DURBAN UNIVERSITY OF TECHNOLOGY

# DEVELOPING A SUSTAINABILITY ASSESSMENT FRAMEWORK FOR BUILDINGS IN UGANDA

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# DEVELOPING A SUSTAINABILITY ASSESSMENT FRAMEWORK FOR BUILDINGS IN UGANDA

Submitted in fulfilment of the requirements of the degree of Doctor of Philosophy of Management Sciences specializing in Business Administration in the Faculty of Management Sciences at Durban University of Technology

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## Abstract

Sustainability aims to fulfill the current generation's needs without jeopardizing the quality of life for future generations. This is primarily achieved through saving the environment, enhancing society, and prospering the economy; hence, developing a construction sustainability assessment framework for buildings in Uganda will help to streamline the construction industry towards achieving environmental, social, and economic sustainability. The purpose of this research was to develop a Uganda Building Sustainability Assessment Framework (UBSAF). The rationale is based on the fact that sustainability assessment of buildings has acquired new momentum in recent years. Currently, the Building Research Establishment Environmental Assessment Method (BREEAM) in the United Kingdom (UK), LEED Green Building Rating System in the US), and the Green Star Assessment Method (GSAM) in Australia (AU) are being used as best practices globally. However, these methods have been criticized for their unsuitability and inability to consider country and regional contexts, such as global variations in climate, geographical differences, etc., which need consideration. Therefore, this study was intended to address this challenge by developing a building assessment framework specifically for buildings in Uganda. Triangulation research method was used to collect relevant data for the study. A systematic literature search and review was conducted on the available literature, and various sustainability assessment indicators were established under the environmental, social, and economic aspects. Forty-nine (49) sustainability assessment indicators were obtained from the literature and the pilot study done by industry experts. Delph technique was used to obtain primary data from an expert group of 30 construction industry experts, including structural engineers, urban planners, environmentalists, architects, quantity surveyors, mechanical engineers, and academicians. A three-round questionnaire was administered to construction industry experts to ascertain the importance of the various sustainability indicators in the construction industry in Uganda, with the overall objective of achieving consistency in the construction industry experts' opinions about the various sustainability indicators. The contribution of this research will be developing a sustainability assessment framework for buildings in Uganda. Several statistical measures like weighted mean score, standard deviation, Cronbach's alpha reliability test, a Shapiro-Wilk test of normality, Kendall's concordance test, Chi-square test, and inter-rater agreement (IRA), were used to analyze the various sustainability indicators and discussions. Consistency was achieved after Delphi round three; hence, the various sustainability indicators relevant to the construction industry were attained. These indicators include but are not limited to land use, access to social, domestic, and socio-economic facilities, building form and orientation, daylighting and viewing comfort, building total lifecycle costs, access to public transport, parking capacity, annual operating costs, natural ventilation, and affordability. The relative weights of the sub-criteria (indicators) were determined using the CRiteria Importance Through Intercriteria Correlation (CRITIC) method, a Multi-Criteria Decision Analysis (MCDA) technique. This method measures the correlation between different criteria and helps to determine their relative weights. The study used the Normalized Weighted Mean Score (NWMS) to evaluate the sustainability of construction projects in Uganda. This is a commonly used sustainability study technique that aggregates the scores of different sub-criteria to provide an overall score for sustainability. To test the proposed framework's practicality, the study applied it to three case studies, including one completed and two ongoing construction projects. The framework's applicability was determined by consulting with experts, and the results indicated that it could be widely used in different projects to assess their sustainability. The proposed framework will enable contractors and developers to evaluate sustainability in new construction. In addition, the framework promotes corporate social responsibility, which can enhance the quality and standards of the construction industry.


**Key words**: Sustainability Framework, Delphi, MCDA, CRITIC, NWMS, IRA, UBSAF

## Declaration

This work has not previously been presented in any form to the University or to any other body of knowledge except otherwise where portions of the work were specifically excerpted for the sole purposes of peer-review assessment and publication. Apart from the express acknowledgment of references and/or bibliographies cited in the work, I confirm that the intellectual content of the work is the result of my own efforts and not of other persons.

Signature:

Date: January 2024

## Dedication

This research is dedicated to God Supreme- the One whose inevitable divine grace knows no bound.

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First and foremost, I am especially indebted to my supervisors: Professor Sibusiso Moyo, Dr. Samuel Chikafalimani and Dr. Nathan Kibwami for their seemingly endless patience throughout this study. Their encouragements, dedication, commitment, insightful and constructive contributions to this study will always be appreciated and remembered. I am very grateful for their contributions.

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Thank you all! No words can say enough.

## List of Acronyms

| | |
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| **BOD** | Benefit of the Doubt |
| **BRE** | Building Research Establishment |
| **BREEAM** | Building Research Establishment Environmental Assessment Method |
| **CA EPBD** | Concerted Action Energy Performance of Buildings Directive |
| **CASBEE** | Comprehensive Assessment System for Built Environment Efficiency |
| **CEM** | Construction Engineering and Management |
| **CEM** | Construction Engineering and Management |
| **CIB** | International Council for Building |
| **CRITIC** | CRiteria Importance Through Intercriteria Correlation |
| **DCLG** | Department of Communities and Local Government |
| **GBC** | Green Building Council |
| **GBRS** | Green Building Rating Systems |
| **GDP** | Gross Domestic Product |
| **IETC** | International Environmental Technology Centre |
| **IRA** | Inter-Rater Agreement (IRA). |
| **KIP** | Kampung Improvement Programme |
| **LEED** | Leadership in Energy and Environmental Design |
| **MCDA** | Multi-Criteria Decision Analysis |
| **OECD** | Organization of Economic Co-operation and Development |
| **PA** | Factor Analysis |
| **PCA** | Principal Components Analysis |
| **SI** | Sustainability Weighting |
| **SLR** | Systematic Literature Review |
| **UBOS** | Uganda Bureau of Statistics |
| **UBSAF** | Uganda Building Sustainability Assessment Framework |
| **UNDP** | United Nations Development Program |
| **UNEP** | United Nations Environment Program |

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# CHAPTER ONE: THE PROBLEM AND ITS SETTING

## 1.1 Introduction

This chapter provides the essential background information for the study, which will help contextualize the research and justify the importance of the research problem. This chapter includes: background of the study, research problem, objectives of the study, research questions, justification for focusing on the research area, theory to support the relevance of the research focus area, and the scope of the study.

## 1.2 Background of the study

The construction industry now widely recognizes the concept of sustainability due to its negative impact on the economy and natural environment (Son *et al.* 2011: 337). Sustainability assessment evaluates if man's activities and resource use affect long-term sustainability (Forbes, 2008: 28). According to Pope, Annandale, and Morrison-Saunders (2004: 596), sustainability assessment is used to evaluate the impacts of policies, plans, and projects to ascertain the extent to which they affect sustainable development. ‘Sustainability’ originates from the Latin word *sustinere*, which means 'maintain,' 'support,' or 'endure' (Dimian, Bildea and Kiss 2014: 679).

According to Yılmaz and Bakış (2015: 3) and Bragança *et al.* (2010a: 1) sustainability means using natural resources in such a way that they do not reach a point of decay, depletion, or becoming unrenewable and passing them on to future generations through development. In this context, sustainability appears to be an overarching concept applied across a wide range of fields, from global development policy to energy source usage and from production planning to architectural design (Vehbi, Hoskara and Hoskara 2010: 26). This agrees with Brundtland’s report (Imperatives 1987: 1), where sustainability was seen as "Ensuring that our actions today do not jeopardize the ability of the future generations to meet their own need."

Furthermore, research by Bragança, Mateus and Koukkari (2010: 2) postulated that a building project can be considered sustainable only when all the various aspects of sustainability (environmental, economic, social, and cultural) are addressed. The interaction of a building with its surroundings is meaningful due to the interwoven sustainability issues. Environmental issues share, in common, concerns that involve reducing the use of non-renewable materials and water and reducing emissions, wastes, and pollutants (Bragança *et al.* 2010: 2).

Additionally, sustainability assessments gather and report information for decision-making during different phases of building construction, design, and use (Akhanova *et al.* 2019: 6). More importantly, Property developers, advised by local public authorities, increasingly undertake sustainability assessments before development and thereafter may make subsequent assessments to consider the design and management of each phase of a building's life cycle, including its demolition and disposal as waste (Akhanova *et al.* 2019: 9). For such reasons, the sustainability assessment tools used in building construction have received much attention. However, assessing building sustainability  is not straightforward (Bragança *et al.* 2010: 2).

