampling criteria in this section for conducting the study because they have a good working experience as well as actively engaged in the construction sectors like design preparation; construction of the buildings; teaching and learning about the designing and construction of buildings; consulting in the design, supervision, and contract administration of the construction; and monitoring, controlling, regulating and evaluation of the overall building construction processes. The investigation was conducted with contestants in the form of a questionnaire. The survey questionnaires included closed-ended and open-ended questions. Out of the 100 participants, 93 (Architects, 23 (24.7%); Designers, 2 (2.2%); Urban Planners, 6 (6.5%); Engineers, 48 (51.5%); and Construction

Managers, 14 (15.1%) responded to the questionnaires as shown in Figure 4.2 below. The response rate was 93%.

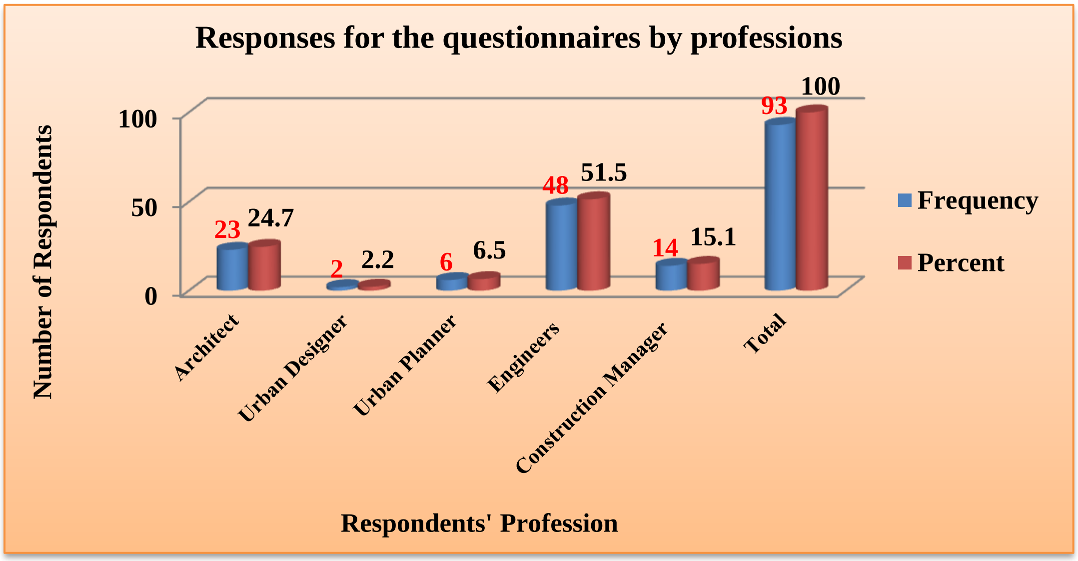

Figure 4.2: Responses for the questionnaires by the participants by professions

(Source: SPSS Survey Result, 2021)

The most acceptable sustainable building assessment categories and criteria, which were used by the selected 10 SBATs, are summarized in Table 4.5 what shows the eight (8) categories and sixty-seven (67) criteria for the evaluation of sustainable/green buildings as per the Ethiopian context. This information was gathered using survey questionnaires from respondents who were involved in the building construction sector, such as contractors, consultants, academia (teaching and learning), senior experts, and regulatory body (government).

Table 4.5: The major categories and criteria used for the survey questionnaires

S/No.	8 Categories	67 Criteria
1	Economic Aspects	Building's affordability concerning the distance of facilities of transportation
2		Building's affordability concerning the distance of getting shops/marketplaces
3		Building's affordability concerning the distance of getting health services
4		Building's affordability concerning the distance of getting education services

5		Building's affordability concerning the distance of the workplace
6		Building's affordability concerning rental for residential
7		Costs for maintenance and operation
8		Costs of buildings' life cycle
9		Investment risk
10		Construction cost
11	Energy-Efficiency	Use of energy monitoring /management system
12		Energy for internal lighting
13		Energy for external lighting
14		Use of energy-efficient equipment
15		Use of natural energy resources/ renewable energy
16		Use of hot water/steam
17		HVAC systems
18		Energy savings
19	Water-Efficiency	Water consumption
20		Regular water leak detection and monitoring
21		Use of rainwater harvesting
22		Use of water-efficient fittings and equipment
23		Regular water usage monitoring
24		Recycling wastewater
25		Recharge of groundwater
26	Location and Transportation	Availability of alternative modes of transportation
27		Provision of the car parking area and parking capacity
28		Community/local connectivity
29		Density development location
30		Sensitive land protection
31		Surrounding density and diverse uses
32		Accessibility to public transportation
33	Sustainable Sites and Ecology	Site selection and protection
34		Reuse of land
35		Ecological/land value
36		Reclaimed contaminated land
37		Enhance site ecology
38		Use of local /indigenous plants/flora
39		Protect or restore open space
40		Existence of open space, green area, playground area, and public space
41	Indoor	Noise level

42	Environmental Quality	Sound insulation
43		Sound absorption
44		Thermal comfort for cooling control and comfort
45		Thermal comfort for heating control and comfort
46		Thermal comfort for humidity control and comfort
47		Lighting and illumination for lighting controllability
48		Lighting and illumination for a view out
49		Lighting and illumination for glare measure and control
50		Indoor air quality
51		Visual Comfort
52		Existence of natural ventilation
53		Availability of ventilation system
54		Air purification- supply of fresh air
55	Materials and Resources	Use of Materials with low environmental impact
56		Use of non-renewable-virgin materials
57		Reuse of structural frame materials
58		Use of locally available materials
59		Use of materials with recycled content
60		Use of finishing materials
61		Material efficiency over its life cycle
62	Management	Facility management
63		Commissioning
64		Consultation
65		Construction process planning and management
66		Waste management during construction and operation
67		Security

(Source: Extracted by a researcher from the different categories and criteria suitable to the Ethiopian context, 2021)

The aforementioned sustainable building assessment categories and criteria were selected from among those used by various nations around the world, such as BREEAM-United Kingdom, CASBEE-Japan, CEPAS-Hong Kong, and DGNB-Germany. In addition to LEED-USA and SBTool^{PT}-Portugal, other certifications include GBI-Malaysia, Green Mark-Singapore, Green Star-South Africa, and HQE^{TM}-France.

The survey questionnaires were developed to conduct the AHP analysis on the identified sustainable building assessment categories and criteria. Various professionals/respondents from academia, well-known professionals, government agencies, and industries were consulted. To ensure that everyone was on the same page, the researcher gave the survey questionnaires to each responder and then had a conversation with each one to get their thoughts. Through this process, the questionnaire's validity is determined, and any necessary adjustments to the categories and criteria were made.

Table 4.6 below is an example of a pairwise scale that illustrates the significance of the identified assessment criteria. The scale spans from 1 to 5. Each number denotes the relative weight each criterion has concerning the others.

Table 4.6: Scales for the importance of criteria

Important scale	Definition of Important Scale
1	Equally Important
2	Moderately Important
3	Strongly Important
4	Very Strongly Important
5	Extremely Important

(Source: Ahmed et al. (2017))

The AHP process was used to carry out the weightings, prioritizing, and rankings of the chosen categories and criteria because, as noted by the authors Ahmed et al. (2017), it is a decision-making tool that assigns weights to each category and criterion as well as prioritizes and ranks the credits according to their importance.

The researcher employed the AHP technique as outlined by Saaty (2005) to develop new sustainable building assessment schemes for the Ethiopian setting. The author, Saaty (2005), has drawn the key stages necessary to develop the AHP framework, which includes hierarchy construction, pairwise comparisons, deriving relative weights, consistency checking, and results synthesis. Therefore, the AHP technique was used to analyze the weightings, relative priority values (%), and rankings of the determined appropriate categories and criteria. These stages were discussed in detail in the following sections.

4.1.1.1. Hierarchy Construction

There is no unique method for creating a hierarchy; rather, this stage serves as the cornerstone of AHP and is regarded as a crucial element of AHP. The process of creating a hierarchy is top-down and involves several levels (in this study, there are just three levels, namely the proposed SBAT for the Ethiopian context, the categories, and the criteria) as shown in Figure 4.3 below. According to the authors' findings (Muhammad et al. (2019), the elements of hierarchical levels are handled so that they are of equal scale and magnitude. Additionally, there must be a correlation between the elements of the same hierarchy level and the other associated structure aspects.

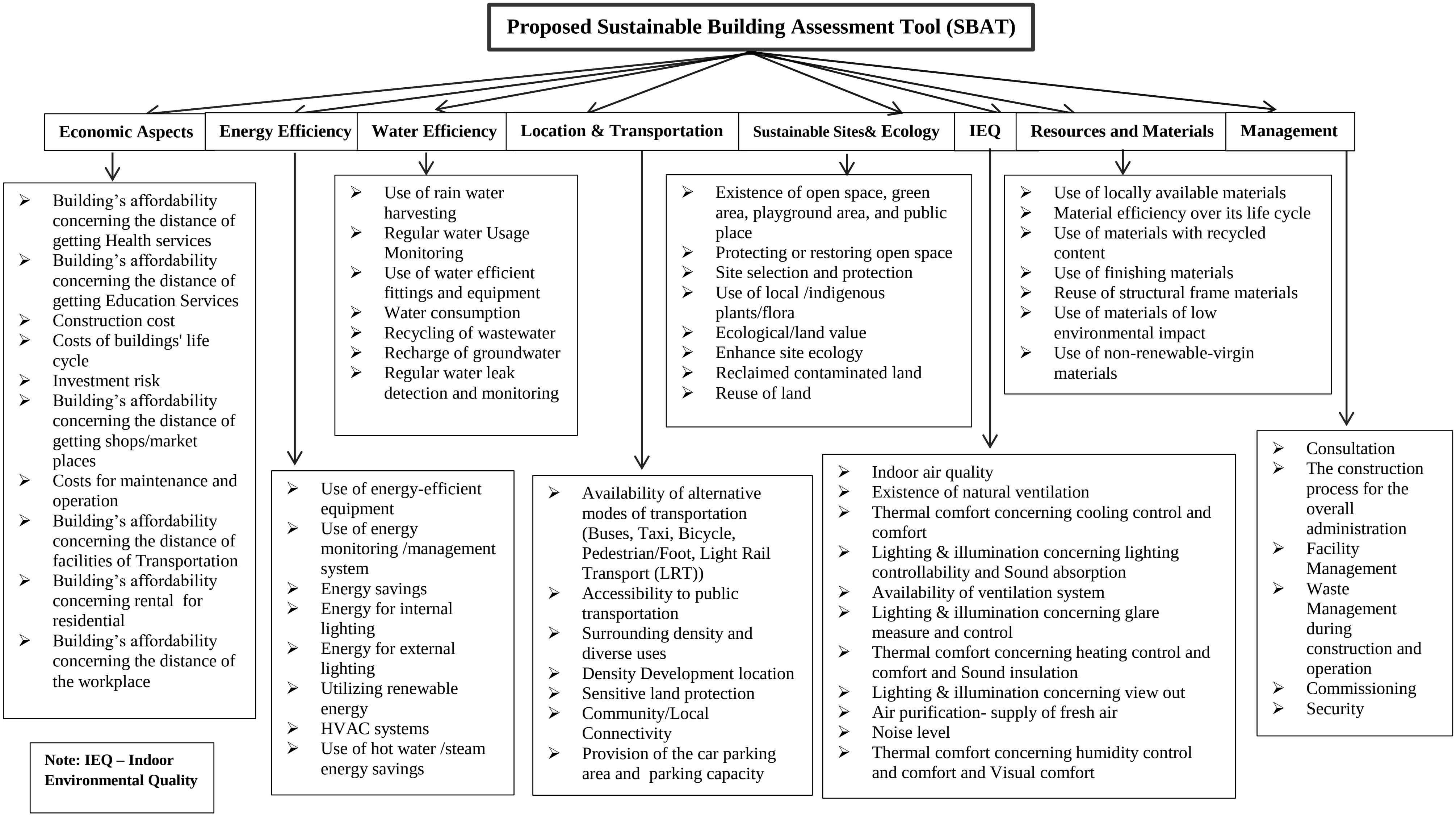

Figure 4.3: The hierarchical structure of the AHP technique for the development of SBAT for the Ethiopian context (Source: Developed by the researcher, 2021)

4.1.1.2. Pairwise Comparison Matrix of the Categories and Criteria

The authors Cheung et al. (2001) and Saaty (1980) depicted that the AHP can prioritize (or "pair-wise" compare) a set of categories and criteria and distinguish in general the more important factors from the less important factors. The pair-wise comparison judgments were made concerning the attributes of one level of hierarchy given the attribute of the next higher level of hierarchy (from the main criteria to the sub-criteria). The consistency test allows AHP to obtain a reliable subjective expert assessment. In addition to this, the pairwise comparison is an important step and also a backbone for the AHP technique. In this process, the criteria in each set of the hierarchy are compared with their corresponding categories. The pairwise judgments are recorded in a decision matrix.

For the analysis of weightings, rankings, and prioritization of the selected sustainable building assessment categories and criteria, the survey questionnaire responses were computed in the matrix, where the results of the questionnaire were converted into numbers 1, 2, 3, 4, and 5 and 1/2, 1/3, 1/4, and 1/5 based on the importance of each category to the other criteria Ahmed et al. (2017), and a pairwise comparison matrix was developed for the categories as shown in the Table 4.7 and for each selected categories and criteria as shown in the Table 4.8-4.15 below. This comparison matrix was created using the respondents' comparative judgments and displays the weight of the criteria about one another as well as their relative importance. It's vital to note that the matrix's diagonal values are all 1, indicating that the weight of criteria with itself is always 1, as seen in the bold cells of Tables 4.8-4.15. Furthermore, the grey cells', in the same Tables 4.8-4.15, comparing judgments demonstrated that both the row and column criteria are seen as equally important.

The Eight selected sustainable building assessment Category

Table 4.7: The Eight category of AHP comparison-paired matrix

Category	EA	EE	WE	LT	SE	IEQ	RM	MAN
EA	**1.00**	0.50	2.00	2.00	0.33	0.50	1.00	1.00
EE	2.00	**1.00**	2.00	2.00	0.50	0.50	1.00	1.00
WE	0.50	0.50	**1.00**	2.00	0.50	0.50	0.50	1.00
LT	0.50	0.50	0.50	**1.00**	0.33	1.00	0.33	0.50
SE	3.00	2.00	2.00	3.00	**1.00**	0.50	1.00	1.00

IEQ	2.00	2.00	2.00	1.00	2.00	**1.00**	0.33	2.00
RM	1.00	1.00	2.00	3.00	1.00	3.00	**1.00**	2.00
MAN	1.00	1.00	1.00	2.00	1.00	0.50	0.50	**1.00**
SUM	11.00	8.50	12.50	16.00	6.67	7.50	5.67	9.50

(Source: Calculated by the researcher by using MS-Excel, 2021)

N.B: EA = Economic Aspects, EE = Energy Efficiency, WE = Water Efficiency, LT = Location and Transportation, ES = Ecology and Sustainable Sites, IEQ = Indoor Environmental Quality, RM = Resources and Materials, and MAN = Management

Economic Aspect Category

Table 4.8: The criteria of the Economic Aspects (EA) category of AHP comparison-paired matrix

Criteria	EA_1	EA_2	EA_3	EA_4	EA_5	EA_6	EA_7	EA_8	EA_9	EA_10
EA_1	**1.00**	0.50	0.50	0.50	0.50	0.50	2.00	0.50	0.50	0.20
EA_2	2.00	**1.00**	0.25	0.25	0.33	1.00	0.50	0.33	0.33	0.20
EA_3	2.00	4.00	**1.00**	2.00	3.00	4.00	2.00	1.00	1.00	0.50
EA_4	2.00	4.00	0.50	**1.00**	1.00	3.00	4.00	1.00	3.00	1.00
EA_5	2.00	3.00	0.33	1.00	**1.00**	2.00	3.00	1.00	0.33	1.00
EA_6	2.00	1.00	0.25	0.33	0.50	**1.00**	0.33	0.20	0.33	0.33
EA_7	0.50	2.00	0.50	0.25	0.33	3.00	**1.00**	0.33	0.50	0.50
EA_8	2.00	3.00	1.00	1.00	1.00	5.00	3.00	**1.00**	1.00	1.00
EA_9	2.00	3.00	1.00	0.33	3.00	3.00	2.00	1.00	**1.00**	1.00
EA_10	5.00	5.00	1.00	1.00	1.00	3.00	2.00	1.00	1.00	**1.00**
Sum	**20.50**	**26.50**	**6.33**	**7.67**	**11.67**	**25.50**	**19.83**	**7.37**	**9.00**	**6.73**