Incorporating sustainability into construction activities is an important aspect of building design. To promote building sustainability, building practitioners can use sustainability assessment systems, which provide reference methods for setting design priorities and goals and quantifying environmental performance. By using assessment tools, building practitioners can ensure that their designs prioritize sustainability and contribute to a more sustainable future (Akhanova *et al.* 2019: 6) (Akhanova et al., 2019: 6). In addition, assessment tools are used to evaluate performance measures and collect information that guides sustainable design and helps decision-making processes (Cole 2005: 460; Ali and Al Nsairat 2009a: 1053).

Assessment tools serve the purpose of improving the functionality of buildings, reducing their environmental impact, estimating their environmental influence, and objectively assessing and evaluating their development (Luangcharoenrat and Intrachooto 2018: 4). Sustainability indicators form the basis of the assessment and help the sustainability rating tools to assess the performance of a building. Fowler and Rauch (2006: 9) define the sustainability rating tools as "tools that analyze a building's overall performance and provide a means of comparing it with other buildings." The most prominent sustainability rating tools include BREEAM, LEED, and CASBEE.

Sustainability assessment is of great importance, especially in developing countries like Uganda; through its focus on eco-friendly practices, it plays a role in conserving natural resources, safeguarding the biosphere, minimization of waste production, economically improves economic growth, reduces energy consumption and costs, minimization of environmental damage costs, and socially; improves quality of life for all, alleviate poverty, satisfy human needs, promotes harmony between humanity and nature (Assylbekov *et al.*, 2021: 2; Zarghami and Fatourehchi, 2020: 1).

Globally, the building industry began recognizing the impact of its activities on sustainability development in the 1990s (Haapio and Viitaniemi, 2008: 469). The common concerns are that buildings have contributed to environmental degradation, reduction and depletion of non-renewable materials and water, and production of emissions, waste, and pollutants (Bragança *et al.*, 2010: 2). This study partially intends to support international and local efforts in protecting the environment by developing a sustainability assessment framework of buildings in Uganda so that good buildings that are friendly to the environment, economically viable, and socio-culturally acceptable to the country are constructed for the benefit of future generations. It is envisaged that this framework, even though developed for the Ugandan context, will form a basis for similar frameworks that take into account country contexts to be developed for other African countries.

As people become more aware of the impact of modern development practices on the environment and as the global trend towards constructing high-performance and sustainable buildings gains momentum, the building industry is rapidly evolving. Kibert (2016a: 42) states that alterations in both the construction process and the built environment are impacted by such changes. This newly emerging approach differs from established practice in the following important ways: Promoting collaboration between project team members and stakeholders, focusing on identifying individuals with eco-efficient building expertise, greater focus on global building performance than on building systems, a strong emphasis on environmental protection for the whole life-cycle of a building; careful consideration of worker health and occupant health and comfort throughout all phases; scrutiny of all decisions for their resource and life-cycle implications; the added requirement of building commissioning, and a real emphasis on reducing construction and demolition waste (Islam *et al.* 2019: 3) .

The concept of sustainability has been categorized in the environmental, social, and economic dimensions namely, triple bottom line or TBL (United Nations 2005). The environmental dimension indicates minimizing the environmental impacts over the life cycle of a building (Berardi 2013: 6). The economic dimension implies the affordability to support the direct and indirect costs of a building without neglecting other essential needs (Son *et al.*, 2011: 5). However, this requisite depends on the context and people and recalls the time uncertainty of economic sustainability. In fact, a change in what an economically sustainable choice in buildings is possible according to economic cycles and market developments. A sustainable building should deliver economic value over time, taking into account future life-cycle costs of operation, maintenance, refurbishment, and disposal (Brundtland 2005: 150).

Sustainable development is characterized as an advancement that allows an improvement in the quality of life while also ensuring the safety and health of the human and non-human inhabitants (Kibert, 2007: 2). It also heightens the present and future generations' social, economic, and environmental aspects (Ortiz *et al.* 2009: 29; Atanda, 2019: 3). Furthermore, Vollenbroek (2002: 1) described it as a harmony between accessible technologies, development procedures, and governments' approaches. Fricker (1998: 2) defines it as the aspect of life that encompasses non-material aspects, such as our emotional, impulsive, inventive, and spiritual selves. It requires us to engage all our ways of learning, including insight, intuition, as well as knowledge, and skills, to be effective in achieving it. Sustainable development was described as a dynamic state of equilibrium that can be attained by balancing long-term environmental, social, economic, and social health (Dempsey *et al.* 2011: 4; Atanda 2019: 3).

A building system consists of different stages, where the users are at the bottom of the hierarchy; they live with the consequences and decisions of the planners, architects, engineers, and consultants (Atanda 2019: 3). In most cases, people affected by the designs are never involved in the decision-making or planning of the design.

**1.3 Research Problem**

Countries where sustainability has been incorporated in their construction industries have enjoyed a reduction in environmental footprint, long-term financial benefits, improved public health, and a preservation of resources for future generations.

There is no sustainability assessment framework for buildings in Uganda, making it difficult for relevant authorities to assess buildings and proposed building projects to determine if they meet sustainability requirements, namely environmental, economic, and socio-cultural factors. Resulting from this problem, the following sub-problems have been experienced in Uganda:

a. Lack of laws regarding the aspects of sustainable assessment in construction, particularly social and economic indicators.
b. Other than the Environmental Impact Assessment (EIA) and a building permit from the National Environment Management Authority (NEMA), Kampala Capital City Authority (KCCA), and other regulatory bodies, the issues of economic and social assessments are not catered for.
c. Environmental degradation is rampant as buildings have cropped up in many wetland areas as a result of the lack of a one-package set of laws comprising environmental, social, and economic aspects.

This study will develop a sustainability assessment framework for buildings in Uganda, which will assist in solving the sub-problems stated above.

## 1.4 Aim of the study

The main aim of this study is to develop a suitable and acceptable sustainability assessment framework for buildings in Uganda, which will satisfy local Ugandan conditions and stakeholders environmentally, economically, and socio-culturally in the future.

### 1.4.1 Research objectives

i. To identify sustainability assessment indicators for the assessment of buildings in Uganda.
ii. To assess the relevance of building sustainability assessment indicators in Uganda's building industry.
iii. To determine the building sustainability assessment criteria for benchmarking the performance of buildings in Uganda.
iv. To develop the building sustainability assessment framework in Uganda.

## 1.5 Research questions

i. What are the appropriate sustainability assessment criteria for buildings in Uganda?
ii. What is the relevance of building sustainability assessment indicators under each sustainability assessment criterion in Uganda?
iii. What are the acceptable building sustainability assessment indices for benchmarking the performance of buildings to be developed in Uganda?
iv. What can be done to assess sustainability of buildings in Uganda?

## 1.6 Justification for this research study

Owners and investors who undertake building projects typically have several goals in mind. These include maximizing the potential of the site, safeguarding the identity and culture of the surrounding region, reducing energy consumption, and preserving and conserving water resources. The use of building materials that are friendly to the environment, provision of a healthy and convenient indoor climate, and optimization of operational and building maintenance practices are also additional building project agendas that building owners and investors seek to achieve (Gomes *et al.* 2008: 72).

To achieve these goals and build sustainability, various methods of sustainability assessment of building performance are used worldwide, including BREEAM in the UK, LEED in the USA, and GSAM in AU. However, these methods have been criticized for not being effective in assessing building sustainability in other countries due to large differences in climate, economic, and socio-cultural factors. Based on this criticism, the justification for this study is that it will assist in the development of a locally acceptable and effective sustainability assessment framework for buildings in Uganda that meets local environmental, economic, and socio-cultural requirements. This will be accomplished by carrying out a thorough local building industry survey to collect important information that will be used to design a suitable sustainability assessment framework for Uganda.

## 1.7 Research motivation

The motivation behind this research stems from the pressing need to address the lack of a sustainability assessment framework for buildings in Uganda. The absence of such a framework has led to various detrimental outcomes, including environmental degradation, unchecked urban development in ecologically sensitive areas, and the lack of comprehensive assessments of building projects with regard to their long-term sustainability. The motivation also arises from the recognition that sustainable construction practices have far-reaching benefits, encompassing environmental, economic, and socio-cultural aspects. By incorporating sustainability into the construction industry, Uganda can reduce its environmental footprint, ensure long-term financial benefits, improve public health, and preserve resources for future generations. Therefore, the research is motivated by the potential to bring about positive and sustainable change within the construction industry and the broader societal and environmental context.

Furthermore, the lack of laws concerning sustainable assessment in construction, particularly social and economic indicators, has highlighted the urgency of developing a comprehensive sustainability assessment framework. By addressing this gap, the research is motivated to contribute to the establishment of a regulatory and assessment framework that considers not only environmental impacts but also social and economic factors, thereby striving for a more holistic approach to sustainable development in the construction sector. The motivating factors for this research also include the desire to accommodate local Ugandan conditions and stakeholder needs. Recognizing that sustainability must be contextually relevant and acceptable within the local setting, the research aims to develop a framework that aligns with the specific social, economic, and environmental circumstances in Uganda, thereby ensuring its practicality and effectiveness in addressing the unique challenges and opportunities within the country.

## 1.8 Theory to support significance of the study

Systems theory, one of the most essential theories in management science, supports the significance of this study. With its holistic approach, this theory emphasizes that all parts (subsystems) of a system must work together for the system to achieve its goals (Von Bertalanffy 1968: 23). Similarly, in this study, an effective and locally acceptable framework for the sustainability assessment of buildings will be achieved if all relevant stakeholders in the construction industry in Uganda interact and work closely in the development of the framework. These stakeholders in the building industry in Uganda include relevant non-governmental organizations (NGOs), the government, local authorities, building owners, building professionals, and practitioners.

## 1.9 The scope of the study

### 1.9.1 Contextual scope

Contextually, the study focused on developing a sustainability framework for buildings in Uganda.

### 1.9.2 Scope of study area

The study was conducted in Kampala, Uganda, in the administrative divisions where the various building projects have been done. Uganda is a landlocked country located in East Africa. Its official name is the Republic of Uganda, and it covers an area of approximately 241,038 square kilometers (UBOS 2021a: 1). The country is bordered by South Sudan to the north, Kenya to the east, Tanzania and Rwanda to the south, and the Democratic Republic of the Congo to the west (UBOS 2021b: 1). The country's diverse landscape is characterized by savannas, forests, and mountains (UBOS 2021b: 3). The country is divided into four main regions: Northern, Eastern, Central, and Western (UBOS 2021b: 1). Each region has its own distinct culture and traditions.

Uganda has a population of approximately 44 million people, making it the 32nd most populous country in the world (UBOS 2021a: 14). The official languages are English and Swahili, although there are over 40 different languages spoken throughout the country (USAID 2020: 4). The majority of the population is Christian, with a significant Muslim minority (UBOS 2016: 19). Uganda is known for its diverse wildlife, including gorillas, chimpanzees, elephants, lions, and various species of birds (UBOS 2021a: 224). The country is home to 10 national parks and several other protected areas, which attract tourists from all over the world (UBOS 2021a: 224). Uganda's economy is largely based on agriculture, with coffee being the country's main export. Other important industries include tourism, manufacturing, and mining (UBOS 2021b: 105).

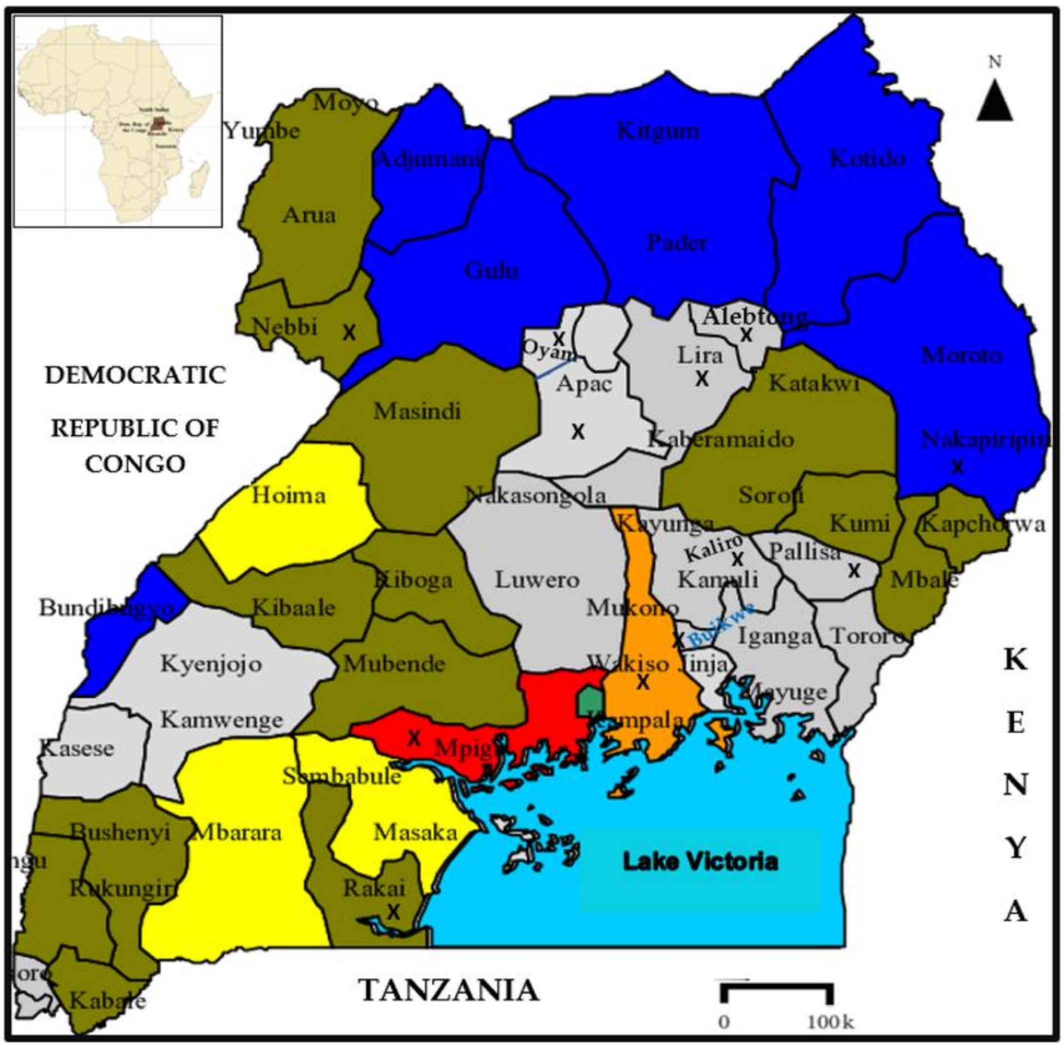



Figure 1.1: Map of Uganda showing the location of districts

# CHAPTER TWO: LITERATURE REVIEW

## 2.1 Introduction

In this chapter, the definition and, therefore, interpretation of sustainable construction is explored. The various drivers for sustainable construction are also presented.

## 2.2 Sustainable construction

Kibert recognized the emergence of sustainable construction during the first international conference on the topic held in Tampa, Florida, United States of America in 1994 (Shen, Ou and Feng 2005: 5). According to Hill and Bowen (1997a: 225), sustainable construction is defined as a the process of developing and maintaining a healthy built environment that focuses on resource efficiency and ecological design. However, the most commonly cited definition of sustainable development according (Brundtland 2005: 32) is: "development that fulfills the present needs while ensuring the ability of future generations to meet their own needs. Furthermore, since sustainable construction is related to sustainable development, sustainable construction practices should address the pillars of sustainability.

Edum-Fotwe and Price (2009: 314) added that there are three components to sustainability, i.e., Environmental, economic, and social, often referred to as the triple bottom line approach and that for sustainable development to be effectively attained, all these three aspects must be addressed appropriately. Other commenters arguably suggest that sustainable construction should be viewed as the construction industry's responsibility toward sustainability (Bourdeau 1999: 224; Hill and Bowen 1997: 354). According to Mavi *et al.* (2021: p.3), sustainable construction should be viewed as a subset of sustainable development, which means that the construction industry can play a role in achieving sustainable development through sustainable construction practices (Brundtland 2005: 5). Based on these definitions, Brundtland interpreted sustainable construction as the application of the principles of sustainable development to construction.

From the Venn diagram in Figure 2.1, achieving sustainable development requires the intersection of sustainability's economic, environmental, and social pillars. The concept of sustainability comprises three pillars: environmental, economic, and social. The environmental pillar focuses on minimizing the adverse impact of human activities on the environment, while the economic pillar aims to maintain high economic growth without compromising human necessities ( Fortune 2015: 122; Gan et.al 2015: 62; Majdalani, Ajam and Mezher 2006a: 34).

On the other hand, the social pillar is about fulfilling the legal, moral, and ethical obligations in the society where an activity takes place, as explained by Adetunji et.al (2003: p.185–187). As such, the three pillars of sustainability ought to be optimized to promote sustainable construction in line with the principles of sustainable development.