(Source: Calculated by the researcher by using MS-Excel, 2021)

N.B: EA_1 = Building's affordability concerning the distance of facilities of transportation, EA_2 = Building's affordability concerning the distance of the workplace, EA_3 = Building's affordability concerning the distance of getting health services, EA_4 = Building's affordability concerning the distance of getting education Services, EA_5 = Building's affordability concerning the distance of getting shops/marketplaces, EA_6 = Building's affordability concerning rental for residential, EA_7 = Costs for maintenance and operation, EA_8 = Costs of buildings' life cycle, EA_9 = Investment risk, EA_10 = Construction cost

Energy Efficiency Category

Table 4.9: The criteria of the Energy Efficiency (EE) category of the AHP comparison-paired matrix

Criteria	EE_1	EE_2	EE_3	EE_4	EE_5	EE_6	EE_7	EE_8
EE_1	**1.00**	3.00	3.00	0.50	3.00	4.00	3.00	1.00
EE_2	0.33	**1.00**	1.00	0.25	3.00	3.00	3.00	0.50
EE_3	0.33	1.00	**1.00**	0.25	3.00	3.00	3.00	0.50
EE_4	2.00	4.00	4.00	**1.00**	3.00	4.00	4.00	3.00
EE_5	0.33	0.33	0.33	0.33	**1.00**	3.00	3.00	1.00
EE_6	0.25	0.33	0.33	0.25	0.33	**1.00**	0.33	0.25
EE_7	0.33	0.33	0.33	0.25	0.33	3.00	**1.00**	0.25
EE_8	1.00	2.00	2.00	0.33	1.00	4.00	4.00	**1.00**
Sum	5.58	12.00	12.00	3.17	14.67	25.00	21.33	7.50

(Source: Calculated by the researcher by using MS-Excel, 2021)

N.B: EE_1 = Use of energy monitoring /management system, EE_2 = Energy for internal lighting, EE_3 = Energy for external lighting, EE_4 = Use of energy-efficient equipment, EE_5 = Use of natural energy resources/ Renewable Energy, EE_6 = Use of Hot Water /Steam, EE_7 = HVAC Systems, and EE_8 = Energy savings

Water Efficiency Category

Table 4.10: The criteria of the Water Efficiency (WE) category of AHP comparison-paired matrix

Criteria	WE_1	WE_2	WE_3	WE_4	WE_5	WE_6	WE_7
WE_1	**1.00**	3.00	0.25	0.25	0.25	2.00	1.00
WE_2	0.33	**1.00**	0.25	1.00	0.50	0.33	0.50
WE_3	4.00	4.00	**1.00**	1.00	3.00	3.00	3.00
WE_4	4.00	1.00	1.00	**1.00**	0.50	3.00	2.00
WE_5	4.00	2.00	0.33	2.00	**1.00**	3.00	3.00
WE_6	0.50	3.00	0.33	0.33	0.33	**1.00**	1.00
WE_7	1.00	2.00	0.33	0.50	0.33	1.00	**1.00**
Sum	14.83	16.00	3.50	6.08	5.92	13.33	11.50

(Source: Calculated by the researcher by using MS-Excel, 2021)

N.B: WE_1 = Water consumption, WE_2 = Regular water leak detection and monitoring, WE_3 = Use of rain water harvesting, WE_4 = Use of water efficient fittings and equipment, WE_5 = Regular water usage monitoring, WE_6 = Recycling of wastewater, and WE_7 = Recharge of groundwater

Location and Transportation Category

Table 4.11: The criteria of the Location and Transportation (LT) category of AHP comparison-paired matrix

Criteria	LT_1	LT_2	LT_3	LT_4	LT_5	LT_6	LT_7
LT_1	**1.00**	3.00	4.00	3.00	3.00	3.00	1.00
LT_2	0.33	**1.00**	0.50	0.50	0.33	0.50	0.33
LT_3	0.25	2.00	**1.00**	0.50	0.33	0.33	0.25
LT_4	0.33	2.00	2.00	**1.00**	3.00	0.50	0.33
LT_5	0.33	3.00	3.00	0.33	**1.00**	0.50	0.33
LT_6	0.33	2.00	3.00	2.00	2.00	**1.00**	0.33
LT_7	1.00	3.00	4.00	3.00	3.00	3.00	**1.00**
Sum	3.58	16.00	17.50	10.33	12.67	8.83	3.58

(Source: Calculated by the researcher by using MS-Excel, 2021)

N.B: LT_1 = Availability of alternative modes of transportations, LT_2 = Provision of the car parking area and parking capacity, LT_3 = Community/Local Connectivity, LT_4 = Density Development location, LT_5 = Sensitive land protection, LT_6 = Surrounding density and diverse uses, and LT_7 = Accessibility to public transportation

Sustainable Sites and Ecology Category

Table 4.12: The criteria of the Sustainable Sites and Ecology (SE) category of AHP comparison-paired matrix

Criteria	SE_1	SE_2	SE_3	SE_4	SE_5	SE_6	SE_7	SE_8
SE_1	**1.00**	3.00	3.00	3.00	3.00	1.00	0.50	0.33
SE_2	0.33	**1.00**	0.25	1.00	0.33	0.33	0.25	0.25
SE_3	0.33	4.00	**1.00**	3.00	3.00	0.33	0.33	0.25
SE_4	0.33	1.00	0.33	**1.00**	1.00	0.33	0.33	0.25
SE_5	0.33	3.00	0.33	1.00	**1.00**	0.33	0.25	0.20
SE_6	1.00	3.00	3.00	3.00	3.00	**1.00**	0.33	0.33
SE_7	2.00	4.00	3.00	3.00	4.00	3.00	**1.00**	0.50
SE_8	3.00	4.00	4.00	4.00	5.00	3.00	2.00	**1.00**
Sum	8.33	23.00	14.92	19.00	20.33	9.33	5.00	3.12

(Source: Calculated by the researcher by using MS-Excel, 2021)

N. B: SE_1 = Site selection and protection, SE_2 = Reuse of Land, SE_3 = Ecological/Land Value, SE_4 = Reclaimed Contaminated Land, SE_5 = Enhance site Ecology, SE_6 = Use of local /indigenous plants/flora, SE_7 = Protect and Restore Open Space, and SE_8 = Existence of open space, green area, playground area, and public space

Materials and Resources Category

Table 4.13: The criteria of the Materials and Resources (MR) category of AHP comparison-paired matrix

Criteria	MR_1	MR_2	MR_3	MR_4	MR_5	MR_6	MR_7
MR_1	**1.00**	4.00	0.33	0.33	1.00	0.33	0.33
MR_2	0.25	**1.00**	0.33	0.25	0.20	0.25	0.25
MR_3	3.00	3.00	**1.00**	0.33	0.50	0.33	0.33
MR_4	3.00	4.00	3.00	**1.00**	3.00	3.00	1.00
MR_5	1.00	5.00	2.00	0.33	**1.00**	3.00	0.33
MR_6	3.00	4.00	3.00	0.33	0.33	**1.00**	0.33
MR_7	3.00	4.00	3.00	1.00	3.00	3.00	**1.00**
SUM	14.25	25.00	12.67	3.58	9.03	10.92	3.58

(Source: Calculated by the researcher by using MS-Excel, 2021)

N.B: MR_1 = Use of materials of low environmental impact, MR_2 = Use of non-renewable-virgin materials, MR_3 = Reuse of structural frame materials, MR_4 = Use of locally available materials, MR_5 = Use of materials with recycled content, MR_6 = Use of finishing materials, and MR_7 = Material efficiency over its life cycle

Indoor Environmental Quality Category

Table 4.14: The criteria of the Indoor Environmental Quality (IEQ) category of AHP comparison-paired matrix

Criteria	IEQ_1	IEQ_2	IEQ_3	IEQ_4	IEQ_5	IEQ_6	IEQ_7	IEQ_8	IEQ_9	IEQ_10	IEQ_11	IEQ_12	IEQ_13	IEQ_14
IEQ_1	**1.00**	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	1.00	0.50	1.00	1.00
IEQ_2	1.00	**1.00**	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.33	1.00	1.00	1.00	1.00
IEQ_3	1.00	1.00	**1.00**	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
IEQ_4	1.00	1.00	1.00	**1.00**	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00	2.00
IEQ_5	1.00	1.00	1.00	1.00	**1.00**	1.00	1.00	1.00	1.00	0.33	1.00	1.00	1.00	1.00
IEQ_6	1.00	1.00	1.00	1.00	1.00	**1.00**	1.00	1.00	0.50	0.50	1.00	1.00	0.50	0.50
IEQ_7	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	1.00	1.00	0.50	1.00	2.00	1.00	1.00
IEQ_8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	1.00	0.50	2.00	0.50	0.50	1.00
IEQ_9	1.00	1.00	1.00	1.00	1.00	2.00	1.00	1.00	**1.00**	0.50	1.00	0.50	1.00	1.00
IEQ_10	2.00	3.00	1.00	1.00	3.00	2.00	2.00	2.00	2.00	**1.00**	3.00	1.00	1.00	1.00
IEQ_11	1.00	1.00	1.00	0.50	1.00	1.00	1.00	0.50	1.00	0.33	**1.00**	0.50	1.00	1.00
IEQ_12	2.00	1.00	1.00	0.50	1.00	1.00	0.50	2.00	2.00	1.00	2.00	**1.00**	3.00	3.00
IEQ_13	1.00	1.00	1.00	0.50	1.00	2.00	1.00	2.00	1.00	1.00	1.00	0.33	**1.00**	0.50
IEQ_14	1.00	1.00	1.00	0.50	1.00	2.00	1.00	1.00	1.00	1.00	1.00	0.33	0.33	**1.00**
Sum	16.00	16.00	14.00	12.00	16.00	18.00	14.50	16.50	15.50	9.50	19.00	12.67	15.33	16.00

(Source: Calculated by the researcher by using MS-Excel, 2021)

N.B: IEQ_1 = Noise level, IEQ_2 = Sound insulation, IEQ_3 = Sound absorption, IEQ_4 = Thermal comfort concerning cooling control and comfort, IEQ_5 = Thermal comfort concerning heating control and comfort, IEQ_6 = Thermal comfort concerning humidity control and comfort, IEQ_7 = Lighting and illumination concerning lighting controllability, IEQ_8 = Lighting and illumination concerning view out, IEQ_9 = Lighting and illumination concerning glare measure and control, IEQ_10 = Indoor Air Quality, IEQ_11 = Visual Comfort, IEQ_12 = Existence of natural ventilation, IEQ_13 = Availability of Ventilation system, and IEQ_14 = Air purification- supply of fresh air

Management Category

Table 4.15: The criteria of the Management (MAN) category of AHP comparison-paired matrix

Criteria	MAN_1	MAN_2	MAN_3	MAN_4	MAN_5	MAN_6
MAN_1	**1.00**	4.00	0.33	1.00	1.00	3.00
MAN_2	0.25	**1.00**	0.25	0.33	0.33	3.00
MAN_3	3.00	3.00	**1.00**	1.00	0.50	3.00
MAN_4	1.00	1.00	1.00	**1.00**	2.00	3.00
MAN_5	1.00	1.00	2.00	0.50	**1.00**	3.00
MAN_6	0.33	0.33	0.33	0.33	0.33	**1.00**
SUM	6.58	10.33	4.92	4.17	5.17	16.00

(Source: Calculated by the researcher by using MS-Excel, 2021)

N.B: MAN_1 = Facility Management, MAN_2 = Commissioning, MAN_3 = Consultation, MAN_4 = Construction process planning and management, MAN_5 = Waste Management during construction and operation, and MAN_6 = Security

4.1.1.3. Deriving Relative Weights/ Relative Priority

For deriving the relative weights of the sustainable building assessment categories and criteria, estimation of relative weights for each of the categories and criteria of decision hierarchy is required. From the comparison matrix shown in Tables 4.7-4.15 above, it is possible to find the relative weights of the categories and criteria. For this task, normalization of the resulting matrix of the categories and criteria (from Tables 4.16-4.24) has to be done, which means calculating the priority of each criterion according to its contribution to the overall goal. These normalization processes were applied in two steps as shown below as demonstrated by the authors Ahmed et al. (2017):

i. The values in each column of the pairwise comparison matrix were summed.
ii. Each criterion in the pairwise comparison matrix was divided by the sum of the values in each column, and the resulting value is considered as the Weight (***Weight is the result of the sum of the criteria across the row divided by the number of criteria***). A normalized pairwise comparison matrix was the outcome or matrix.

The following Tables 4.16-4.24 showed the normalized pairwise comparison matrix of the categories (Table 4.16) and criteria (Table 4.17-4.24). In all these Tables 4.17-4.24, the Sum, Weight, Relative Priority, and Rank of the criteria in each category and the category itself are also demonstrated.

Normalization of the Eight Categories

Table 4.16: The eight category of AHP normalization

Category	**EA**	**EE**	**WE**	**LT**	**SE**	**IEQ**	**RM**	**MAN**	**Sum**	**Weight**	**Relative Priority (%)**	**RANK**
EA	0.09	0.06	0.16	0.13	0.05	0.07	0.18	0.11	**0.83**	**0.1041**	**10.41**	**5**
EE	0.18	0.12	0.16	0.13	0.08	0.07	0.18	0.11	**1.01**	**0.1260**	**12.60**	**4**
WE	0.05	0.06	0.08	0.13	0.08	0.07	0.09	0.11	**0.64**	**0.0806**	**8.06**	**7**
LT	0.05	0.06	0.04	0.06	0.05	0.13	0.06	0.05	**0.50**	**0.0627**	**6.27**	**8**
SE	0.27	0.24	0.16	0.19	0.15	0.07	0.18	0.11	**1.35**	**0.1692**	**16.92**	**2**
IEQ	0.18	0.24	0.16	0.06	0.30	0.13	0.06	0.21	**1.34**	**0.1678**	**16.78**	**3**
RM	0.09	0.12	0.16	0.19	0.15	0.40	0.18	0.21	**1.49**	**0.1866**	**18.66**	**1**
MAN	0.09	0.12	0.08	0.13	0.15	0.07	0.09	0.11	**0.82**	**0.1030**	**10.30**	**6**

(Source: Calculated by the researcher by using MS-Excel, 2021)

For the average eight categories shown in Table 4.16 above, it is important to note that the numerical representation of a comparative judgment does not necessarily mean that one criterion is preferred to the other by the numerical amount instead the weight in number and the relative priority vectors in % for all criteria carry actual importance which is calculated and tallied in the comparison matrix's final column. The rankings of the criteria that had been employed to prioritize the most appropriate criteria in the given category for the development of SBAT for the Ethiopian setting are seen from this tabulation. According to Table 4.16, the researcher has identified that the average of resources and materials (RM) has the highest relative priority vector value, at 18.66% (1st ranking), followed by the average of sustainable sites and ecology (SE), at 16.92% (2nd rankings), and the average of indoor environmental quality (IEQ), at 16.78% (3rd ranking). The 4th ranking of the category is the average of energy efficiency (EE) with the relative priority vector value of 12.60% which is followed by the average of economic aspects (EA) and an average of management (MAN) with the relative priority vector values of 10.41% (5th ranking) and 10.30% (6th ranking) respectively. The least rankings are the average of water efficiency (WE) with a relative priority vector value of 8.06% (7th ranking) and the average of location and transportation (LT) with a relative priority vector value of 6.27% (8th ranking).

Normalization of Economic Aspect Category

Table 4.17: The criteria of the Economic Aspect (EA) category of AHP normalization

Criteria	EA_1	EA_2	EA_3	EA_4	EA_5	EA_6	EA_7	EA_8	EA_9	EA_10	Sum	Weight	Relative Priority (%)	RANK
EA_1	0.05	0.02	0.08	0.07	0.04	0.02	0.10	0.07	0.06	0.03	**0.53**	**0.0528**	**5.28**	**8**
EA_2	0.10	0.04	0.04	0.03	0.03	0.04	0.03	0.05	0.04	0.03	**0.41**	**0.0412**	**4.12**	**10**
EA_3	0.10	0.15	0.16	0.26	0.26	0.16	0.10	0.14	0.11	0.07	**1.50**	**0.1503**	**15.03**	**1**
EA_4	0.10	0.15	0.08	0.13	0.09	0.12	0.20	0.14	0.33	0.15	**1.48**	**0.1481**	**14.80**	**2**
EA_5	0.10	0.11	0.05	0.13	0.09	0.08	0.15	0.14	0.04	0.15	**1.03**	**0.1031**	**10.31**	**6**
EA_6	0.10	0.04	0.04	0.04	0.04	0.04	0.02	0.03	0.04	0.05	**0.43**	**0.0431**	**4.31**	**9**
EA_7	0.02	0.08	0.08	0.03	0.03	0.12	0.05	0.05	0.06	0.07	**0.58**	**0.0583**	**5.83**	**7**
EA_8	0.10	0.11	0.16	0.13	0.09	0.20	0.15	0.14	0.11	0.15	**1.33**	**0.1328**	**13.28**	**4**
EA_9	0.10	0.11	0.16	0.04	0.26	0.12	0.10	0.14	0.11	0.15	**1.28**	**0.1283**	**12.83**	**5**
EA_10	0.24	0.19	0.16	0.13	0.09	0.12	0.10	0.14	0.11	0.15	**1.42**	**0.1420**	**14.20**	**3**

(Source: Calculated by the researcher by using MS-Excel, 2021)

It is crucial to note that just because one criterion is represented numerically in a comparison judgment for the economic aspect category in Table 4.17 above, that doesn't mean it is favored over another. The actual relevance of each criterion is calculated and tabulated in the final column of the comparison matrix, together with the weight in number and the relative priority vectors in percent for each criterion. This tabulation makes the ranks of the factors that were taken into account when prioritizing the most acceptable criteria in the given category for the development of SBAT for the Ethiopian setting very visible.

According to Table 4.17, the researcher has identified that the affordability of the building regarding the distance to access health services (EA_3) has the highest relative priority vector value with 15.03% (ranking 1), followed by the affordability of the building concerning the distance of getting education services (EA_4), which has a relative priority vector value of 14.80% (ranking 2), and construction cost (EA_10), which has a relative priority vector value of 14.20% (3rd ranking). Life cycle cost (EA_8) and investment risk (EA_9), are ranked fourth and fifth in this category, respectively, with relative priority vector values of 13.27% and 12.83%. The affordability of the building concerning rental for residential (EA_6) and affordability of the building concerning the distance of workplace (EA_2), with relative priority vector values of 4.31% and 4.12%, respectively, come in ninth and tenth position.

Normalization of Energy Efficiency Category

Table 4.18: The criteria of the Energy Efficiency (EE) category of AHP normalization

Criteria	**EE_1**	**EE_2**	**EE_3**	**EE_4**	**EE_5**	**EE_6**	**EE_7**	**EE_8**	**Sum**	**Weight**	**Relative Priority (%)**	**RANK**
EE_1	0.18	0.25	0.25	0.16	0.20	0.16	0.14	0.13	**1.48**	**0.1844**	**18.44**	**2**
EE_2	0.06	0.08	0.08	0.08	0.20	0.12	0.14	0.07	**0.84**	**0.1046**	**10.46**	**4**
EE_3	0.06	0.08	0.08	0.08	0.20	0.12	0.14	0.07	**0.84**	**0.1046**	**10.46**	**4**
EE_4	0.36	0.33	0.33	0.32	0.20	0.16	0.19	0.40	**2.29**	**0.2866**	**28.66**	**1**
EE_5	0.06	0.03	0.03	0.11	0.07	0.12	0.14	0.13	**0.68**	**0.0853**	**8.53**	**5**
EE_6	0.04	0.03	0.03	0.08	0.02	0.04	0.02	0.03	**0.29**	**0.0364**	**3.64**	**7**
EE_7	0.06	0.03	0.03	0.08	0.02	0.12	0.05	0.03	**0.42**	**0.0521**	**5.21**	**6**
EE_8	0.18	0.17	0.17	0.11	0.07	0.16	0.19	0.13	**1.17**	**0.1458**	**14.58**	**3**

(Source: Calculated by the researcher by using MS-Excel, 2021)

It is significant to note that, for the energy efficiency category in Table 4.49 above, the weight in number and the relative priority vectors in percent for each criterion carry actual importance, which is calculated and tabulated in the last column of the comparison matrix. This does not appear to suggest that one criterion is recommended to the other by the numerical amount. The rankings of the criteria that were utilized for prioritizing the most preferred criterion in the given category for the development of SBAT for the Ethiopian setting are discernible from this tabulation.

Table 4.18 demonstrates that the use of energy-efficient equipment (EE_4) has the highest relative priority vector value, with 28.66% (1st ranking), followed by the energy monitoring /management (EE_1), with 18.44% (2nd ranking), and energy savings (EE_8), with 14.58% (3rd ranking). Internal lighting (EE_2) and external lighting (EE_3) both rank fourth and have identical relative priority values of 10.46%. Use of natural energy resources/ renewable energy (EE_5) and HVAC Systems (EE_7), with relative priority vector values of 8.53% and 5.21%, respectively, are ranked fifth and sixth in this category of criteria. The use of hot water/steam (EE_6), with a relative priority vector value of 3.64%, has the lowest position (7th ranking).

Normalization of Water Efficiency Category

Table 4.19: The criteria of the Water Efficiency (WE) category of AHP normalization

Criteria	WE_1	WE_2	WE_3	WE_4	WE_5	WE_6	WE_7	Sum	Weight	Relative Priority %)	RANK
WE_1	0.07	0.19	0.07	0.04	0.04	0.15	0.09	**0.65**	**0.0924**	**9.24**	**4**
WE_2	0.02	0.06	0.07	0.16	0.08	0.03	0.04	**0.47**	**0.0677**	**6.77**	**7**
WE_3	0.27	0.25	0.29	0.16	0.51	0.23	0.26	**1.96**	**0.2804**	**28.04**	**1**
WE_4	0.27	0.06	0.29	0.16	0.08	0.23	0.17	**1.27**	**0.1808**	**18.08**	**3**
WE_5	0.27	0.13	0.10	0.33	0.17	0.23	0.26	**1.47**	**0.2105**	**21.05**	**2**
WE_6	0.03	0.19	0.10	0.05	0.06	0.08	0.09	**0.59**	**0.0842**	**8.42**	**5**
WE_7	0.07	0.13	0.10	0.08	0.06	0.08	0.09	**0.59**	**0.0840**	**8.40**	**6**

(Source: Calculated by the researcher by using MS-Excel, 2021)

It should be noted that the numerical depiction of a comparison judgment for the water efficiency category in Table 4.19 above does not suggest that one criterion is necessarily preferred over another by a numerical amount. Instead, the relative priority vectors in percent and weight in number, which are produced and summarized in the final column of the comparison matrix, have definite importance for all criteria. This tabulation makes it easy to see how the criteria were ranked to determine which criterion was most important for the creation of SBAT for the Ethiopian context.

As per Table 4.19, the researcher has identified that the use of rainwater harvesting (WE_3) has the highest relative priority vector value, at 28.04% (1st ranking), followed by regular water usage monitoring (WE_1), at 21.05% (2nd ranking), use of water efficient fittings and equipment (WE_4), at 18.08% (3rd ranking). The water consumption (WE_1) and regular water usage monitoring (WE_5), which rank fourth and fifth in this category respectively, have relative priority vector values of 9.24% and 8.42%. Recharge of groundwater (WE_7) and regular water leak detection and monitoring (WE_2), with relative priority vector values of 8.40% and 6.77%, respectively, receive the lowest ranks (sixth and seventh).

Normalization of Location and Transportation Category

Table 4.20: The criteria of the Location and Transportation (LT) category of AHP normalization

Criteria	LT_1	LT_2	LT_3	LT_4	LT_5	LT_6	LT_7	Sum	Weight	Relative Priority (%)	RANK
LT_1	0.28	0.19	0.23	0.29	0.24	0.34	0.28	**1.84**	**0.2630**	**26.30**	**1**
LT_2	0.09	0.06	0.03	0.05	0.03	0.06	0.09	**0.41**	**0.0583**	**5.83**	**6**
LT_3	0.07	0.13	0.06	0.05	0.03	0.04	0.07	**0.43**	**0.0620**	**6.20**	**5**
LT_4	0.09	0.13	0.11	0.10	0.24	0.06	0.09	**0.82**	**0.1165**	**11.65**	**3**
LT_5	0.09	0.19	0.17	0.03	0.08	0.06	0.09	**0.71**	**0.1018**	**10.18**	**4**
LT_6	0.09	0.13	0.17	0.19	0.16	0.11	0.09	**0.95**	**0.1353**	**13.53**	**2**
LT_7	0.28	0.19	0.23	0.29	0.24	0.34	0.28	**1.84**	**0.2630**	**26.30**	**1**

(Source: Calculated by the researcher by using MS-Excel, 2021)

It is important to realize that, in the example of the location and transportation category in Table 4.20 above, the numerical representation of a comparison judgment does not necessarily suggest that one criterion is favored over another by an arithmetical amount. Instead, true importance is estimated and tabulated in the final column of the comparison matrix and expressed as the weight in number and the relative priority vectors in percent for each criterion. This tabulation makes it easy to see how the criteria were ranked to determine which criterion was most important for the creation of SBAT for the Ethiopian context.

According to Table 4.20, the researcher has identified that the relative priority vector values for accessibility to public transportation (LT_7) and the availability of alternative modes of transportation (LT_1) are both highest at 26.30% (1st rankings), followed by the surrounding density and diverse uses (LT_6) at 13.53% (2nd ranking), and the density development location (LT_4) at 11.65% (3rd ranking). Sensitive land protection (LT_5) and community/local connectivity (LT_3) are ranked fourth and fifth in this category, respectively, with relative priority vector values of 10.18% and 6.20%. The provision of the car parking area and parking capacity (LT_2), with a relative priority vector value of 8.40%, has the lowest position (6th).

Normalization of Sustainable Sites and Ecology Category

Table 4.21: The criteria of the Sustainable Sites and Ecology (SE) category of AHP normalization

Criteria	SE_1	SE_2	SE_3	SE_4	SE_5	SE_6	SE_7	SE_8	Sum	Weight	Relative Priority (%)	RANK
SE_1	0.12	0.13	0.20	0.16	0.15	0.11	0.10	0.11	**1.07**	**0.1339**	**13.39**	**3**
SE_2	0.04	0.04	0.02	0.05	0.02	0.04	0.05	0.08	**0.34**	**0.0419**	**4.19**	**8**
SE_3	0.04	0.17	0.07	0.16	0.15	0.04	0.07	0.08	**0.77**	**0.0961**	**9.61**	**5**
SE_4	0.04	0.04	0.02	0.05	0.05	0.04	0.07	0.08	**0.39**	**0.0488**	**4.88**	**7**
SE_5	0.04	0.13	0.02	0.05	0.05	0.04	0.05	0.06	**0.44**	**0.0556**	**5.56**	**6**
SE_6	0.12	0.13	0.20	0.16	0.15	0.11	0.07	0.11	**1.04**	**0.1297**	**12.97**	**4**
SE_7	0.24	0.17	0.20	0.16	0.20	0.32	0.20	0.16	**1.65**	**0.2064**	**20.64**	**2**
SE_8	0.36	0.17	0.27	0.21	0.25	0.32	0.40	0.32	**2.30**	**0.2876**	**28.76**	**1**

(Source: Calculated by the researcher by using MS-Excel, 2021)

The weight in number and the relative priority vectors in percent for each criterion for the sustainable sites and ecological category indicated in Table 4.21 above carry actual importance, which is calculated and recorded in the final column of the comparison matrix. The numerical representation of a comparison judgment need not necessarily indicate that one criterion is favored over another by the specified amount. The rankings of the criteria that were used to prioritize the most suitable criteria in the given category for the development of an SBAT for the Ethiopian setting may readily be determined from this tabulation.

According to Table 4.21, the researcher has identified that the existence of open space, green space, playground areas, and public spaces (SE_8) has the highest relative priority vector value with a value of 28.76% (ranking 1), followed by protect or restore open space (SE_7) with a value of 20.64% (ranking 2), and site selection and protection (SE_1) with a value of 13.39% (3rd ranking). Use of local/indigenous plants/flora (SE_6), which has a relative priority vector value of 12.97%, is ranked fourth in this category, followed by ecological/land value (SE_3), which is ranked fifth and enhances site ecology (SE_5), which has a relative priority vector value of 5.56% (6th ranking). Reclaimed polluted land (SE_4) and reuse of land (SE_2) had the lowest ranks, coming in at 7th and 8th, respectively, with relative priority vector values of 4.88% and 4.19%.

Normalization of Indoor Environmental Quality Category

Table 4.22: The criteria of the Indoor Environmental Quality (IEQ) category of AHP normalization

Criteria	IEQ_1	IEQ_2	IEQ_3	IEQ_4	IEQ_5	IEQ_6	IEQ_7	IEQ_8	IEQ_9	IEQ_10	IEQ_11	IEQ_12	IEQ_13	IEQ_14	Sum	Weight	Relative Priority (%)	RANK
IEQ_1	0.06	0.06	0.07	0.08	0.06	0.06	0.07	0.06	0.06	0.05	0.05	0.04	0.07	0.06	**0.8644**	**0.0617**	**6.17**	**11**
IEQ_2	0.06	0.06	0.07	0.08	0.06	0.06	0.07	0.06	0.06	0.04	0.05	0.08	0.07	0.06	**0.8863**	**0.0633**	**6.33**	**8**
IEQ_3	0.06	0.06	0.07	0.08	0.06	0.06	0.07	0.06	0.06	0.11	0.05	0.08	0.07	0.06	**0.9565**	**0.0683**	**6.83**	**5**
IEQ_4	0.06	0.06	0.07	0.08	0.06	0.06	0.07	0.06	0.06	0.11	0.11	0.16	0.13	0.13	**1.2158**	**0.0868**	**8.68**	**3**
IEQ_5	0.06	0.06	0.07	0.08	0.06	0.06	0.07	0.06	0.06	0.04	0.05	0.08	0.07	0.06	**0.8863**	**0.0633**	**6.33**	**8**
IEQ_6	0.06	0.06	0.07	0.08	0.06	0.06	0.07	0.06	0.03	0.05	0.05	0.08	0.03	0.03	**0.8077**	**0.0577**	**5.77**	**12**
IEQ_7	0.06	0.06	0.07	0.08	0.06	0.06	0.07	0.06	0.06	0.05	0.05	0.16	0.07	0.06	**0.9828**	**0.0702**	**7.02**	**4**
IEQ_8	0.06	0.06	0.07	0.08	0.06	0.06	0.07	0.06	0.06	0.05	0.11	0.04	0.03	0.06	**0.8844**	**0.0632**	**6.32**	**9**
IEQ_9	0.06	0.06	0.07	0.08	0.06	0.11	0.07	0.06	0.06	0.05	0.05	0.04	0.07	0.06	**0.9199**	**0.0657**	**6.57**	**7**
IEQ_10	0.13	0.19	0.07	0.08	0.19	0.11	0.14	0.12	0.13	0.11	0.16	0.08	0.07	0.06	**1.6239**	**0.1160**	**11.60**	**1**
IEQ_11	0.06	0.06	0.07	0.04	0.06	0.06	0.07	0.03	0.06	0.04	0.05	0.04	0.07	0.06	**0.7748**	**0.0553**	**5.53**	**13**
IEQ_12	0.13	0.06	0.07	0.04	0.06	0.06	0.03	0.12	0.13	0.11	0.11	0.08	0.20	0.19	**1.3760**	**0.0983**	**9.83**	**2**
IEQ_13	0.06	0.06	0.07	0.04	0.06	0.11	0.07	0.12	0.06	0.11	0.05	0.03	0.07	0.03	**0.9471**	**0.0676**	**6.76**	**6**
IEQ_14	0.06	0.06	0.07	0.04	0.06	0.11	0.07	0.06	0.06	0.11	0.05	0.03	0.02	0.06	**0.8742**	**0.0624**	**6.24**	**10**

(Source: Calculated by the researcher by using MS-Excel, 2021)

It is critical to remember that, for the Indoor Environmental Quality category in Table 4.22 above, the numerical representation of a comparative judgment does not always imply that one criterion is preferred over another by a numerical amount. Rather, the weight in number and the relative priority vectors in percent for all criteria carry real importance, which is calculated and tabulated in the last column of the comparison matrix. The rankings of the criteria that were utilized for prioritizing the most preferred criterion in the given category for the development of SBAT for the Ethiopian setting are discernible from this tabulation.