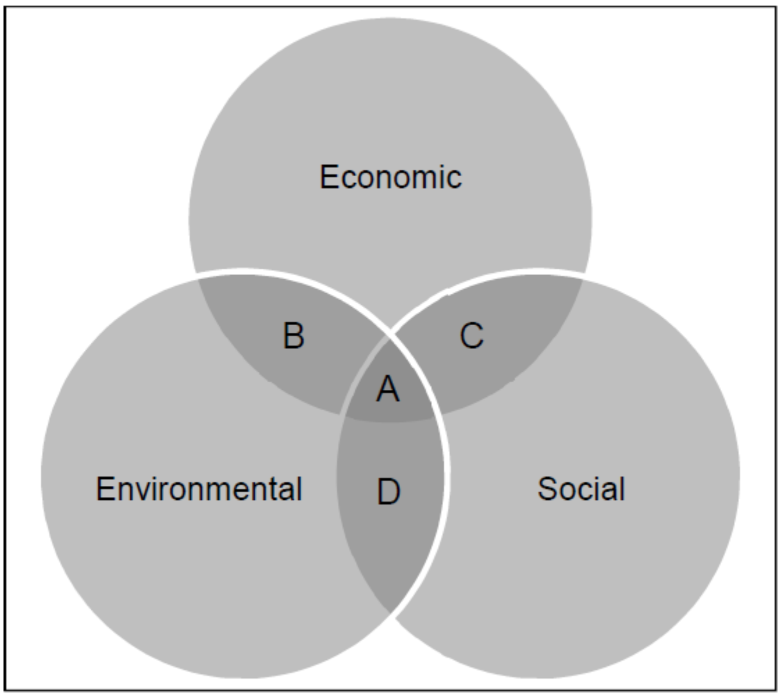



**Figure 2.1: The three pillars of sustainability**

A is Sustainable development (3rd order sustainability); B, C, and D are 2nd orders of sustainability (Edum-Fotwe and Price 2009b: 314), with reference to Figure 1, sustainable construction can be interpreted to manifest in several states. In a nutshell, consideration of one pillar only, two pillars only, and all three pillars relates to first-order, second-order, and third-order states of sustainable construction, respectively. In the construction industry, sustainable construction has hitherto been interpreted mainly in terms of the first and second-order states of sustainability that relate to 'environmental' and 'environmental and economic' pillars, respectively (Zainu2010: 422-423; Majdalani et al. 2006a: 34-34; Bourdeau 1999a: 354). As such, environmental and economic sustainability pillars have hitherto been optimized at the expense of the social sustainability pillar (Edum-Fotwe and Price 2009b: 314-315; and Shen et al. 2005: 4-5). This is negated by the fact that social sustainability is often the least understood among the 3 (three) pillars of sustainability and, consequently, usually the least considered (Lehtonen 2004: 207-208). Therefore, one of the challenges in promoting sustainable construction is the making of strategies that can facilitate optimizing the three pillars of sustainability to progress towards achieving the often elusive third-order state of sustainability.

### 2.2.1 Construction in Uganda

The construction industry is of significant importance to Uganda's economic development. According to UBOS (2013: 48–49), construction activities contribute 14% to Gross Domestic Product (GDP), while construction-related businesses employ the largest number of people per business (UBOS 2012a: 50). Construction activities, which cover the public and private sectors, predominantly involve the construction of roads, bridges, and buildings (UBOS 2013: 48–49). Building construction is a major activity that involves the construction of residential, commercial, industrial, and institutional structures (Wang, Hao and Shi 2023: 95; UBOS 2014b: 51). This implies that the building sector accounts for a significant proportion of all construction activities. There is a persistent increase in residential and commercial construction activities within the building sector. As illustrated in Figure 2, data on building plans approved by the various local authorities suggest that commercial buildings are only second to residential buildings. An increase in building construction activities is envisaged due to the need for the provision of the necessary infrastructure, such as shopping centers, office spaces, schools, and hospitals requisite for meeting the demands of the ever-increasing population (Leles Da Silva *et al.* 2024: 2; Bragança, Mateus and Koukkari 2010a: 2; Crawley and Aho 1999a: 303). However, the increase in building construction presents several challenges.

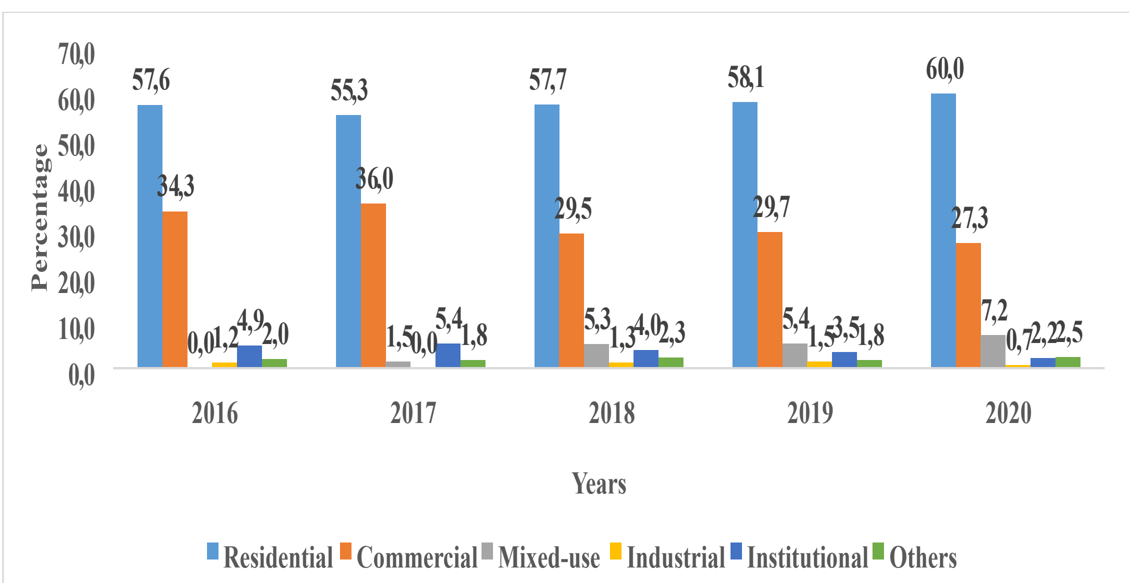



Figure 2.2: Building plans in Uganda approved from 2016 to 2020

Source: UBOS (2021: 50) based on a sample of 25 municipalities and 60 town Councils across Uganda.

As a developing country, Uganda grapples with addressing environmental problems without undermining economic development. Stefania (2012: 57–58) revealed that most technologies utilized are highly energy-intensive, inefficient, and resulted in elevated pollution levels. Additionally, Kibwami and Tutesigensi (2016a: 65) stated that Uganda's prevalent low level of industrialization implies that construction activities are highly labor intensive, largely involve unskilled labor, and use primitive construction methods. Alinaitwe, Mwakali and Hansson (2007: 70) found that the average embodied energy consumed to make bricks in Uganda is over five times higher than that in developed countries. Moreover, Kibwami and Tutesigensi (2016: 65–67) highlight that the assessment of energy or embodied carbon associated with the construction of buildings is not considered in the prevailing environmental impact assessment practices. Although assistance was provided to governments at national and local levels to review and revise building laws and standards, with the aim of promoting low-carbon practices (*State of the world`s cities* 2013: 93), there is scanty knowledge on how such initiatives will amplify sustainable construction. More so, the effects of construction activities on the environment are severe, mainly due to unsustainable material production processes (Stefania 2012: 57). Therefore, strategies must be developed to enhance sustainable construction practices in Uganda.

### 2.2.2 Challenges and opportunities

Embracing sustainable construction in developing countries like Uganda is by no means an easy call, not to mention that the concept of sustainability is relatively new in such countries (CIB and UNEP-IETC 2002: 54). Developing countries face multiple stresses from factors such as extreme poverty, housing shortages, and poor governance, which often lead to conflicting interests when deciding what needs to be done to address such stresses without compromising sustainable development (Du Plessis 2007: 1–2). The report 'Agenda 21 for Sustainable Construction in Developing Countries' identifies the primary obstacles to the implementation of sustainable construction practices in such regions. These include a lack of capacity within the construction industry, an unpredictable economic landscape, limited availability of accurate data, a lack of interest in sustainability issues, and a dearth of research into sustainable practices. This report was jointly published by the International Council for Research (ICR) and Innovation in Building, Construction (CIB), United Nations Environment Programme (UNEP), and International Environmental Technology Centre (IETC) (UNEP-IETC) in 2002.