As per Table 4.22, the researcher has determined that Indoor Air Quality (IEQ_10) has the highest value of relative priority vector with 11.60% (1st rankings), followed by the existence of natural ventilation (IEQ_12) with the relative priority vector value of 9.83% (2nd ranking) and thermal comfort concerning Cooling control and comfort (IEQ_4) which has a relative priority vector value of 8.68% (3rd ranking). The 4th ranking of the criteria under this category is lighting & illumination concerning lighting controllability (IEQ_7) with relative priority vector values of 7.02% which is followed by sound absorption (IEQ_3) with relative priority vector values of 6.83% (5th ranking) and availability of ventilation system (IEQ_13) with the relative priority vector values of 6.76% (6th rankings). The last rankings (12th and 13th) are thermal comfort concerning humidity control and comfort (IEQ_6) and visual comfort (IEQ_11) with the relative priority vector value of 5.77% and 5.53% respectively.

Normalization of Materials and Resources Category

Table 4.23: The criteria of the Materials and Resources (MR) category of AHP normalization

Criteria	**MR_1**	**MR_2**	**MR_3**	**MR_4**	**MR_5**	**MR_6**	**MR_7**	**Sum**	**Weight**	**Relative Priority (%)**	**RANK**
MR_1	0.07	0.16	0.03	0.09	0.11	0.03	0.09	**0.58**	**0.0834**	**8.340**	**5**
MR_2	0.02	0.04	0.03	0.07	0.02	0.02	0.07	**0.27**	**0.0383**	**3.835**	**6**
MR_3	0.21	0.12	0.08	0.09	0.06	0.03	0.09	**0.68**	**0.0973**	**9.734**	**4**
MR_4	0.21	0.16	0.24	0.28	0.33	0.27	0.28	**1.77**	**0.2532**	**25.320**	**1**
MR_5	0.07	0.20	0.16	0.09	0.11	0.27	0.09	**1.00**	**0.1428**	**14.280**	**2**
MR_6	0.21	0.16	0.24	0.09	0.04	0.09	0.09	**0.92**	**0.1317**	**13.170**	**3**
MR_7	0.21	0.16	0.24	0.28	0.33	0.27	0.28	**1.77**	**0.2532**	**25.320**	**1**

(Source: Calculated by the researcher by using MS-Excel, 2021)

For the Materials and Resources category shown in Table 4.23 above, it is important to note that the numerical representation of a comparative judgment does not necessarily mean that one criterion is preferred to the other by the numerical amount instead the weight in number and the relative priority vectors in % for all criteria carry actual importance which is calculated and tabulated in the last column of the comparison matrix. From this tabulation, it can easily be identified the rankings of the criteria which were used for prioritization of the most preferable criteria in the given category for the development of SBAT for the Ethiopian context.

Table 4.23 shows that both use of locally available materials (MR_4) and material efficiency over its life cycle (MR_7) have the highest value of relative priority vector with 25.32% (1st rankings), followed by the use of materials with recycled content (MR_5) with the relative priority vector value of 14.28% (2nd ranking) and use of finishing materials (MR_6) which has a relative priority vector value of 13.17% (3rd ranking). The 4th and 5th rankings of the criteria under this category are the reuse of structural frame materials (MR_3) and use of materials of low environmental impact (MR_1) with the relative priority vector values of 9.73% and 8.34% respectively. The last ranking (6th) is the use of non-renewable-virgin materials (MR_2) with a relative priority vector value of 3.84%.

Normalization of Management Category

Table 4.24: The criteria of the Management (MAN) category of AHP normalization

Criteria	**MAN_1**	**MAN_2**	**MAN_3**	**MAN_4**	**MAN_5**	**MAN_6**	**Sum**	**Weight**	**Relative Priority (%)**	**RANK**
MAN_1	0.15	0.39	0.07	0.24	0.19	0.19	**1.228**	**0.205**	**20.50**	**3**
MAN_2	0.04	0.10	0.05	0.08	0.06	0.19	**0.518**	**0.086**	**8.60**	**5**
MAN_3	0.46	0.29	0.20	0.24	0.10	0.19	**1.474**	**0.246**	**24.60**	**1**
MAN_4	0.15	0.10	0.20	0.24	0.39	0.19	**1.267**	**0.211**	**21.10**	**2**
MAN_5	0.15	0.10	0.41	0.12	0.19	0.19	**1.157**	**0.193**	**19.10**	**4**
MAN_6	0.05	0.03	0.07	0.08	0.06	0.06	**0.358**	**0.060**	**5.00**	**6**

(Source: Calculated by the researcher by using MS-Excel, 2021)

For the Management category shown in Table 4.24 above, it is important to note that the numerical representation of a comparative judgment does not necessarily mean that one criterion is preferred to the other by the numerical amount instead the weight in number and the relative priority vectors in % for all criteria carry actual importance which is calculated and tabulated in the last column of the comparison matrix. From this tabulation, it can easily be identified the rankings of the criteria which were used for prioritization of the most preferable criteria in the given category for the development of SBAT for the Ethiopian context.

In Table 4.24 above, the researcher has depicted that consultation (MAN_3) has the highest value of relative priority vector with 24.60% (1st rankings), followed by construction process planning and management (MAN_4) with the relative priority vector value of 21.10% (2nd ranking) and facility management (MAN_1) which has a relative priority vector value of 20.50% (3rd ranking). The 4th and 5th rankings of the criteria under this category are waste management during construction and operation (MAN_5) and commissioning (MAN_2) with relative priority vector values of 19.10% and 8.60% respectively. The last ranking (6th) is security (MAN_6) with a relative priority vector value of 5.00%.

4.1.1.4. Testing Consistency Index (CI) and Consistency Ratio (CR)

The measure of "Consistency Ratio" (CR) is an important part of the AHP technique, and consistency analysis was used in this study to guarantee that original preference ratings were consistent, a consistency ratio was generated and its value checked. The author Saaty (2005) went on to say that an index was created to measure the consistency of weights to calculate the consistency ratio. The acceptable CR range should be less than or equal to 0.10. If CR is more than this threshold value, a pairwise comparison must be revised, as stated by Saaty (2005). The authors Nahla et al. (2020) recommended that the following steps be followed for determining the consistency ratio:

i. The first column's each value was multiplied by the prominence of the first item; the same was done to the remained columns (Table 4.26-4.34).
ii. Values across rows were summed to get a vector of values called a "Weighted Sum".

iii. The Weighted Sums of every element were divided using each equivalent prioritized criterion to get a Weighted Sum/Weight.

iv. The average of the values in Weighted Sum/Weight was calculated and expressed as λ_{max}

v. Then CI was calculated as shown in equation [4.1]

$$CI = \frac{(\lambda_{max} - \mathrm{n})}{(\mathrm{n}-1)} \quad \ldots\ldots (4.1)$$

Where n is the number of items (criteria) being compared

CI is the consistency index, and

λ_max is the sum of the weighted sum divided by the number of items

$$CR = \frac{\mathrm{CI}}{\mathrm{RI}} \quad \ldots\ldots (4.3)$$

Where CR is the consistency ratio as shown in equation [4.3],

CI is consistency index, and

RI is the random inconsistency index.

Note that the Random Inconsistency Index (RI) for n 1, 2, 3, ..., 15, is displayed in Table 4.25 below.

Table 4.25: Random Inconsistency Index (RI) for n = 1, 2, 3, ..., 15

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.6	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

(Source: Adapted from Saaty (1980), pp.21)

The following Tables 4.26-4.34 showed the Consistency Ratio (CR) and the Consistency Index (CI) of the pairwise comparison matrix of the category and the criteria.

The Consistency Index (CI) and Consistency Ratio (CR) of the Eight Categories

Table 4.26: The eight categories of AHP Consistency Index (CI) and Consistency Ratio (CR)

Category	EA	EE	WE	LT	SE	IEQ	RM	MAN	Weighted Sum	Weighted Sum/Weight
EA	0.104	0.063	0.161	0.125	0.056	0.084	0.187	0.103	0.884	8.484
EE	0.208	0.126	0.161	0.125	0.085	0.084	0.187	0.103	1.079	8.564
WE	0.052	0.063	0.081	0.125	0.085	0.084	0.093	0.103	0.686	8.514
LT	0.052	0.063	0.040	0.063	0.056	0.168	0.062	0.051	0.556	8.867
SE	0.312	0.252	0.161	0.188	0.169	0.084	0.187	0.103	1.456	8.605
IEQ	0.208	0.252	0.161	0.063	0.338	0.168	0.062	0.206	1.458	8.692
RM	0.104	0.126	0.161	0.188	0.169	0.503	0.187	0.206	1.644	8.811
MAN	0.104	0.126	0.081	0.125	0.169	0.084	0.093	0.103	0.885	8.600
									SUM	69.137

(Source: Calculated by the researcher by using MS-Excel, 2021)

For these eight categories,

- **λ_{max} = Sum of Weighted Sum /Weight divided by the criteria's number**

  = **69.14/8 = <u>8.64</u>**

- **Consistency Index** $CI = \frac{(\lambda_{max} - \text{n})}{(\text{n} - 1)}$

  $= \frac{(8.64 - 8)}{(8 - 1)}$

  = **<u>0.09</u>**

- **Consistency Ratio** $CR = \frac{\text{CI}}{\text{RI}}$

  $= \frac{0.09}{1.41}$

CR = 0.07 ≤0.1≈ Consistent

Judges have been rated on their reliability and consistency with an index below that recommended by Saaty (2006). The 0.07 is the outcome of CR, meaning conclusions are drawn which is reliable and ensure a good level of consistency (validity) with a given category.

The Consistency Index (CI) and Consistency Ratio (CR) of the Economic Aspect Category

Table 4.27: The criteria of the Economic Aspects (EA) category of AHP Consistency Index (CI) and Consistency Ratio (CR)

Criteria	EA_1	EA_2	EA_3	EA_4	EA_5	EA_6	EA_7	EA_8	EA_9	EA_10	Weighted Sum	Weighted Sum/Weight
EA_1	0.05	0.02	0.08	0.07	0.05	0.02	0.12	0.07	0.06	0.03	0.57	10.81
EA_2	0.11	0.04	0.04	0.04	0.03	0.04	0.03	0.04	0.04	0.03	0.44	10.76
EA_3	0.11	0.16	0.15	0.30	0.31	0.17	0.12	0.13	0.13	0.07	1.65	10.96
EA_4	0.11	0.16	0.08	0.15	0.10	0.13	0.23	0.13	0.38	0.14	1.62	10.94
EA_5	0.11	0.12	0.05	0.15	0.10	0.09	0.17	0.13	0.04	0.14	1.11	10.76
EA_6	0.11	0.04	0.04	0.05	0.05	0.04	0.02	0.03	0.04	0.05	0.46	10.78
EA_7	0.03	0.08	0.08	0.04	0.03	0.13	0.06	0.04	0.06	0.07	0.62	10.67
EA_8	0.11	0.12	0.15	0.15	0.10	0.22	0.17	0.13	0.13	0.14	1.42	10.73
EA_9	0.11	0.12	0.15	0.05	0.31	0.13	0.12	0.13	0.13	0.14	1.39	10.81
EA_10	0.26	0.21	0.15	0.15	0.10	0.13	0.12	0.13	0.13	0.14	1.52	10.71
											SUM	107.93

(Source: Calculated by the researcher by using MS-Excel, 2021)

For this category (Economic Aspects),

- **λ_{max} = Sum of Weighted Sum /Weight divided by the criteria's number**

  = **107.93/10**

  = **<u>10.79</u>**

- **Consistency Index** $CI = \frac{(\lambda_{max} - \text{n})}{(\text{n} - 1)}$

  $= \frac{(10.79 - 10)}{(10 - 1)}$

  = **<u>0.088</u>**

- **Consistency Ratio** $CR = \frac{\text{CI}}{\text{RI}}$

  $= \frac{0.088}{1.49}$

CR = 0.059 ≤0.1≈ Consistent

For this matrix, the CR value is 0.059. Because this ratio is less than 0.1, the matrix is regarded as consistent, and the judgments are considered reliable and consistent. With an index below the recommended, the validity of the selected criteria is confirmed Saaty (2006).

The Consistency Index (CI) and Consistency Ratio (CR) of the Energy Efficiency Category

Table 4.28: The criteria of the Energy Efficiency (EE) category of AHP Consistency Index (CI) and Consistency Ratio (CR)

Criteria	EE_1	EE_2	EE_3	EE_4	EE_5	EE_6	EE_7	EE_8	Weighted Sum	Weighted Sum/Weight
EE_1	0.18	0.31	0.31	0.14	0.26	0.15	0.16	0.15	**1.66**	**9.00**
EE_2	0.06	0.10	0.10	0.07	0.26	0.11	0.16	0.07	**0.94**	**8.95**
EE_3	0.06	0.10	0.10	0.07	0.26	0.11	0.16	0.07	**0.94**	**8.95**
EE_4	0.37	0.42	0.42	0.29	0.26	0.15	0.21	0.44	**2.54**	**8.86**
EE_5	0.06	0.03	0.03	0.10	0.09	0.11	0.16	0.15	**0.72**	**8.48**
EE_6	0.05	0.03	0.03	0.07	0.03	0.04	0.02	0.04	**0.31**	**8.42**
EE_7	0.06	0.03	0.03	0.07	0.03	0.11	0.05	0.04	**0.43**	**8.23**
EE_8	0.18	0.21	0.21	0.10	0.09	0.15	0.21	0.15	**1.28**	**8.80**
									SUM	**69.69**

(Source: Calculated by the researcher by using MS-Excel, 2021)

For this category (Energy Efficiency),

- **λ_{max} = Sum of Weighted Sum /Weight divided by the criteria's number**

  = **69.69/8**

  = **<u>8.71</u>**

- **Consistency Index** $CI = \frac{(\lambda_{max} - n)}{(n-1)}$

  $= \frac{(8.71 - 8)}{(8-1)}$

  = **<u>0.10</u>**

- **Consistency Ratio** $CR = \frac{CI}{RI}$

  $= \frac{0.10}{1.41}$

CR ***= 0.07 ≤0.1≈ Consistent***

The CR value for this matrix is 0.07. The matrix is viewed as consistent because this ratio is smaller than 0.1, and the judgments are regarded as dependable and consistent (Saaty (2006). The viability of the chosen criteria is confirmed by an index below the recommended.

The Consistency Index (CI) and Consistency Ratio (CR) of the Water Efficiency Category

Table 4.29: The criteria of the Water Efficiency (EE) category of AHP Consistency Index (CI) and Consistency Ratio (CR)

Criteria	WE_1	WE_2	WE_3	WE_4	WE_5	WE_6	WE_7	Weighted Sum	Weighted Sum/Weight
WE_1	0.09	0.20	0.07	0.05	0.05	0.17	0.08	0.72	7.75
WE_2	0.03	0.07	0.07	0.18	0.11	0.03	0.04	0.52	7.75
WE_3	0.37	0.27	0.28	0.18	0.63	0.25	0.25	2.24	7.98
WE_4	0.37	0.07	0.28	0.18	0.11	0.25	0.17	1.42	7.88
WE_5	0.37	0.14	0.09	0.36	0.21	0.25	0.25	1.68	7.96
WE_6	0.05	0.20	0.09	0.06	0.07	0.08	0.08	0.64	7.62
WE_7	0.09	0.14	0.09	0.09	0.07	0.08	0.08	0.65	7.74
								SUM	54.67

(Source: Calculated by the researcher by using MS-Excel, 2021)

For this category (Water Efficiency),

- **λ_{max} = Sum of Weighted Sum /Weight divided by the number of criteria**

  = **54.67/7**

  = <u>7.81</u>

- **Consistency Index** $CI = \frac{(\lambda_{max} - n)}{(n - 1)}$

  $= \frac{(7.81 - 7)}{(7 - 1)}$

  = <u>0.13</u>

- **Consistency Ratio** $CR = \frac{CI}{RI}$

  $= \frac{0.13}{1.32}$

CR = 0.10 ≤0.1≈ Consistent

For this matrix, the CR value is 0.10. Because this ratio is equal to 0.1, the matrix is regarded as consistent, and the judgments are considered reliable and consistent Saaty (2006). With an index below the recommended, the validity of the selected criteria is confirmed.