Despite the challenges, there is growing advocacy to promote sustainable construction practices in developing countries. The underdevelopment in these countries allows them to avoid some of the mistakes the developed countries made and, therefore, tread a more sustainable path to development(CIB and UNEP-IETC 2002: 69). Unlike in the developed world, where maximization of sustainable construction opportunities is limited by the fact that most buildings operating in decades to come are already built (Maqbool, Arul and Ashfaq 2023: 3; Radulescu, Radulescu and Boncea 2023: 4), in developing countries like Uganda, what is being constructed now should be "sustainable in every sense of the word" (Plessis 2005: 4).

### 2.2.3 Sustainability and the construction industry

The construction industry has a long history of developing and using indicators alongside many general efforts to develop sustainable development indicators (Cui *et al.* 2021: 3). According to research conducted by Jin *et al.* (2023: 5), the construction industry is considered to have a pivotal role in the attainment of sustainable development. This is because the industry's activities have been reported to have more significant impacts on the environment, society, and economy than other industries, as stated in a study by Wang and Hao (2023: 7).

The construction industry plays an important role in sustainable development by protecting the environment, fostering economic growth, and promoting social progress (Graeber 2015: 7). The industry in question has been identified as having issues with regards to inefficient use of resources, producing high levels of waste, and low levels of productivity. These factors have been documented in various studies, including Castro, Mateus and Bragança (2017: 50) and Khoury (2019: 167–168). The construction industry has been under scrutiny due to its negative outcome on the natural environment. As a response to this challenge, there is a global call for the widespread adoption of sustainable practices in construction (Fortune 2013: 122–123). Sustainable construction is regarded as a part of sustainable development, and it is perceived as the industry's contribution to achieving sustainability goals (Kibert 2013: 134–134).

#### 2.2.3.1 Environmental sustainability

In regards to Environmental sustainability, there have been many contributors to the indicators; among them are  (Ali and Al Nsairat, 2009a; AlWaer *et al.* 2008; Bakhoum and Brown, 2012; Chen *et al.,* 2012; Larimian *et al.* 2013; Shen *et al.* 2017; Shen *et al.* 2011; Ugwu and Haupt, 2007). The developed indicators mainly focus on main categories such as site and land use, energy efficiency, water efficiency, materials, indoor environment quality, waste management, and pollution issues.

#### 2.2.3.2 Economic sustainability

Regarding the economic sustainability indicators, lifecycle cost is an indicator addressed by many researchers and is considered the main measure of this dimension. However, effects on the local economy and development (Ocampo and Estanislao 2014: 123; Clements-Croome 2010: 7), supply and demand side (Alaloul *et al.* 2022: 3; Ocampo and Estanislao 2014: 124), productivity and performance (Ocampo and Estanislao 2014: 125; Tang 2003: 3), profitability (Clements-Croome 2010: 4), and employment (Alaloul *et al.* 2022: 8; Ocampo and Estanislao 2014: 127; Clements-Croome 2010: 4; Tang 2003: 3) are among economic indicators that are considered in the literature.

#### 2.2.3.3 Social sustainability

According to Gates and Lee (2005: 5) it is clear that social sustainability comprises three components, i.e., basic needs, individual or human capacity, and social or community capacity. Littig and Griessler (2005: 15) indicated that social sustainability is intended to satisfy human needs and to fulfill social justice, human dignity and engagement. According to Zuo, Jin and Flynn (2012: 50–51) and Farzanehrafat, Akbarnezhad and Ghoddousi (2015: 1–2), equity is a critical component of social sustainability. The social impacts as the social and cultural consequences on society in various aspects from both short-term and long-term perspectives were highlighted in Misopoulos, Manthou and Michaelides (2019: 34).

Scholars observe social sustainability in several dimensions. Bamgbade, *et al.* (2022: 741) discusses social sustainability through democracy and equity. Afzal, Lim and Prasad (2017: 203) describe it as a longtime relationship between nature and society. Meanwhile, Karji, Woldesenbet and Khanzadi (2017: 762) portray it as a movement that occurs while adjusting the advancement of civil society and the improvement bringing about a rich environment. Sharif (2023: 2) highlighted certain features that hinder urban development and the social aspect of sustainable development:

- (i) Provision of infrastructure that creates opportunities for social interaction.
- (ii) Availability of job opportunities with the working area serving as a place for social interaction.
- (iii) Accessibility to available infrastructure and residences with convenient traveling times.
- (iv) The aesthetics used to design the townscapes should encourage communal social interaction.
- (v) Local features preservation for generations to come.
- (vi) Aptitude to accomplish psychological necessities.

### 2.2.4 Benefits of sustainability in construction

The momentum of the sustainable construction movement is rising as the environmental impact of building activities becomes more evident and significant (Okoye, Odesola and Okolie 2021: 64). Sustainable construction leads to more substantial benefits and profitable rewards, as shown in Figure 2.3 below.

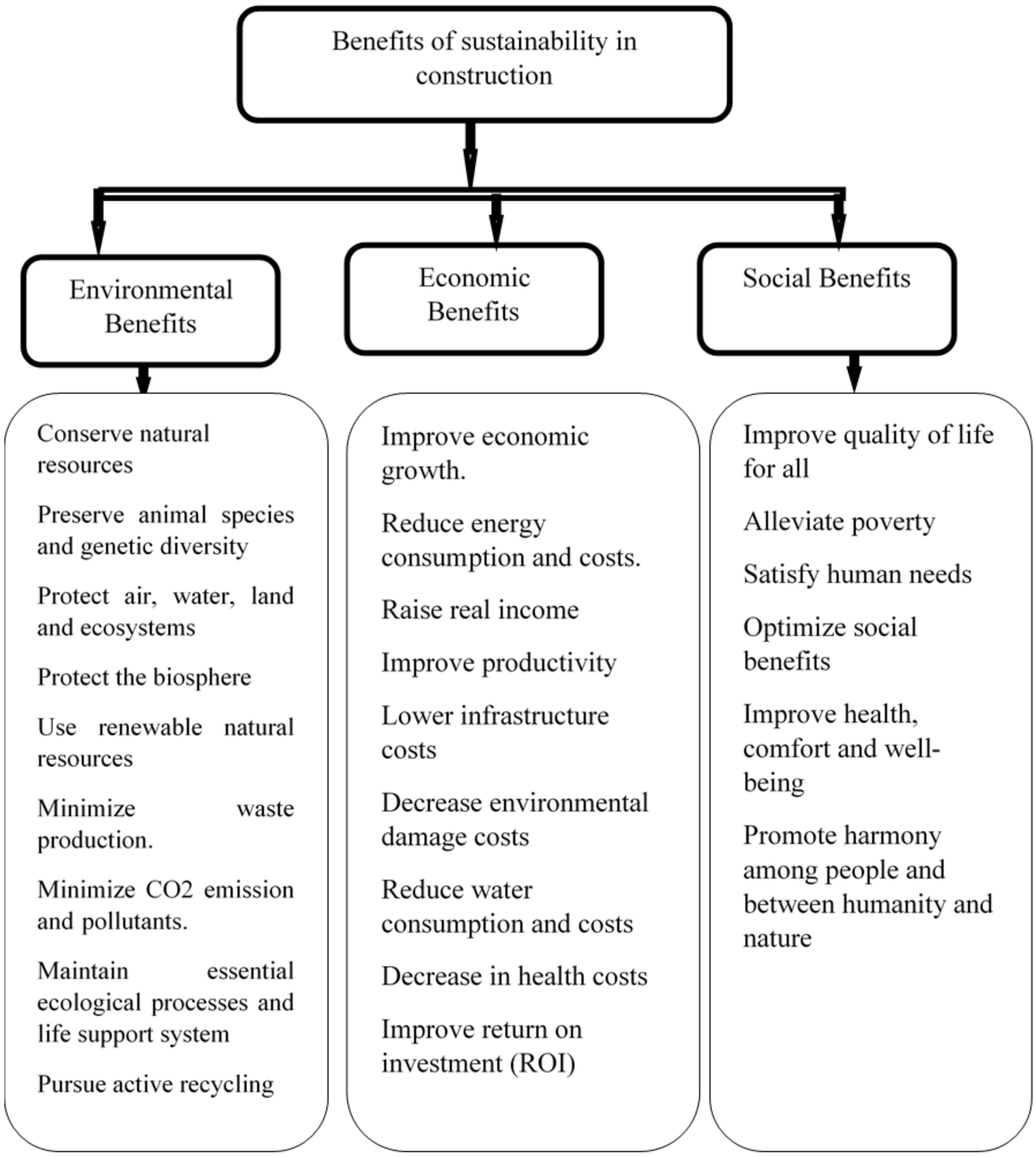



**Figure 2.3: The benefits of sustainability in construction**

## 2.3 Building sustainability rating systems (BSRSs)

Research by Marchi, Antonini and Politi (2021: 998–999) highlighted that building sustainability rating systems are a comprehensive strategy by the construction sector, private consultancy organizations, and international administrations to evaluate and confirm the greenness and sustainability of buildings. Additionally, according to Berardi (2015: 4), building sustainability rating systems generally differ according to the characteristics, cultural variations, climatic conditions, and geographical and possible energy resources of the designated country/region.

According to research by Arafat *et al.* (2023: 446–447); Babu, Lamano and Pawar (2017: 752); Politi and Antonini (2017: 42–43); and Berardi (2015: 3), building sustainability rating systems have been increasingly considered a critical baseline in the expansion of green buildings, as they can assist owners of the building in benchmarking, decision-making, and documentation to fulfill sustainable rules and regulations. Furthermore, Arafat *et al.* (2023: 447) elaborated that BSRSs evaluate a building's greenness by focusing on a set of criteria with fixed points organized in pre-defined groups and that the level of sustainability of construction is assigned by calculating the total score of criteria and sub-criteria of the selected BSRS based on the specific scope and context. In a nutshell, Okoye *et al.* (2021: 64) point out that many BSRSs have been introduced to assess the sustainability of buildings worldwide. The vast majority specifically fit the construction sector requirements of the place where they are developed. Such building sustainability rating tools include but are not limited to the BREEAM of the U.K., LEED of the USA, "CASBEE" of Japan, and "GBI" of Malaysia (Braulio-Gonzalo, Jorge-Ortiz and Bovea 2022: 1–2; Abdel-Basset *et al.* 2021: 2–3; Abu Bakar and Cheen 2013: 485; Fauzi and Malek 2013: 1–2) generally, as pointed out by Marchi *et al.* (2021: 1000) each certification tool has different characteristics and sustainability categories according to the local context of each nation.

### 2.3.1 Building Research Establishment's Environmental Assessment Method (BREEAM)

BREEAM is seen as the first green building rating assessment in the world launched and operated by BRE (Building Research Establishment) in the U.K. (Desivyana *et al.* 2023: 1753; Labaran *et al.* 2022: 1–2). It was introduced to the market in 1990 and was first revised to assess offices in 1993 (O'Malley *et al.* 2014: 211). It is widely accepted that almost all major sustainability framework, such as LEED, Green Star, and CASBEE, are under the influence of BREEAM (Figure 2.4).

BREEAM is widely used owing to its flexibility. It assesses local codes and conditions and allows application in international buildings (Saka *et al.* 2024: 2). In addition, BREEAM enables evaluation of a building's lifecycle in view to design, build, operation, and refurbishment; BRE provides new construction, in-use, refurbishment, and fit-out, communities, and infrastructure manuals for planners, local authorities, developers, and investors. As a result, BREEAM has so far issued over 560,000 certifications (Freitas and Zhang 2018: 403). This number is anticipated to follow its increasing pattern (from 250,000 buildings in 2014 (Izvekova, Roy and Murgul 2016: 1807) to 425,000 buildings in 2015 (Rajabi, El-Sayegh and Romdhane 2022: 1–2) and 540,00 buildings in 2016 *(Nesteby et* *al.* 2016: 101). A similar incremental pattern applied to the number of countries adopting BREEAM since 1990 (50 countries in 2014 (Wong, et al. 2024: 2), 70 countries in 2016 (Jerzak 2017: 53), and over 75 countries in 2017 (Maqbool, Arul and Ashfaq 2023b: 2).

BREEAM certifications account for 80% of the European market share for sustainable building certifications (Dsilva, Zarmukhambetova and Locke 2023: 2). Although BREEAM could assess all of the sustainability pillars, the environmental factor is still predominant with eight main categories: *Management, Energy, Transport, Water, Materials, Waste, Land use and impacts on ecology and Ecology,* and *pollution*.

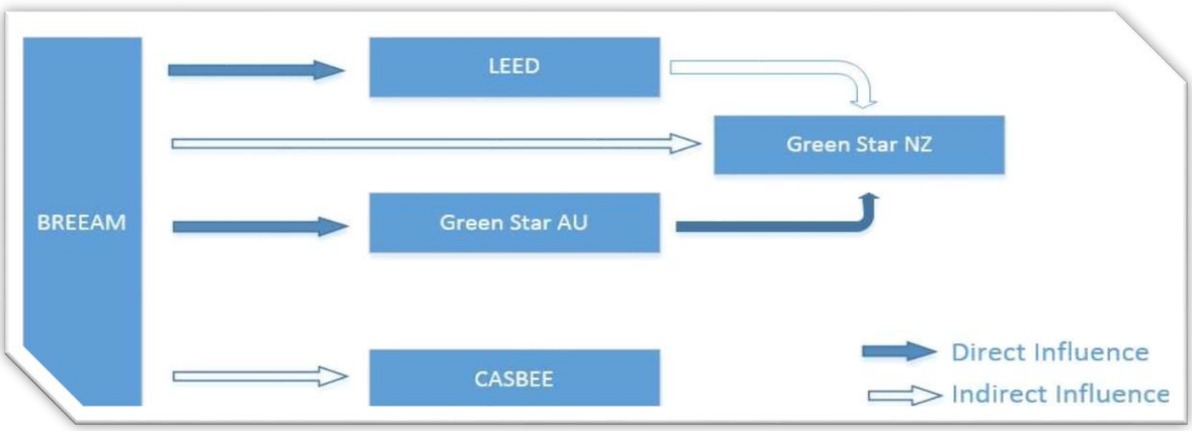
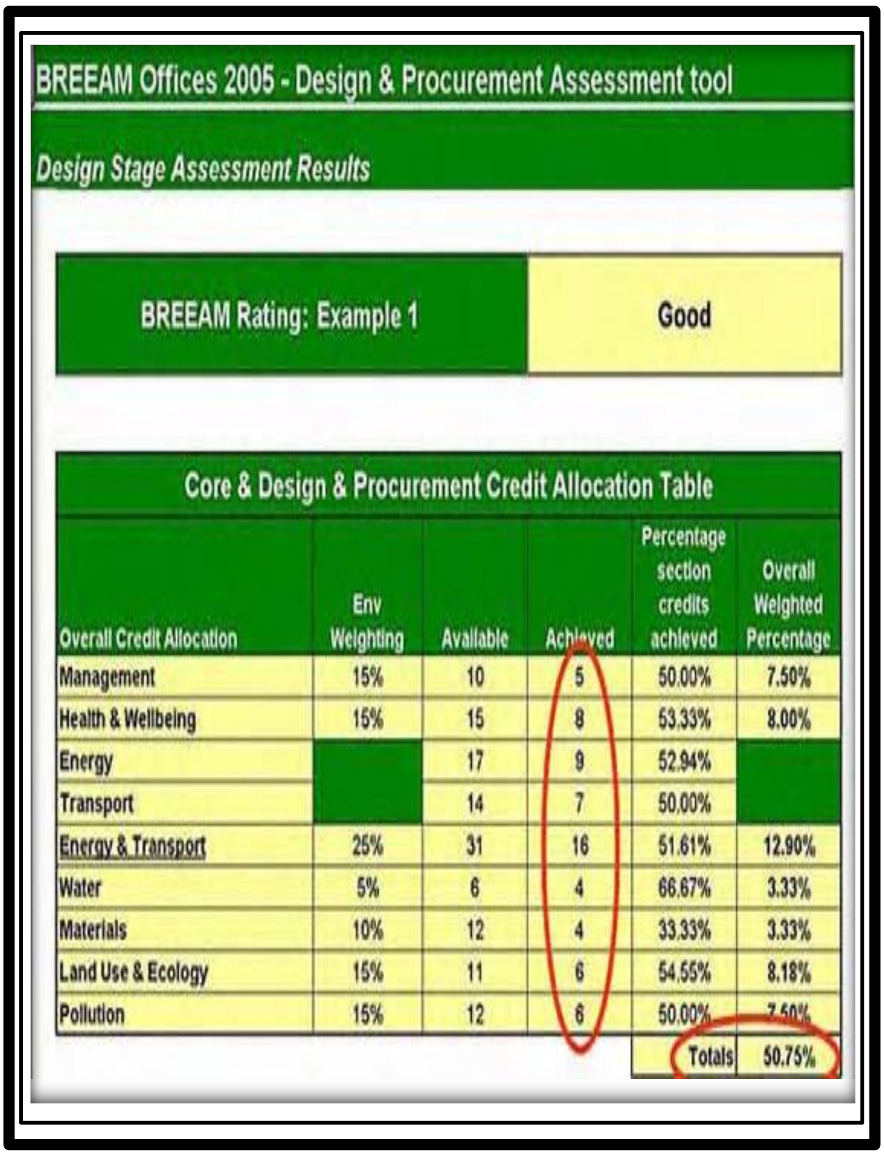



**Figure 2.4: The relationship among sustainability rating systems**

***Source:*** Nesteby *et al*. (2016)

BREEAM is a system that evaluates various building types, such as offices, homes, industrial units, retail units, and schools. The assessment process involves awarding points for each criterion, which are then added up to calculate a total score. The scoring system is based on the number of credits achieved for each category, the available credits, and the weighting factor.