The Consistency Index (CI) and Consistency Ratio (CR) of Location and Transportation Category

Table 4.30: The criteria of the Location and Transportation (LT) category of AHP Consistency Index (CI) and Consistency Ratio (CR)

Criteria	LT_1	LT_2	LT_3	LT_4	LT_5	LT_6	LT_7	Weighted Sum	Weighted Sum/Weight
LT_1	0.26	0.18	0.25	0.35	0.31	0.41	0.26	2.01	7.64
LT_2	0.09	0.06	0.06	0.06	0.03	0.07	0.09	0.46	7.81
LT_3	0.07	0.12	0.06	0.06	0.03	0.05	0.07	0.45	7.22
LT_4	0.09	0.12	0.12	0.12	0.31	0.07	0.09	0.91	7.77
LT_5	0.09	0.18	0.19	0.04	0.10	0.07	0.09	0.74	7.31
LT_6	0.09	0.12	0.19	0.23	0.20	0.14	0.09	1.05	7.76
LT_7	0.26	0.18	0.25	0.35	0.31	0.41	0.26	2.01	7.64
								SUM	53.16

(Source: Calculated by the researcher by using MS-Excel, 2021)

For this category (Location and Transportation),

- **λ_{max} = Sum of Weighted Sum /Weight divided by the number of criteria**

  = **53.16/7**

  = **<u>7.59</u>**

- **Consistency Index** $CI = \frac{(\lambda_{max} - n)}{(n-1)}$

  $= \frac{(7.59 - 7)}{(7-1)}$

  = **<u>0.099</u>**

- **Consistency Ratio** $CR = \frac{CI}{RI}$

  $= \frac{0.099}{1.32}$

CR = 0.075 ≤0.1≈ Consistent

The CR value for this matrix is 0.075. The matrix is regarded as consistent since this ratio is less than 0.1, and the evaluations are regarded as credible and consistent. The viability of the predetermined criteria is confirmed by such an index below the recommended Saaty (2006).

The Consistency Index (CI) and Consistency Ratio (CR) of Sustainable Sites and Ecology Category

Table 4.31: The criteria of the Sustainable Sites and Ecology category of AHP Consistency Index (CI) and Consistency Ration (CR)

Criteria	SE_1	SE_2	SE_3	SE_4	SE_5	SE_6	SE_7	SE_8	Weighted Sum	Weighted Sum/Weight
SE_1	0.13	0.13	0.29	0.15	0.17	0.13	0.10	0.10	1.19	8.89
SE_2	0.04	0.04	0.02	0.05	0.02	0.04	0.05	0.07	0.34	8.23
SE_3	0.04	0.17	0.10	0.15	0.17	0.04	0.07	0.07	0.81	8.38
SE_4	0.04	0.04	0.03	0.05	0.06	0.04	0.07	0.07	0.41	8.34
SE_5	0.04	0.13	0.03	0.05	0.06	0.04	0.05	0.06	0.46	8.26
SE_6	0.13	0.13	0.29	0.15	0.17	0.13	0.07	0.10	1.16	8.91
SE_7	0.27	0.17	0.29	0.15	0.22	0.39	0.21	0.14	1.83	8.87
SE_8	0.40	0.17	0.38	0.20	0.28	0.39	0.41	0.29	2.52	8.75
									SUM	68.62

(Source: Calculated by the researcher by using MS-Excel, 2021)

For this category (Sustainable Sites and Ecology),

- **λ_{max} = Sum of Weighted Sum /Weight divided by the number of criteria**

  = **68.62/8**

  = <u>8.56</u>

- **Consistency Index** $CI = \frac{(\lambda_{max} - \text{n})}{(\text{n} - 1)}$

  $= \frac{(8.56 - 8)}{(8 - 1)}$

  = <u>0.083</u>

- **Consistency Ratio** $CR = \frac{\text{CI}}{\text{RI}}$

  $= \frac{0.083}{1.41}$

CR = 0.095 ≤0.1≈ Consistent

For this matrix, the CR value is 0.095. Because this ratio is less than 0.1, the matrix is regarded as consistent, and the judgments are considered reliable and consistent Saaty (2006). With an index below the recommended, the validity of the selected criteria is confirmed.

The Consistency Index (CI) and Consistency Ratio (CR) of the Indoor Environmental Quality Category

For this category (Indoor Environmental Quality),

- **λ_{max} = Sum of Weighted Sum /Weight divided by the Number of criteria**
  = **203.85/14**
  = <u>14.56</u>
- **Consistency Index** $CI = \frac{(\lambda_{max} - n)}{(n-1)}$

  $= \frac{(14.56 - 14)}{(14-1)}$

  = <u>0.043</u>
- **Consistency Ratio** $CR = \frac{CI}{RI}$

  $= \frac{0.043}{1.57}$

CR = 0.027 ≤0.1≈ Consistent

The CR value for this matrix is 0.027. The matrix is viewed as consistent because this ratio is smaller than 0.1, and the judgments are regarded as dependable and consistent. The viability of the chosen criteria is confirmed by an index below the advised Saaty (2006).

Table 4.32: The criteria of the Indoor Environmental Quality (IEQ) category of AHP Consistency Index (CI) and Consistency Ratio

Criteria	IEQ _1	IEQ _2	IEQ _3	IEQ _4	IEQ _5	IEQ _6	IEQ _7	IEQ _8	IEQ _9	IEQ _10	IEQ _11	IEQ _12	IEQ _13	IEQ _14	Weighted Sum	Weighted Sum /Weight
IEQ_1	0.06	0.06	0.07	0.09	0.06	0.06	0.07	0.06	0.07	0.06	0.06	0.05	0.07	0.06	0.89	14.46
IEQ_2	0.06	0.06	0.07	0.09	0.06	0.06	0.07	0.06	0.07	0.04	0.06	0.10	0.07	0.06	0.92	14.58
IEQ_3	0.06	0.06	0.07	0.09	0.06	0.06	0.07	0.06	0.07	0.12	0.06	0.10	0.07	0.06	1.00	14.64
IEQ_4	0.06	0.06	0.07	0.09	0.06	0.06	0.07	0.06	0.07	0.12	0.11	0.20	0.14	0.12	1.28	14.78
IEQ_5	0.06	0.06	0.07	0.09	0.06	0.06	0.07	0.06	0.07	0.04	0.06	0.10	0.07	0.06	0.92	14.58
IEQ_6	0.06	0.06	0.07	0.09	0.06	0.06	0.07	0.06	0.03	0.06	0.06	0.10	0.03	0.03	0.84	14.63
IEQ_7	0.06	0.06	0.07	0.09	0.06	0.06	0.07	0.06	0.07	0.06	0.06	0.20	0.07	0.06	1.04	14.82
IEQ_8	0.06	0.06	0.07	0.09	0.06	0.06	0.07	0.06	0.07	0.06	0.11	0.05	0.03	0.06	0.91	14.48
IEQ_9	0.06	0.06	0.07	0.09	0.06	0.12	0.07	0.06	0.07	0.06	0.06	0.05	0.07	0.06	0.95	14.45
IEQ_10	0.12	0.19	0.07	0.09	0.19	0.12	0.14	0.13	0.13	0.12	0.17	0.10	0.07	0.06	1.68	14.51
IEQ_11	0.06	0.06	0.07	0.04	0.06	0.06	0.07	0.03	0.07	0.04	0.06	0.05	0.07	0.06	0.80	14.43
IEQ_12	0.12	0.06	0.07	0.04	0.06	0.06	0.04	0.13	0.13	0.12	0.11	0.10	0.20	0.19	1.43	14.53
IEQ_13	0.06	0.06	0.07	0.04	0.06	0.12	0.07	0.13	0.07	0.12	0.06	0.03	0.07	0.03	0.98	14.50
IEQ_14	0.06	0.06	0.07	0.04	0.06	0.12	0.07	0.06	0.07	0.12	0.06	0.03	0.02	0.06	0.90	14.47
															SUM	**203.85**

(Source: Calculated by the researcher by using MS-Excel, 2021)

The Consistency Index (CI) and Consistency Ratio (CR) of the Materials and Resources Category

Table 4.33: The criteria of the Materials and Resources (MR) category of AHP Consistency Index (CI) and Consistency Ratio (CR)

Criteria	MR_1	MR_2	MR_3	MR_4	MR_5	MR_6	MR_7	Weighted Sum	Weighted Sum /Weight
MR_1	0.083	0.15	0.03	0.08	0.14	0.04	0.08	**0.62**	**7.49**
MR_2	0.021	0.04	0.03	0.06	0.03	0.03	0.06	**0.28**	**7.30**
MR_3	0.25	0.11	0.09	0.08	0.07	0.04	0.08	**0.75**	**7.67**
MR_4	0.25	0.15	0.29	0.25	0.43	0.4	0.25	**2.03**	**7.99**
MR_5	0.083	0.19	0.03	0.08	0.14	0.4	0.08	**1.01**	**7.10**
MR_6	0.25	0.15	0.29	0.08	0.05	0.13	0.08	**1.04**	**7.93**
MR_7	0.25	0.15	0.29	0.25	0.43	0.4	0.25	**2.03**	**7.99**
								SUM	**53.48**

(Source: Calculated by the researcher by using MS-Excel, 2021)

For this category (Materials and Resources),

- **λ_{max} = Sum of Weighted Sum /Weight divided by the Number of criteria**

  = **53.48/7**

  = **<u>7.64</u>**

- **Consistency Index** $CI = \frac{(\lambda_{max} - n)}{(n-1)}$

  $= \frac{(7.64 - 7)}{(7-1)}$

  = **<u>0.10</u>**

- **Consistency Ratio** $CR = \frac{CI}{RI}$

  $= \frac{0.10}{1.32}$

***CR* = 0.08 ≤0.1≈ Consistent**

For this matrix, the CR value is 0.08. Because this ratio is less than 0.1, the matrix is regarded as consistent, and the judgments are considered reliable and consistent Saaty (2006). With an index below the recommended, the validity of the selected criteria is confirmed.

The Consistency Index (CI) and Consistency Ratio (CR) of the Management Category

Table 4.34: The criteria of Management (MAN) category of AHP Consistency Index (CI) and Consistency Ratio (CR)

Criteria	MAN_1	MAN_2	MAN_3	MAN_4	MAN_5	MAN_6	Weighted Sum	Weighted Sum/Weight
MAN_1	0.20	0.35	0.08	0.21	0.19	0.18	**1.21**	**5.93**
MAN_2	0.05	0.09	0.06	0.07	0.06	0.18	**0.51**	**5.94**
MAN_3	0.61	0.26	0.25	0.21	0.10	0.18	**1.60**	**6.53**
MAN_4	0.20	0.09	0.25	0.21	0.39	0.18	**1.31**	**6.22**
MAN_5	0.20	0.09	0.49	0.11	0.19	0.18	**1.26**	**6.53**
MAN_6	0.07	0.03	0.08	0.07	0.06	0.06	**0.37**	**6.26**
							SUM	**37.41**

(Source: Calculated by the researcher by using MS-Excel, 2021)

For this category (Management),

- **λ_{max} = Sum of Weighted Sum /Weight divided by the Number of criteria**
  = 37.412/6
  = <u>6.24</u>
- **Consistency Index** $CI = \frac{(\lambda_{max} - n)}{(n - 1)}$
  $= \frac{(6.24 - 6)}{(6 - 1)}$
  = <u>0.047</u>
- **Consistency Ratio** $CR = \frac{CI}{RI}$
  $= \frac{0.047}{1.24}$

CR ***= 0.095 ≤0.1≈ Consistent***

The CR value for this matrix is 0.095. The matrix is viewed as consistent because this ratio is less than 0.1, and the assessments are regarded as trustworthy and consistent. The viability of the selected criteria is proven by an index below the recommended Saaty (2006).

Table 4.35 displays every criterion's weighting, the relative priority (%), ranking results, and categories for each criterion that are appropriate for the Ethiopian context. According to "Deriving Relative Weights/Relative Priority," for the normalization process of the selected eight assessment categories which consist of various assessment criteria that are shown in Tables 4.17-4.24; the weights, relative priority (%), rank by category, and overall ranks are highlighted in yellow, grey, pink, and blue colors, respectively. The "Rank by Category" in Table 4.35 below shows the rankings for each criterion in these Tables 4.17-4.24.

Table 4.35: The Weight, Relative Priority (%), Rank by Category, and Overall Ranking results for each category of SBAT for Ethiopian Context

ID	**Criteria**	**Weight**	**Relative Priority (%)**	**Rank by Category**	**Overall Rank**
A. Economic Aspects (EA)					
EA_1	Building's affordability concerning the distance of facilities of Transportation	**0.0528**	**5.28**	**8**	**55**
EA_2	Building's affordability concerning the distance of the workplace	**0.0412**	**4.12**	**10**	**60**
EA_3	Building's affordability concerning the distance of getting Health services	**0.1503**	**15.03**	**1**	**14**
EA_4	Building's affordability concerning the distance of getting Education Services	**0.1481**	**14.81**	**2**	**15**
EA_5	Building's affordability concerning the distance of getting Shops/marketplaces	**0.1031**	**10.31**	**6**	**28**
EA_6	Building's affordability concerning rental for residential	**0.0431**	**4.31**	**9**	**58**
EA_7	Costs of operation and maintenance	**0.0583**	**5.83**	**7**	**51**
EA_8	Cost for building life cycle	**0.1328**	**13.28**	**4**	**21**
EA_9	Investment risk	**0.1283**	**12.83**	**5**	**24**
EA_10	Construction cost	**0.1420**	**14.20**	**3**	**18**
B. Energy Efficiency (EE)					
EE_1	Use of energy monitoring /management system	**0.1844**	**18.44**	**2**	**12**
EE_2	Energy for internal lighting	**0.1046**	**10.46**	**4**	**27**
EE_3	Energy for external lighting	**0.1046**	**10.46**	**4**	**27**
EE_4	Use of energy-efficient equipment	**0.2866**	**28.66**	**1**	**2**
EE_5	Use of natural energy resources/ Renewable Energy	**0.0853**	**8.53**	**5**	**36**
EE_6	Use of Hot Water /Steam	**0.0364**	**3.64**	**7**	**62**
EE_7	HVAC Systems	**0.0521**	**5.21**	**6**	**56**
EE_8	Energy savings	**0.1458**	**14.58**	**3**	**16**
C. Water efficiency (WE)					
WE_1	Water consumption	**0.0924**	**9.24**	**4**	**33**
WE_2	Regular water leak detection and monitoring	**0.0677**	**6.77**	**7**	**42**
WE_3	Use of rain Water Harvesting	**0.2804**	**28.04**	**1**	**3**

WE_4	Use of water Efficient Fittings and equipment	**0.1808**	**18.08**	**3**	**13**
WE_5	Regular water Usage Monitoring	**0.2105**	**21.05**	**2**	**8**
WE_6	Recycling of wastewater	**0.0842**	**8.42**	**5**	**37**
WE_7	Recharge of groundwater	**0.0840**	**8.40**	**6**	**38**
D. Location and Transportation (LT)					
LT_1	Availability of alternative modes of transportation (Buses, Taxi, Bicycle, Pedestrian/Foot, Light Rail Transport (LRT))	**0.2630**	**26.30**	**1**	**4**
LT_2	Provision of the car parking area and parking capacity	**0.0583**	**5.83**	**6**	**51**
LT_3	Community/Local Connectivity	**0.0620**	**6.20**	**5**	**48**
LT_4	Density Development location	**0.1165**	**11.65**	**3**	**25**
LT_5	Sensitive land protection	**0.1018**	**10.18**	**4**	**29**
LT_6	Surrounding density and diverse uses	**0.1353**	**13.53**	**2**	**19**
LT_7	Accessibility to public transportation	**0.2630**	**26.30**	**1**	**4**
E. Sustainable Sites and Ecology (SE)					
SE_1	Site selection and protection	**0.1339**	**13.39**	**3**	**20**
SE_2	Reuse of Land	**0.0419**	**4.19**	**8**	**59**
SE_3	Ecological/Land Value	**0.0961**	**9.61**	**5**	**32**
SE_4	Reclaimed Contaminated Land	**0.0488**	**4.88**	**7**	**57**
SE_5	Enhance site Ecology	**0.0556**	**5.56**	**6**	**53**
SE_6	Use of local /indigenous plants/flora	**0.1297**	**12.97**	**4**	**23**
SE_7	Protect or Restore Open Space	**0.2064**	**20.64**	**2**	**9**
SE_8	Existence of open space, green area, playground area, and public space	**0.2876**	**28.76**	**1**	**1**
F. Indoor environmental quality (IEQ)					
IEQ_1	Noise level	**0.0617**	**6.17**	**11**	**49**
IEQ_2	Sound insulation	**0.0633**	**6.33**	**8**	**45**
IEQ_3	Sound absorption	**0.0683**	**6.83**	**5**	**41**
IEQ_4	Thermal comfort concerning Cooling control and comfort	**0.0868**	**8.68**	**3**	**34**
IEQ_5	Thermal comfort concerning Heating control and comfort	**0.0633**	**6.33**	**8**	**45**
IEQ_6	Thermal comfort concerning Humidity control and comfort	**0.0577**	**5.77**	**12**	**52**
IEQ_7	Lighting & Illumination concerning Lighting Controllability	**0.0702**	**7.02**	**4**	**40**
IEQ_8	Lighting & Illumination concerning View out	**0.0632**	**6.32**	**9**	**46**
IEQ_9	Lighting & Illumination concerning Glare measure and control	**0.0657**	**6.57**	**7**	**44**
IEQ_10	Indoor Air Quality	**0.1160**	**11.60**	**1**	**26**
IEQ_11	Visual Comfort	**0.0553**	**5.53**	**13**	**54**
IEQ_12	Existence of natural ventilation	**0.0983**	**9.83**	**2**	**30**

IEQ_13	Availability of Ventilation system	**0.0676**	**6.76**	**6**	**43**
IEQ_14	Air purification- supply of fresh air	**0.0624**	**6.24**	**10**	**47**
G. Materials and Resources (MR)					
MR_1	Use of materials of low environmental impact	**0.0834**	**8.34**	**5**	**39**
MR_2	Use of non-renewable-virgin materials	**0.0383**	**3.83**	**6**	**61**
MR_3	Reuse of structural frame materials	**0.0973**	**9.73**	**4**	**31**
MR_4	Use of locally available materials	**0.2532**	**25.32**	**1**	**5**
MR_5	Use of materials with recycled content	**0.1428**	**14.28**	**2**	**17**
MR_6	Use of finishing materials	**0.1317**	**13.17**	**3**	**22**
MR_7	Material efficiency over its life cycle	**0.2532**	**25.32**	**1**	**5**
H. Management (MAN)					
MAN_1	Facility Management	**0.2046**	**20.46**	**3**	**10**
MAN_2	Commissioning	**0.0863**	**8.63**	**5**	**35**
MAN_3	Consultation	**0.2456**	**24.56**	**1**	**6**
MAN_4	Construction process planning and management	**0.2111**	**21.11**	**2**	**7**
MAN_5	Waste Management during construction and operation	**0.1927**	**19.27**	**4**	**11**
MAN_6	Security	**0.0596**	**5.96**	**6**	**50**

(Source: Calculated by the researcher by using MS-Excel, 2021)

The weight, relative priority (%), rank by category, and an overall rank of the identified criteria within each category are all shown in Table 4.35 above which are highlighted by yellow, grey, pink, and blue colors respectively. The existence of open spaces, green areas, playground areas, and public spaces are the key criteria under the sustainable sites and ecology category. It has the 1st ranking in overall rankings with a relative priority value of 28.76%, and the next is of use of energy-efficient equipment under the energy-efficiency category with a relative priority value of 28.66%, plus use of rainwater harvesting under the water efficiency category with a relative priority value of 28.04%. The first criterion (existence of open space, green areas, playground areas, and public spaces) is essential for the built environment to be alive and well, meaning that sustainability has been attained. Because Ethiopia is rich in renewable energy sources such as wind, hydropower, geothermal, and solar, energy-efficient equipment is essential for harnessing these resources (if generated and utilized) to satisfy the energy demands of buildings and industries, resulting in the country's economic success. Rainwater harvesting from these buildings is also highly suggested for usage in a variety of applications such as gardening, washing, urban agriculture, and watering vegetation and various types of trees, which aids climate management and lowers the heat island effects of the built environment. As a result, these three sustainable building assessment criteria of ranks from diverse categories are the most strongly examined of the 67 criteria analyzed when developing the Ethio-SBAT.

The 4th ranking and most important criteria are both the availability of alternative transport means (buses, taxis, bicycles, pedestrians on foot, and light rail) and accessibility to public transportation under the location and transportation category with a relative priority (%) value of 26.30%. The 5th ranking is both utilizing locally available materials and material efficiency over its life cycle under the resources and materials category, with a relative priority (%) value of 25.32%. The 6th and 7th rankings are the criteria consultation and the construction process for the overall administration with the (%) value of 24.56% and 21.11% respectively under the management category. By focusing on the criteria of alternate modes of transportation, such as buses, emissions of pollutants that result in air pollution can be reduced. At the same time, users should have access to this form of transportation to improve their efficacy and efficiency by lowering the amount of time they spend waiting for transportation. The use of locally available construction materials, as well as their efficiency over their life cycle, is also critical because these materials are compatible with local climatic conditions, and their costs are lower than imported materials, resulting in import substitutions, which leads to the country economic growth and economic sustainability. As a result of these rankings (4th-7th) of assessment criteria from various categories, it is clear that, in addition to the first three criteria listed above, a focus on the development of an SBAT should be given.

The 8th ranking is regular water usage monitoring under the water–efficiency category with a relative priority (%) value of 21.05%, followed by protecting or restoring open space from the sustainable sites and ecology category with a relative priority (%) value of 20.64% (9th ranking) and the facility management under the management category with a relative priority (%) value of 20.46% (10th ranking). The least important criterion, among 67 criteria, is utilizing non-renewable-virgin materials under the resources and management category, with a relative priority (%) value of 3.83% that has a 61st ranking.

Water's limited resources should be adequately and consistently monitored while being used, resulting in a reduction in water costs. The open spaces are also protected and restored to their original state. To increase productivity, all construction-related facilities should be appropriately and efficiently managed. As a result of adopting these three assessment criteria, while developing Ethio-SBAT, rankings from 8th to 10th are examined about the aforementioned criterion (1st-7th ranking).

4.2. Appropriate assessment categories and criteria to develop SBAT for Ethiopia

Research Question 2: How to develop an SBAT that is appropriate for the Ethiopian context for the evaluation and certification of buildings by using the selected categories and criteria?

The sustainable building assessment categories and criteria chosen for the Ethiopian context were agreed upon through survey questionnaires by senior experts who are well-known and knowledgeable in the construction sectors, such as engineers, architects, designers, planners, and managers. These assessment categories and criteria are the best applicable solution to form an appropriate standardization for local conditions while also taking into consideration what has been disregarded, such as social and cultural considerations, environmental concerns, and economic factors. The inclusion of international standards and regulations is sometimes strongly advised, as buildings must adhere to them to receive credit for meeting environmental standards.

The SBAT for the Ethiopian context was developed in response to the findings of these two research questions. This tool gives the decision-maker the ability to evaluate the effectiveness of the criteria in attaining the overall goals of the assessment of sustainable buildings. Furthermore, it can draw the decision-attention makers to several areas where the existing criteria need to be changed to more effectively support the objectives of the sustainable building assessment.

4.2.1. Approaches for the Development of New Proposed SBAT

There are various types of environments, such as physical, biological, and socioeconomic, and the sustainability of these environments play significant roles in the realization of sustainable development. To this end, applying environmental assessments by using different assessment tools is indispensable, as there are several assessment tools available. However; as clearly stated by authors James (1997) and Elizabeth (2018), there is a lack of a clear path toward 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 that lead to the development of an SBAT suitable for Ethiopia, as shown in Figure 4.4 below.

The author Wilber (1995), who is also the creator of Integral Perspectivism, is credited with developing the quadrant model. Integrative perspectivism is a method for utilizing and integrating many viewpoints within the quadrant paradigm. The quadrant model is, in other words, an integrative operating system for the growth of complex knowledge and practice in a variety of spheres of life. The quadrant model describes four fundamental views that, when combined with precision and focus, a broad scope, and a clear overview, can aid in deepening our understanding of a particular event.

This four-quadrant model approach is organized into four quadrants, in which all development steps are subject to evaluating points to achieve vigorous development. These four quadrants are:

I. Quadrant 1: Identification and selection of the 10 SBATs and categories and criteria.
II. Quadrant 2: Evaluate and customize the categories and criteria.
III. Quadrant 3: Corroborate the development process.
IV. Quadrant 4: Plan the next step.

A sustainable building uses fewer resources, is ecologically friendly, costs less to build and maintain, is healthy, and upholds social responsibility throughout its whole life. Due to the large energy and environmental footprints that the building sector leaves behind, it must adopt sustainable practices to combat climate change and global warming. Systems for assessing sustainable buildings have been created all around the world as a way to advance sustainability in this sector.

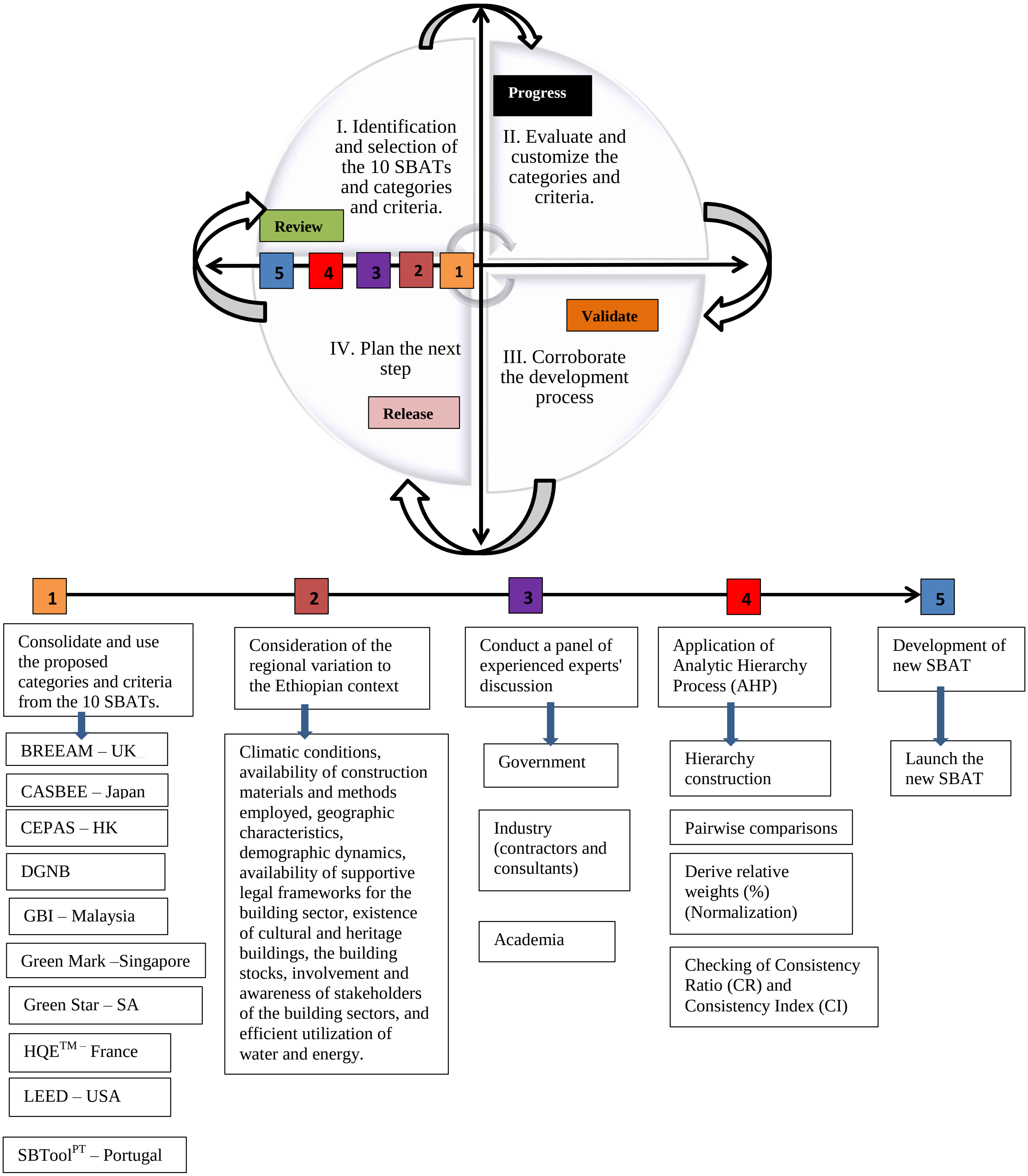

Figure 4.4: Four Quadrant and Helical Flow Models of relating phases for developing SBAT for Ethiopia (Source: Formulated by the researcher, 2021)

An SBAT was created for the Ethiopian context based on the selected eight (8) assessment categories and sixty seven (67) criteria as shown in Table 4.4, as well as the Four Quadrant and Helical Flow Model of related phases as shown in Figure 4.4. Five steps are taken in the development of this new SBAT as follows:

a) **Consolidate and use the proposed categories and criteria**: The review aims to identify, consolidate, and use the most prominent, reliable, and widely used 10 SBATs, based on a set of criteria. This is the starting point for the development of the new SBAT as noted by the authors James (1997) and Elizabeth (2018).
b) **Consideration of local variation to the Ethiopian context**: this is a significant step because each region has its unique characteristics. This variation matters to develop a new SBAT for each region James (1997) and Elizabeth (2018).
c) **Conduct a 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) James (1997), Chang (2007) and Elizabeth (2018).
d) **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 and socioeconomic concerns. To establish a valid weighting system, the following processes were taken into account: hierarchy constructions, pairwise comparisons, deriving relative weights (normalization) and checking of consistency ratio (CR) and consistency index (CI) James (1997).
e) **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.

Table 4.35 demonstrates that each assessment category has specific criteria for determining the building's sustainability level, which are based on the socioeconomic, cultural, and environmental circumstances of the nation.

The authors Alyami (2015) have unambiguously indicated that weighting is the primary component of a rating system and that the differentiation between evaluation systems is made by the variation in the weight of the criterion. The consistency ratio (CR) in all pairwise comparisons matrix for each category and criteria as shown in Tables 4.27-4.34 is acceptable (it is less than or equal to 0.10 or 10%), which confirms the validity of the selected sustainable building assessment categories and criteria. Table 4.36 displays the weight of the proposed assessment categories and criteria for Ethiopia.