The building is then assigned one of the Unclassified (<30%), Pass (30%), Good (45%), Very Good (55%), Excellent (70%), and Outstanding (85%) categories and a certificate granted, which can be helpful for profile-raising purposes (Ali and Al Nsairat 2009b: 22); (Zarghami *et al.* 2018: 14). Figure 2.4 shows sample reporting and certification pages for a BREEAM. The findings of an investigation are integrated into the stage of building design development, leading to modifications that fulfill pre-established criteria (Crawley and Aho 1999b: 3-4); (Kibert 2008: 9). The BREEAM rating tool is widely acknowledged as helpful for improving a project's sustainability and gaining sustainability credentials by corporations and developers. However, one of its drawbacks is that it requires a considerable investment of capital. Furthermore, the tool's energy performance assessment employs the U.K. Building Regulation as a benchmark to rate performance improvement, which may not be suitable for regions that have different assessment structures.



BREEAM Offices 2005 - Design & Procurement Assessment tool

Design Stage Assessment Results

| BREEAM Rating: Example 1 | Good |
| --- | --- |

Core & Design & Procurement Credit Allocation Table

| Overall Credit Allocation | Env Weighting | Available | Achieved | Percentage section credits achieved | Overall Weighted Percentage |
| --- | --- | --- | --- | --- | --- |
| Management | 15% | 10 | 5 | 50.00% | 7.50% |
| Health & Wellbeing | 15% | 15 | 8 | 53.33% | 8.00% |
| Energy | | 17 | 9 | 52.94% | |
| Transport | | 14 | 7 | 50.00% | |
| Energy & Transport | 25% | 31 | 16 | 51.61% | 12.90% |
| Water | 5% | 6 | 4 | 66.67% | 3.33% |
| Materials | 10% | 12 | 4 | 33.33% | 3.33% |
| Land Use & Ecology | 15% | 11 | 6 | 54.55% | 8.18% |
| Pollution | 15% | 12 | 6 | 50.00% | 7.50% |
| | | | | Totals | 50.75% |

**Figure 2.5: The sample reporting and certification for BREEAM**
**Source: (USDOE, 2009)**

### 2.3.2 **Leadership in Energy and Environment Design (LEED)**

Since its development, LEED has been continuously combined, modified, and nationally personalized by professionals in the U.S. construction sector. The LEED Building Assessment System is a performance-based tool used to determine the environmental impact of building products and facilities from a whole-building perspective (Yamany, Afifi and Hassan 2016: 595). It was

LEED 2009 for New Construction and Major Renovations
Project Checklist

Project Name
Date

| Y | ? | N | | | |
|---|---|---|---|---|---|
| 0 | 0 | 0 | | **Sustainable Sites** | Possible Points: 26 |
| Y | | | Prereq 1 | Construction Activity Pollution Prevention | |
| | | | Credit 1 | Site Selection | 1 |
| | | | Credit 2 | Development Density and Community Connectivity | 5 |
| | | | Credit 3 | Brownfield Redevelopment | 1 |
| | | | Credit 4.1 | Alternative Transportation–Public Transportation Access | 6 |
| | | | Credit 4.2 | Alternative Transportation–Bicycle Storage and Changing Rooms | 1 |
| | | | Credit 4.3 | Alternative Transportation–Low-Emitting and Fuel-Efficient Vehicles | 3 |
| | | | Credit 4.4 | Alternative Transportation–Parking Capacity | 2 |
| | | | Credit 5.1 | Site Development–Protect or Restore Habitat | 1 |
| | | | Credit 5.2 | Site Development–Maximize Open Space | 1 |
| | | | Credit 6.1 | Stormwater Design–Quantity Control | 1 |
| | | | Credit 6.2 | Stormwater Design–Quality Control | 1 |
| | | | Credit 7.1 | Heat Island Effect–Non-roof | 1 |
| | | | Credit 7.2 | Heat Island Effect–Roof | 1 |
| | | | Credit 8 | Light Pollution Reduction | 1 |
| 0 | 0 | 0 | | **Water Efficiency** | Possible Points: 10 |
| Y | | | Prereq 1 | Water Use Reduction–20% Reduction | |
| | | | Credit 1 | Water Efficient Landscaping | 2 to 4 |
| | | | Credit 2 | Innovative Wastewater Technologies | 2 |
| | | | Credit 3 | Water Use Reduction | 2 to 4 |
| 0 | 0 | 0 | | **Energy and Atmosphere** | Possible Points: 35 |
| Y | | | Prereq 1 | Fundamental Commissioning of Building Energy Systems | |
| Y | | | Prereq 2 | Minimum Energy Performance | 0 |
| Y | | | Prereq 3 | Fundamental Refrigerant Management | |
| | | | Credit 1 | Optimize Energy Performance | 1 to 19 |
| | | | Credit 2 | On-Site Renewable Energy | 1 to 7 |
| | | | Credit 3 | Enhanced Commissioning | 2 |
| | | | Credit 4 | Enhanced Refrigerant Management | 2 |
| | | | Credit 5 | Measurement and Verification | 3 |
| | | | Credit 6 | Green Power | 2 |
| 0 | 0 | 0 | | **Materials and Resources** | Possible Points: 14 |
| Y | | | Prereq 1 | Storage and Collection of Recyclables | 0 |
| | | | Credit 1.1 | Building Reuse–Maintain Existing Walls, Floors, and Roof | 1 to 3 |
| | | | Credit 1.2 | Building Reuse–Maintain 50% of Interior Non-Structural Elements | 1 |
| | | | Credit 2 | Construction Waste Management | 1 to 2 |
| | | | Credit 3 | Materials Reuse | 1 to 2 |

| Y | ? | N | | | |
|---|---|---|---|---|---|
| | | | | **Materials and Resources, Continued** | |
| | | | Credit 4 | Recycled Content | 1 to 2 |
| | | | Credit 5 | Regional Materials | 1 to 2 |
| | | | Credit 6 | Rapidly Renewable Materials | 1 |
| | | | Credit 7 | Certified Wood | 1 |
| 0 | 0 | 0 | | **Indoor Environmental Quality** | Possible Points: 15 |
| Y | | | Prereq 1 | Minimum Indoor Air Quality Performance | 0 |
| Y | | | Prereq 2 | Environmental Tobacco Smoke (ETS) Control | 0 |
| | | | Credit 1 | Outdoor Air Delivery Monitoring | 1 |
| | | | Credit 2 | Increased Ventilation | 1 |
| | | | Credit 3.1 | Construction IAQ Management Plan–During Construction | 1 |
| | | | Credit 3.2 | Construction IAQ Management Plan–Before Occupancy | 1 |
| | | | Credit 4.1 | Low-Emitting Materials–Adhesives and Sealants | 1 |
| | | | Credit 4.2 | Low-Emitting Materials–Paints and Coatings | 1 |
| | | | Credit 4.3 | Low-Emitting Materials–Flooring Systems | 1 |
| | | | Credit 4.4 | Low-Emitting Materials–Composite Wood and Agrifiber Products | 1 |
| | | | Credit 5 | Indoor Chemical and Pollutant Source Control | 1 |
| | | | Credit 6.1 | Controllability of Systems–Lighting | 1 |
| | | | Credit 6.2 | Controllability of Systems–Thermal Comfort | 1 |
| | | | Credit 7.1 | Thermal Comfort–Design | 1 |
| | | | Credit 7.2 | Thermal Comfort–Verification | 1 |
| | | | Credit 8.1 | Daylight and Views–Daylight | 1 |
| | | | Credit 8.2 | Daylight and Views–Views | 1 |
| 0 | 0 | 0 | | **Innovation and Design Process** | Possible Points: 6 |
| | | | Credit 1.1 | Innovation in Design: Specific Title | 1 |
| | | | Credit 1.2 | Innovation in Design: Specific Title | 1 |
| | | | Credit 1.3 | Innovation in Design: Specific Title | 1 |
| | | | Credit 1.4 | Innovation in Design: Specific Title | 1 |
| | | | Credit 1.5 | Innovation in Design: Specific Title | 1 |
| | | | Credit 2 | LEED Accredited Professional | 1 |
| 0 | 0 | 0 | | **Regional Priority Credits** | Possible Points: 4 |
| | | | Credit 1.1 | Regional Priority: Specific Credit | 1 |
| | | | Credit 1.2 | Regional Priority: Specific Credit | 1 |
| | | | Credit 1.3 | Regional Priority: Specific Credit | 1 |
| | | | Credit 1.4 | Regional Priority: Specific Credit | 1 |
| 0 | 0 | 0 | | **Total** | Possible Points: 110 |

Certified 40 to 49 points   Silver 50 to 59 points   Gold 60 to 79 points   Platinum 80 to 110

**Figure 2.6: Sample reporting and certification for LEED**

developed in the US in 1998 as a consensus-based building rating system based on existing building technology (Yamany *et al.* 2016: 595).