Table 4.36: Summarized weightage by assessment Category and Criteria

Category	Priority Weightage	Criteria	Priority Weightage
Materials and Resources (MR)	**0.1866**	Use of locally available materials	**0.2532**
		Material efficiency over its life cycle	**0.2532**
		Use of materials with recycled content	**0.1428**
		Use of finishing materials	**0.1317**
		Reuse of structural frame materials	**0.0973**
		Use of materials of low environmental impact	**0.0834**
		Use of non-renewable-virgin materials	**0.0383**
Sustainable Sites and Ecology (SE)	**0.1692**	Existence of open space, green area, playground area, and public space	**0.2876**
		Protect or restore open space	**0.2064**
		Site selection and protection	**0.1339**
		Use of local /indigenous plants/flora	**0.1297**
		Ecological/Land value	**0.0961**
		Enhance site ecology	**0.0556**
		Reclaimed contaminated land	**0.0488**
		Reuse of land	**0.0419**
Indoor Environmental Quality (IEQ)	**0.1678**	Indoor air quality	**0.1160**
		Existence of natural ventilation	**0.0983**
		Thermal comfort concerning cooling control and comfort	**0.0868**
		Lighting & Illumination concerning lighting controllability	**0.0702**
		Sound absorption	**0.0683**
		Availability of ventilation system	**0.0676**
		Lighting & Illumination concerning glare measure and control	**0.0657**
		Thermal comfort concerning heating control and comfort	**0.0633**
		Sound insulation	**0.0633**
		Lighting & Illumination concerning view out	**0.0632**
		Air purification- supply of fresh air	**0.0624**
		Noise level	**0.0617**
		Thermal comfort concerning humidity control and comfort	**0.0577**
		Visual Comfort	**0.0553**
		Use of energy-efficient equipment	**0.2866**

Energy Efficiency (EE)	**0.1260**	Use of energy monitoring /management system	**0.1844**
		Energy savings	**0.1458**
		Energy for internal lighting	**0.1046**
		Energy for external lighting	**0.1046**
		Use of natural energy resources/ Renewable Energy	**0.0853**
		HVAC Systems	**0.0521**
		Use of hot water /steam	**0.0364**
Economic Aspects (EA)	**0.1041**	Affordability of the building concerning the distance of getting health services	**0.1503**
		Affordability of the building concerning the distance of getting education services	**0.1481**
		Construction cost	**0.1420**
		Life cycle cost (LCC)	**0.1328**
		Investment risk	**0.1283**
		Affordability of the building concerning the distance of getting Shops/marketplaces	**0.1031**
		Operation and maintenance cost	**0.0583**
		Affordability of the building concerning the distance of facilities of transportation	**0.0528**
		Affordability of the building concerning rental for residential	**0.0431**
		Affordability of the building concerning the distance of the workplace	**0.0412**
Management (MAN)	**0.1030**	Consultation	**0.2456**
		Construction process planning and management	**0.2111**
		Facility management	**0.2046**
		Waste management during construction and operation	**0.1927**
		Commissioning	**0.0863**
		Security	**0.0596**
Water efficiency (WE)	**0.0806**	Use of rainwater harvesting	**0.2804**
		Regular water usage monitoring	**0.2105**
		Use of water-efficient fittings and equipment	**0.1808**
		Water consumption	**0.0924**
		Recycling of wastewater	**0.0842**
		Recharge of groundwater	**0.0840**
		Regular water leak detection and monitoring	**0.0677**
Location and Transportation (LT)	**0.0627**	Availability of alternative modes of transportation (Buses, Taxi, Bicycle, Pedestrian/Foot, Light Rail Transport (LRT))	**0.2630**
		Accessibility to public transportation	**0.2630**
		Surrounding density and diverse uses	**0.1353**
		Density development location	**0.1165**
		Sensitive land protection	**0.1018**
		Community/Local connectivity	**0.0620**
		Provision of the car parking area and parking capacity	**0.0583**

(Source: Calculated by the researcher by using MS-Excel, 2021)

Table 4.37 below shows the given points/scores for the classified and prioritized sustainable building evaluation criteria based on the experts' judgment by extracting criteria with a mean/average greater than 2.0 from a list of sixty-seven (67) criteria separated into eight (8) categories. The researcher used the findings of authors Katayon (2018) who classified the mean/average of the experts' judgment for allocating the scores/points for each selected criterion, such as 1 point/score for criteria with a mean/average of 2.0–2.9; 2 points/scores for criteria with a mean/average of 3.0–3.9; and 3 points/scores for criteria with a mean/average of 4.0–5.0. The study has utilized this classification of points/scores for each category's criterion and summed these points/scores to arrive at the category's points/scores.

Table 4.37: The mean/average and score/point of the criteria according to the senior experts' judgment

Category	Criteria	Mean /Average	Scores/ Points
Economic Aspects (EA)	Affordability of the building concerning the distance of facilities of transportation	4.2	3
	Affordability of the building concerning the distance of the workplace	4.0	3
	Affordability of the building concerning the distance of getting health services	3.8	2
	Affordability of the building concerning the distance of getting education services	3.9	2
	Affordability of the building concerning the distance of getting shops/marketplaces	4.0	3
	Affordability of the building concerning rental for residential	3.9	2
	Operation and maintenance cost	3.9	2
	Life cycle cost (LCC)	3.8	2
	Investment risk	3.7	2
	Construction cost	4.0	3
Energy Efficiency (EE)	Use of energy monitoring /management system	4.0	3
	Energy for internal lighting	4.0	3
	Energy for external lighting	4.0	3
	Use of energy-efficient equipment	3.9	2
	Use of natural energy resources/ Renewable Energy	3.9	2
	Use of hot water /steam	3.5	2
	HVAC systems	3.7	2
	Energy savings	3.9	2
Water Efficiency (WE)	Water consumption	4.2	3
	Regular water leak detection and monitoring	3.8	2
	Use of rainwater harvesting	3.6	2
	Use of water-efficient fittings and equipment	3.9	2
	Regular water usage monitoring	3.9	2
	Recycling of wastewater	3.7	2
	Recharge of groundwater	3.6	2
Location and Transportation (LT)	Availability of alternative modes of transportation (Buses, Taxi, Bicycle, Pedestrian/Foot, Light Rail Transport (LRT))	4.2	3
	Provision of the car parking area and parking capacity	4.0	3
	Community/Local connectivity	3.9	2
	Density Development location	3.8	2
	Sensitive land protection	3.7	2

	Surrounding density and diverse uses	**3.7**	**2**
	Accessibility to public transportation	**4.1**	**3**
Sustainable Sites and Ecology (SE)	Site selection and protection	**4.2**	**3**
	Reuse of Land	**3.8**	**2**
	Ecological/Land value	**4.0**	**3**
	Reclaimed contaminated land	**3.7**	**2**
	Enhance site ecology	**3.9**	**2**
	Use of local /indigenous plants/flora	**3.8**	**2**
	Protect or restore open space	**4.0**	**3**
	Existence of open space, green area, playground area, and public space	**4.1**	**3**
Indoor Environmental Quality (IEQ)	Noise level	**4.0**	**3**
	Sound insulation	**3.9**	**2**
	Sound absorption	**3.7**	**2**
	Thermal comfort concerning cooling control and comfort	**3.8**	**2**
	Thermal comfort concerning heating control and comfort	**3.8**	**2**
	Thermal comfort concerning humidity control and comfort	**3.6**	**2**
	Lighting & Illumination concerning lighting controllability	**3.9**	**2**
	Lighting & Illumination concerning view out	**3.9**	**2**
	Lighting & Illumination concerning glare measure and control	**3.8**	**2**
	Indoor air quality	**4.1**	**3**
	Visual Comfort	**4.1**	**3**
	Existence of natural ventilation	**4.3**	**3**
	Availability of ventilation system	**3.9**	**2**
	Air purification- supply of fresh air	**3.7**	**2**
Materials and Resources (MR)	Use of materials of low environmental impact	**4.2**	**3**
	Use of non-renewable-virgin materials	**3.5**	**2**
	Reuse of structural frame materials	**3.7**	**2**
	Use of locally available materials	**4.3**	**3**
	Use of materials with recycled content	**3.9**	**2**
	Use of finishing materials	**4.1**	**3**
	Material efficiency over its life cycle	**4.0**	**3**
Management (MAN)	Facility Management	**4.2**	**3**
	Commissioning	**3.9**	**2**
	Consultation	**4.0**	**3**
	Construction process planning and management	**4.2**	**3**
	Waste Management during construction and operation	**4.0**	**3**
	Security	**4.1**	**3**

(Source: Calculated by the researcher by using MS-Excel, 2021)

Table 4.38 below depicts the % value, criteria number, plus the points/scores of each selected category that were employed to develop SBAT in the Ethiopian context.

Table 4.38: The relative priority (%) value, number of criteria, and the points/scores of Ethiopian SBAT

Category	Relative Priority (%) Value	Number of Criteria	Points/scores	Description
Materials and Resources (MR)	**18.66**	**7**	**18**	The use of locally available materials is highly recommended-Use materials of low environmental impact-Reuse of structural frame materials during the construction process-Materials with recycled content should be used-Use for finishing materials- Material efficiency over its life cycle and Use of non-renewable-virgin materials
Sustainable Sites and Ecology (SE)	**16.92**	**8**	**20**	Site selection and protection-Reuse of Land-Ecological/Land Value- Reclaimed Contaminated Land-Enhance site Ecology- Use of local /indigenous plants/flora-Protect or Restore Open Space and Existence of open space, green area, playground area, and public space.
Indoor Environmental Quality (IEQ)	**16.78**	**14**	**32**	Noise level- Sound insulation-Sound absorption-Thermal comfort concerning Cooling control and comfort-Thermal comfort concerning Heating control and comfort-Thermal comfort concerning Humidity control and comfort-Lighting & Illumination for Lighting Controllability-Lighting & Illumination concerning View out-Lighting & Illumination concerning Glare measure and control-Indoor Air Quality-Visual Comfort-Existence of natural ventilation-Availability of Ventilation system-Air purification- supply of fresh air.
Energy Efficiency (EE)	**12.60**	**8**	**19**	Use of energy monitoring /management system-Energy for internal lighting-Energy for external lighting-Use of energy efficient equipment-Use of natural energy resources/ Renewable Energy-Use of Hot Water /Steam-HVAC Systems and Energy savings
Economic Aspects (EA)	**10.41**	**10**	**24**	Affordability of the building concerning the distance of facilities of Transportation-Affordability of the building concerning the distance of work place-Affordability of the building concerning the distance of getting Health services-Affordability of the building concerning the distance of getting Education Services-Affordability of the building concerning the distance of getting Shops/market places-Affordability of the building concerning rental for residential-Operation and maintenance cost-Life cycle cost (LCC)-Investment risk and Construction cost.
Management (MAN)	**10.30**	**6**	**17**	Facility Management-Commissioning-Consultation-Construction process planning and management and Waste Management during construction and operation-Security.
				Water consumption-Regular water leak detection and monitoring-Use of rain Water Harvesting-Use

Water Efficiency (WE)	**8.06**	**7**	**15**	of water Efficient Fittings and equipment-Regular water Usage Monitoring-Recycling of wastewater and Recharge of groundwater.
Location and Transportation (LT)	**6.27**	**7**	**17**	Availability of alternative modes of transportation (Buses, Taxi, Bicycle, Pedestrian/Foot, Light Rail Transport (LRT))-Provision of the car parking area and parking capacity-Community/Local Connectivity-Density Development location-Sensitive land protection-Surrounding density and diverse uses and Accessibility to public transportation.
Total	**100**	**67**	**162**	

(Source: Formulated by the researcher, 2021)

The results in Table 4.38 show that out of the eight available categories, resources and materials received the highest priority score of 18.66 percent, making it the most acceptable sustainable building assessment category. This assessment category of resources and materials as sustainable building materials is based on the fact that it has performed best in the majority of the study's sustainability categories. Working appropriateness, environmental, and social advantages sustainability have all been outperformed by the resources and materials category. The categories sustainable sites and ecology, with a relative priority vector value of 16.92 percent, and indoor environmental quality, with a relative priority vector value of 16.78 percent, outdo the categories resources and materials in the sustainability category and are thus ranked second and third better alternatives, respectively. Furthermore, the assessment categories of energy efficiency, economic aspects, and water efficiency have relative priority vector values of 12.60 percent, 10.41 percent, and 10.30 percent, respectively, and their rankings in sustainability are 4th, 5th, and 6th, respectively, indicating that they performed less than the aforementioned three assessment categories. Management and location and transportation are the least used assessment categories, with relative priority vector values of 8.06 percent and 6.27 percent, respectively, and rank 7th and 8th. As a result, these categories receive the least attention in the development of Ethio-SBAT.

The certification requirement is based on the total of the points awarded for the evaluation system's categories and criteria depending upon the (%) results of every category depicted in Table 4.38 above. The summing is calculated by multiplying the scores for all assessment items by the weighting factor. There are a total of 162 points available. For awarding the assessed building, the results of the scoring scales (points) have to be calculated from 100 **(i.e. the total points are calculated from 162 points and then change to 100 points)**. The proposed five performance levels of allocated points and awards for the assessed buildings are ≤19 points: Certificate with Yet to be Green (Bronze)Rank; 20–39 points: Certificate with Emerging Green (Silver) Rank; 40–59 points: Certificate with Green (Gold)Rank; 60- 79 points: Certificate with Substantially Green (Platinum); and ≥80 points: Certificate with Extremely Green (Diamond)Rank.

Based on assessments of developed rating systems including LEED, BREEAM, CASBEE, GBI-Malaysia, DGNB, Green Mark-Singapore, Green Star-South Africa, HQETM-France, and GBTool, the assessment categories and criteria of the sustainable/greenness levels were produced. Furthermore, the experts' judgment for computing the scores or points for each chosen criterion is included in the survey questions. The grade level of the Ethio-Sustainable Building Assessment Tool (Ethio-SBAT) is shown in Table 4.39 below, and a minimum score is needed to certify assessed buildings.

Table 4.39: Minimum results required to achieve each grade level of Ethio-SBAT

Assessment level	**Scoring Scale (points)**
Extremely Green (Diamond)	$X \geq 80$
Substantially Green (Platinum)	$60 \leq X \leq 79$
Green (Gold)	$40 \leq X \leq 59$
Emerging Green (Silver)	$20 < X \leq 39$
Yet to be Green (Bronze)	$X \leq 19$

(Source: developed by the researcher, 2022)

Depending upon the (%) results of every category depicted in Table 4.38 and the developed assessment level and scoring scale (points) of the Ethio-SBAT in Table 4.39 above, checklists are prepared for evaluating and certifying existing buildings as shown in Table 4.40 below.

Table 4.40: Proposed checklist for the evaluation of existing building using the proposed Ethio-SBAT

Assessment System for Existing Buildings			
Checklist			
Materials and Resources (MR)		**18**	**100%**
1	Use of materials of low environmental impact	5	28
2	Use of non-renewable-virgin materials	1	6
3	Reuse of structural frame materials	2	11
4	Use of locally available materials	6	32
5	Use of materials with recycled content	2	11
6	Use of finishing materials	1	6
7	Material efficiency over its life cycle	1	6
Sustainable Sites and Ecology (SE)		**20**	**100%**
1	Site selection and protection	2	10
2	Reuse of Land	1	5
3	Ecological/Land value	1	5
4	Reclaimed contaminated land	3	15
5	Enhance site ecology	4	20
6	Use of local /indigenous plants/flora	2	10
7	Protect or restore open space	3	15
8	Existence of open space, green area, playground area, and public space	4	20
Indoor Environmental Quality (IEQ)		**32**	**100%**
1	Noise level	2	6
2	Sound insulation	2	6
3	Sound absorption	2	6
4	Thermal comfort concerning cooling control and comfort	1	3
5	Thermal comfort concerning heating control and comfort	1	3
6	Thermal comfort concerning humidity control and comfort	1	3
7	Lighting & Illumination concerning lighting controllability	1	3
8	Lighting & Illumination concerning view out	1	3
9	Lighting & Illumination concerning glare measure and control	3	9
10	Indoor air quality	5	17
11	Visual Comfort	3	9
12	Existence of natural ventilation	4	14
13	Availability of ventilation system	3	9
14	Air purification- supply of fresh air	3	9
Energy Efficiency (EE)		**19**	**100%**
1	Use of energy monitoring /management system	3	16
2	Energy for internal lighting	1	5
3	Energy for external lighting	1	5
4	Use of energy-efficient equipment	3	16
5	Use of natural energy resources/ Renewable Energy	5	26
6	Use of hot water /steam	1	5
7	HVAC systems	3	16
8	Energy savings	2	11
Economic Aspects (EA)		**24**	**100%**

1	Affordability of the building concerning distance of facilities of transportation	3	13
2	Affordability of the building concerning distance of workplace	4	17
3	Affordability of the building concerning distance of getting health services	4	17
4	Affordability of the building concerning distance of getting education services	4	17
5	Affordability of the building concerning distance of getting shops/marketplaces	2	8
6	Affordability of the building concerning rental for residential	2	8
7	Operation and maintenance cost	2	8
8	Life cycle cost (LCC)	1	4
9	Investment risk	1	4
10	Construction cost	1	4
	Management (MAN)	**17**	**100%**
1	Facility Management	2	12
2	Commissioning	1	6
3	Consultation	2	12
4	Construction process planning and management	5	29
5	Waste Management during construction and operation	5	29
6	Security	2	12
	Water Efficiency (WE)	**15**	**100%**
1	Water consumption	1	7
2	Regular water leak detection and monitoring	4	26
3	Use of rainwater harvesting	3	20
4	Use of water-efficient fittings and equipment	3	20
5	Regular water usage monitoring	2	13
6	Recycling of wastewater	1	7
7	Recharge of groundwater	1	7
	Location and Transportation (LT)	**17**	**100%**
1	Availability of alternative modes of transportation (Buses, Taxi, Bicycle, Pedestrian/Foot, Light Rail Transport (LRT))	4	23
2	Provision of the car parking area and parking capacity	3	18
3	Community/Local connectivity	2	12
4	Density Development location	2	12
5	Sensitive land protection	1	6
6	Surrounding density and diverse uses	1	6
7	Accessibility to public transportation	4	23

(Source: Formulated by the researcher, 2021)

CHAPTER FIVE

5.1. Conclusion

The construction sector sees the sustainable building as a way to work toward environmental conservation. Promoting sustainable building practices aims to balance project performance in terms of economic, social, and environmental factors. Sustainable building in Ethiopia is a significant problem for the construction sector due to growing concerns about climate change and sustainability around the globe.

This study's main goal is to develop a sustainable building assessment tool (SBAT) for Ethiopia: The case of Addis Ababa. To do this, the researcher first identifies which SBATs are most frequently and widely used globally, then choose the most appropriate SBATs, categories, and criteria for the Ethiopian context. Finally, employ the best analytics tools on the selected assessment categories, and criteria.

The Ethiopian Building Codes and Standard (EBCS), the Building Proclamation (Proclamation No. 624/2009), the Buildings Regulation (Regulation No. 243/2011), the Building Directives (Directive No. 5/2003), and the Construction Industry Policy (Policy No. 2006) all provide legal frameworks for the construction of buildings, but their implementation has been challenging due to the absence of SBATs and evaluation criteria so far in Ethiopia.

The benefits of sustainability include but are not limited to maintaining the health and biocapacity of the environment; promoting the health of people and societies; encouraging the development of a robust economy with less pollution and waste lower emissions; better employment opportunities; and more equitable income distribution.

The benefits of sustainable /green buildings include but are not limited to providing better health for building occupants due to the improved indoor quality; leading to the development of more energy-efficient products and services; improving 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 less natural resources to protect the ecosystem; lead to the reduction of annual water cost savings; increase the occupant safety and security; lead lower operational and support costs; waste disposal costs in the green buildings are lower; make risk management manageable (economic, financial, market, etc.); and the cost of maintenance in green building is greatly reduced. Thus, it can be understood that sustainable building has become a future development trend in the building sector.

Ethiopia's building sector is highly increasing from time to time as 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 the seat for international organizations. Recent years have seen an upsurge in Ethiopia's concern for the environment and sustainable development. As of yet, there are no assessment methods or criteria for sustainable buildings. For the achievement of sustainable development, it is necessary to develop new approaches and procedures for taking the theory and implementations of the green building philosophy into consideration.

The ten (10) most popular and widely applied SBATs, including BREEAM, CASBEE, CEPAS, DGNB, GBI, Green Mark-Singapore, Green Star SA, HQETM-France, LEED, and SBToolPT-Portugal, have been examined in this study. Each assessment tool has a different method for weighing the categories and criteria. Additionally, it has been determined that eight (8) categories and sixty-seven (67) criteria for the assessment of sustainable buildings have been identified. These criteria were developed by a consensus-based process with the experienced experts who were involved in the building construction sectors through brainstorming and carrying out deliberative measures, based on the discussion of ideas, to generate lists of applicable categories and criteria for sustainable building assessments that were most appropriate for the Ethiopian context.

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 category was composed of different assessment criteria for instance, economic aspects consist 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.

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. The other assessment category like the materials and resource 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 criteria found in one SBAT may also be present in other SBATs with similar category names or subtle variations on those category names, such as "Health and Well-being" in the BREEAM SBAT whereas "Occupant's Health and Comfort" in the SBTool SBAT and "Health and Safety" in the HQE^{TM} SBAT. Other categories names include "Energy" in the BREEAM, CASBEE, and Green Star SA SBAT; "Energy Efficiency" in the GBI, Green Mark (Singapore), and SBTool SBAT; "Energy and Savings" in the HEQ^{TM} SBAT; and "Energy and Atmosphere" in the LEED SBAT.

Under the economic aspects category, for instance, the life cycle cost of buildings and construction cost were considered as assessment criteria by BREEAM–UK, DGNB, and SBTool^{PT}–Portugal. The other criteria like the affordability of the building concerning distance for transportation services 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. In the energy–efficiency category, on the other hand, 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, HQE^{TM}–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.

Analytical Hierarchy Process (AHP) Technique is used to analyze the weightings, relative priority values (%), and rankings of the determined appropriate categories and criteria and has four stages: Hierarchy Construction, Pairwise Comparison Matrix of the Criteria, Deriving Relative Weights/ Relative Priority, and Testing Consistency Index (CI) and Consistency Ratio (CR)). The values of the consistency ratio (CR) under the AHP technique play a key part in determining whether or not the test's results are acceptable when validating and evaluating the chosen SBAT categories and criteria. The appropriate CR range should be less than or equal to 0.10, according to the author (Saaty T., 2006). The results of the CR of all the assessment categories and criteria are ≤ 0.10 based on the ranges of these CR values, which suggests that conclusions are reached that are reliable and ensure a high level of consistency (validity) with a given category and criteria.

Development of SBAT requires reviewing and examining the most widely and commonly used practices of industrialized nations using the AHP technique, which is appropriate for the Ethiopian context by taking into account agreement among Ethiopian experienced experts on relevant sustainability categories and criteria. In addition; the current AHP analysis results revealed that materials and resources, as well as sustainable sites and ecology, are the main categories, with high priority given to these categories over others, followed by energy efficiency and indoor environmental quality. The use of locally available materials and material efficiency over its life cycle are the most significant factors when developing SBAT for Ethiopia within the category of material and resources.

The selected sustainable building assessment categories for Ethiopian Buildings are Economic Aspects, Energy Efficiency, Water Efficiency, Location and Transport, Sustainable Sites and Ecology, Indoor Environmental Quality, Resources and Materials, and Management). Under each of these assessment categories, there are assessment criteria. These are Economic Aspects composed of ten (10) criteria; Energy Efficiency has eight (8) criteria; Water Efficiency consists of seven (7) criteria; Location and

Transportation composed of seven (7) criteria; Sustainable Sites and Ecology has eight (8) criteria; Indoor Environmental Quality has fourteen (14) assessment criteria; Materials and Resources has seven (7) assessment criteria; and Management category has six (6) assessment criteria.

Materials and resources (18.66%), sustainable sites and ecology (16.92%), energy efficiency (16.78%), indoor environmental quality (12.60%), economic aspects (10.41%), management (10.30%), water efficiency (8.06%), and location and transportation (6.27%) are the most considered categories from a quantitative perspective.

The proposed allocated points and awards for the assessed buildings were ≤20 points: Certificate with Yet to be Green (Bronze) Rank; 20<X≤40 points: Certificate with Emerging Green (Silver) Rank; 40<X≤59 points: Certificate with Green (Gold) Rank; 60<X≤79 points: Certificate with Sustainably Green (Platinum) Rank; and ≥80 points: Certificate with Extremely Green (Diamond) Rank. The newly developed evaluation technique for Ethiopia is the Ethiopian-Sustainable Building Assessment Tool (Ethio-SBAT). Because it is based on the most relevant and applicable assessment tools used internationally, the climatic and socio-cultural conditions, and the consensus-based conclusions of famous professionals in Ethiopia's building sectors, the proposed technique is considered effective and feasible.

5.2. Recommendation

- Building materials must go through rigorous testing and evaluation from a green building perspective to receive the required grade and to be locally available.
- Manufacturers of construction materials should work together to develop green product tools and supply the information required to make life cycle assessment and inventory tools uniform and unbiased.
- It is extremely important to develop stringent laws and create an institution to grant awards based on the evaluation results of the SBAT because Ethiopia does not have any types of green building assessment tools to give certification for those buildings that fulfill the required requirements.

- Focusing on local natural resources like water, renewable energy sources (solar, hydropower, wind turbines), and various types of building materials like grasses, wood, mud, etc. should be of utmost importance.
- Encourage the manufacturing of environment-friendly products, technologies, and materials, such as high-performance lighting, HVAC systems, electrical high-efficiency energy systems, composite water fixtures, electrical appliances, green cleaning products, and recycled products, and lower import taxes to make them accessible to both consumers and businesses. This is important because as these products become more widely available; their costs will gradually drop, encouraging Small and Micro Enterprises (SMEs) and consumers to adopt them.
- Encourage the development and use of green technology, as well as their incorporation into the design process.
- To combat the lack of knowledge about sustainable building benefits and the issue of future resources (energy, water, materials) scarcity, raise public and construction industry understanding of the advantages of sustainable/green construction.
- Even though there are legal frameworks for building construction, such as the Ethiopian Building Codes and Standards (EBCSs), the Building Proclamation (Proclamation No. 624/2009), the Buildings Regulation No. 243/2011, the Construction Industry Policy (Policy No. 2006), and others, their implementation must be assessed about this newly developed Ethio-SBAT and the institution to be established must carry its responsibility accordingly in this respect.
- To determine which of these initiatives is working the best, provide guidelines for local officials to implement sustainable building regulations, legislation, executive actions, and appropriate incentives.
- Raising awareness among investors and developers of sustainable/green building's financial and economic advantages.
- Architects, engineers, designers, planners, and other key stakeholders in the sustainable/green building design process will benefit from seminars and lectures to increase awareness.

- Incorporate sustainable/green building education in the curriculum for engineering faculties, especially for mechanical, electrical, civil, and architectural disciplines.
- A significant objective should be to address strategies and goals for affordability and sustainability.
- To address the shortage of qualified and certified sustainable/green building engineers, offer training programs.
- Countries can benefit from one another's ideas and research, and they ought to incorporate expert work into their deliberations.
- The recommended suggestions for establishing the Ethio-SBAT are: developing such an evaluation technique should be depending upon scientific examination plus the capabilities of experts; experts (Architects, Designers, Planners, Engineers, and Construction Managers) ought to partake in establishing an evaluation technique because it calls for a participatory and cooperative process; and the consideration of international codes and guidelines plus triple bottom lines of sustainability must be incorporated.

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Annexes

Annex 1:

Subject:-<u>Request for cooperation</u>

Dear Participant

This questionnaire is designed to develop sustainable building assessment tool for Ethiopia in the case of Addis Ababa.

Your experience and educational background in the construction industry will greatly contribute to the success of my PhD dissertation and I believe this kind of study will be an input for the development of Ethiopian construction industry. Your response for each questionnaire is highly valuable and contributory to the outcome of the study. So, I am kindly requesting you to respond each and every question.

Thank you,

Mekonnen Abebe

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The Research Instruments: Multiple Evidences

Attachment 1: Questionnaire Survey

NB: - If there are any queries about all or parts or a part of this survey, you are welcome for clarification which is highly appreciable and is very vital to the reliability and validity of the research design.

Research problem

"Developing Sustainable Building Assessment Tool for Ethiopia, in the case of Addis Ababa"

Relevance of the research

To develop sustainable building assessment tool suitable for our scenario for evaluation and certification of the buildings.

Confidentiality

All information provided in this survey will be treated with strict confidentiality and allowed to serve only for the purpose of the research under consideration.

Feedback and Results

Interested participants of this study will be given feedback on the overall research results after the completion of the research work and are also accessible in the institution's library.

Part I: Personal details

1. Name of respondent (optional): ______________________________
2. Date: ______________________________
3. Profession: ________________________________
4. Name of company / organization (optional): ___________________________________
5. Title or Position(s) of respondent: ______________________________________
6. Type of organization / company:

☐ Employer ☐ Consultant ☐ Regulatory Authority ☐ Contractor ☐ Financier

☐ Reputed Practitioner ☐ Beneficiary ☐ Professional institution ☐Others

7. Rate the following proposed sustainable building assessment criteria used for the evaluation and certification of buildings

(5 = Strongly Agree (SA), 4 = Agree (A), 3 = Neutral (N), 2 = Disagree (D), 1 = Strongly Disagree (SD))

S/No.	Assessment Criteria	Yes	No	Ratings					If your rate is less than 3, please give your justification
				5	**4**	**3**	**2**	**1**	
	1. Economic Aspects								
1.1	Building's affordability concerning the distance of facilities of Transportation								
1.2	Building's affordability concerning the distance of the workplace								
1.3	Building's affordability concerning the distance of getting Health services								
1.4	Building's affordability concerning the distance of getting Education Services								
1.5	Building's affordability concerning the distance of getting Shops/market places								
1.6	Building's affordability concerning rental for residential								
1.7	Costs of operation and maintenance								
1.8	Cost for building life cycle								
1.9	Investment risk								
1.10	Construction cost								
	2. Energy Efficiency								
2.1	Utilizing a monitoring /management system								
2.2	Energy for internal lighting								
2.3	Energy for external lighting								
2.4	Use of energy-efficient equipment								
2.5	utilizing Renewable Energy								
2.6	Use of Hot Water /Steam								
2.7	HVAC Systems								
2.8	Energy savings								
	3. Water Efficiency								

3.1.	Water consumption								
3.2.	Regular water leak detection and monitoring								
3.3.	Employing rain Water Harvesting								
3.4	Utilizing water fixtures as well as equipment								
3.5	Regular water Usage Monitoring								
3.6	Recycling of wastewater								
3.7	Recharge of groundwater								
4. Location and Transportation									
4.1	Availability of alternative modes of transportations (Buses, Taxi, Bicycle, Pedestrian/Foot, Light Rail Transport (LRT))								
4.2	Provision of the car parking area and parking capacity								
4.3	Community/Local Connectivity								
4.4.	Density Development location								
4.5.	Sensitive land protection								
4.6.	Surrounding density and diverse uses								
4.7.	Accessibility to public transportation								
5. Ecology and Sustainable Sites (ES)									
5.1.	Site selection and protection								
5.2.	Reuse of Land								
5.3.	Ecological/Land Value								
5.4.	Reclaimed Contaminated Land								
5.5.	Enhance site Ecology								
5.6.	Use of local /indigenous plants/flora								
5.7.	Protecting or Restoring Open Space								
5.8.	Existence of open space, green area, playground area, plus civic place								
6. Interior Environmental Quality (IEQ)									
6.1	Noise level								
6.2	Sound insulation								
6.3	Sound absorption								
6.4	Thermal comfort concerning Cooling control and comfort								
6.5	Thermal comfort concerning Heating control and comfort								
6.6	Thermal comfort concerning								

	Humidity control and comfort								
6.7	Lighting & Illumination concerning Lighting Controllability								
6.8	Lighting & Illumination concerning View out								
6.9	Lighting & Illumination concerning Glare measure and control								
6.10	Interior Air Quality								
6.11	Visual Comfort								
6.12	Existence of natural ventilation								
6.13	Availability of Ventilation system								
6.14	Air purification- supply of fresh air								
7. Resources and Materials (RM)									
7.1.	Utilize low environmental impact materials								
7.2.	Use of non-renewable-virgin materials								
7.3.	Reuse of structural frame materials								
7.4.	Use of locally available materials								
7.5.	Use of recycled materials								
7.6.	Use of finishing materials								
7.7.	Material efficiency over its life cycle								
8. Management (MAN)									
8.1.	Facility Management								
8.2.	Commissioning								
8.3.	Consultation								
8.4.	The construction process for the overall administration								
8.5.	Waste Management during construction and operation								
8.6.	Security								

If others, please specify and rate them accordingly

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Annex 2

Guidelines for Observation and Key Informant Discussions

This interview is designed to Assessing the Affordability of the Existing "40/60" Condominium Buildings and Developing Sustainable Building Assessment Tool (SBAT) for Ethiopia, the Case of Addis Ababa.

Your experience and educational background in the construction industry will greatly contribute to the success of my PhD dissertation and I believe this kind of study will be an input for the development of Ethiopian construction industry. Your response for each interview is highly valuable and contributory to the outcome of the study. So, I am kindly requesting you to respond each and every question.

Thank you for your time.

Mekonnen Abebe

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1. The existing building construction management practices and challenges.
2. The application of sustainability concepts (environmental, social and economic) in building construction industry.
3. The affordability of the condominium building (40/60).
4. The existence of legal frameworks that support construction of sustainable buildings.
5. The roles of the stakeholders in the building construction process to have sustainable buildings.
6. The mechanisms of addressing the sustainable and affordable "40/60" condominium building projects for the beneficiaries.
7. The way forward for sustainable buildings construction practices in Ethiopia.