The Leadership in Energy and Environmental Design (LEED) is a rating system that evaluates the sustainable building practices for various types of construction projects, including commercial, institutional, and high-rise residential new constructions and major renovations (Gelowitz and McArthur 2016: 60; Komurlu, Gurgun and Arditi 2015: 1170-1171). It measures sustainability in five key areas: sustainable sites, water efficiency, energy and atmosphere, innovation and design process, materials and resources, and indoor environmental quality (Gelowitz and McArthur 2016: 60; Komurlu *et al.* 2015: 1170-1171). The LEED certification levels range from Certified (40-49 points) to Silver (50-59 points), Gold (60-79 points), and Platinum (80-110 points) (Pushkar 2023: 2; Worden et al. 2020: 4; Mazzola et al. 2017: 2–3; Gurgun et al. 2015: 3; Gurgun et al. 2016: 4; Ismail and Rashid 2014: 2). Figure 2.6 provides an example of LEED Version 2.0.

The LEED model has raised concerns due to its apparent focus on achieving environmental benefits without sufficient consideration for the durability of the products used. Unfortunately, the current LEED model fails to address emerging ecological requirements. With the popularity of the LEED concept and its disjointed rating system, building owners or designers may face confusion when attempting to apply it to billions of square feet of roofing projects.

#### 2.3.3 Comprehensive Assessment System for Building Environmental Efficiency (CASBEE)

CASBEE is a family of assessment tools that originated in Japan in 2001. The system is designed to evaluate a building's environmental efficiency throughout its entire life cycle, including pre-design, new construction, existing buildings, and renovation. Although the system is available in English, it is a relatively new tool developed specifically for the Japanese market and has not been widely tested in the United States.

Matching the life cycle of buildings, the CASBEE system includes four assessment tools. Unlike the other BSRSs, CASBEE is not based on assigning credits to each factor. It comprises groups in which the weights are calculated and displayed on a radar chart, with each credit point assessed according to a scale rating from 1 to 5. The assessment results are presented on a graph, where the environmental load and the quality of the building are represented on different axes (Huang *et al.* 2020: 565). The best buildings are the ones that fall in the section that has the lowest environmental load and the highest quality. Each indicator is rated on a scale of 1 to 5, with level 1 indicating that the minimum requirements are met, level 3 indicating the typical technical and social levels at the time of assessment, and level 5 indicating a high level of achievement. A visual representation of the rating scale is provided in Figure 2.7. CASBEE has performed as an excellent BSRS in improving green building practices in Japan (Ali and Al Nsairat 2009b: 7); (Shad, Khorrami and Ghaemi 2017: 25); (Zarghami *et al.* 2018: 7). The current system mandates the submission of measurable accomplishments in sustainable design, which are evaluated by certified architects who have successfully completed the CASBEE assessor assessment.

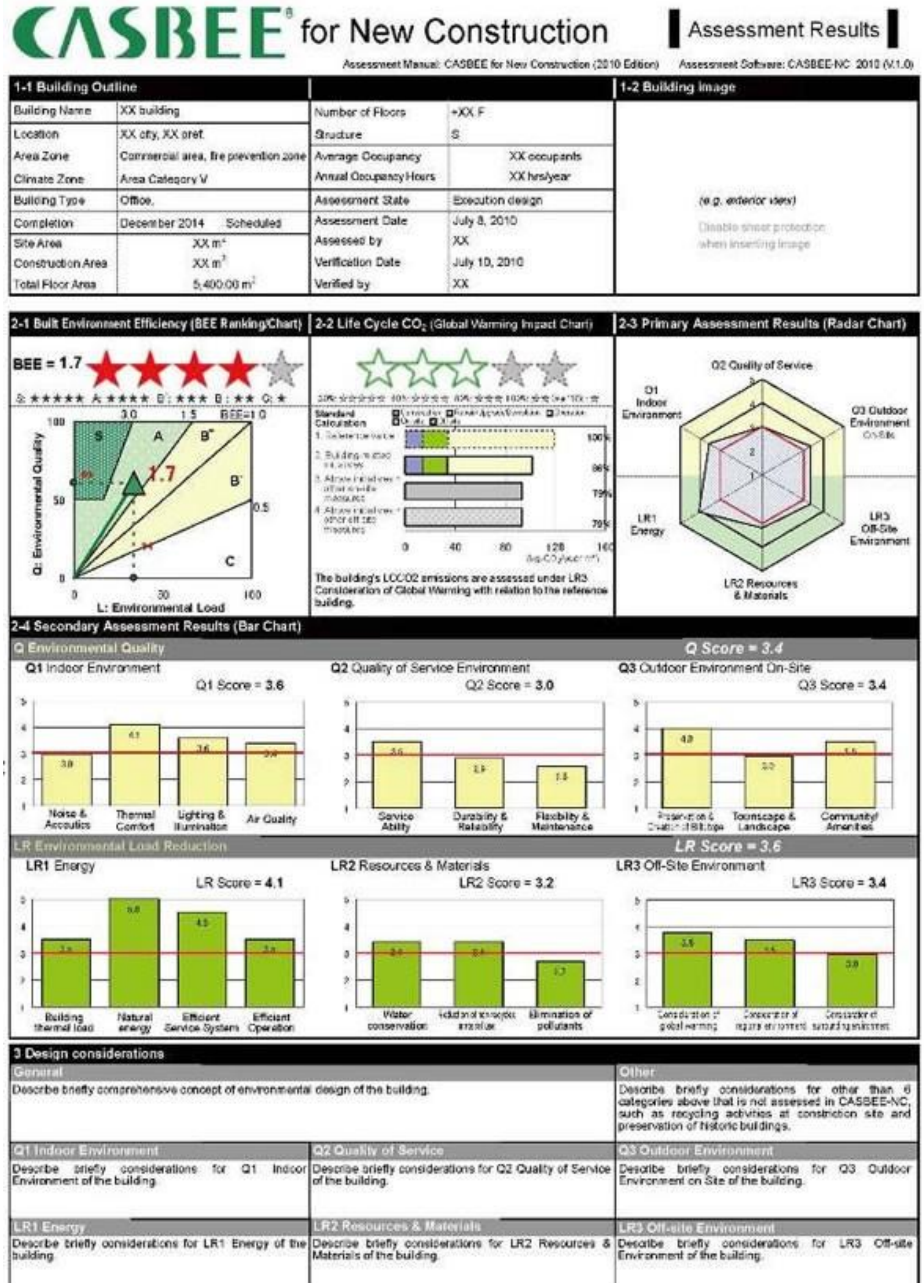



**Figure 2.7: Sample of CASBEE reporting sheet**

### 2.2.4 GREEN-STAR

Green Star is an assessment scheme in Australia that evaluates the environmental impact of buildings in hot climates where cooling systems and solar shading are crucial. The scheme was designed to be similar to BREEAM and uses a credit rating system to determine the level of certification based on the number of points allocated to credits (Anshebo, Mengesha and Sokido 2022: 2; Kissi, Abdulai Sadick and Agyemang 2018: 508; Park *et al.* 2015: 1306). The scheme has a set of criteria that assess management, indoor environmental quality, energy, transport, water, materials, land use, and impacts on ecology, emissions, and innovation. The certification of a building is represented by a star rating system. The rating ranges from 1 to 3 stars, which corresponds to a score of 10 to 44 points and is not eligible for formal certification. A 4-star rating, with a score of 45-59 points, is considered Best Practice and can achieve formal certification. A 5-star rating, with a score of 60-74 points, is Australian Excellence. The highest rating is 6 stars, with a score of 75 points, representing World Leadership (Dubey *et al.* 2023: 2).

The disadvantage of this tool is that its use is limited to the evaluation of lettable areas within office buildings, excluding areas that are not offices or supporting the office. Moreover, the assessment structure is delineated in Australian standards and may not apply to other regions with different socio-technical backgrounds and differing views on impact assessment. Figure 2.8 is a screenshot from the actual assessment tool.

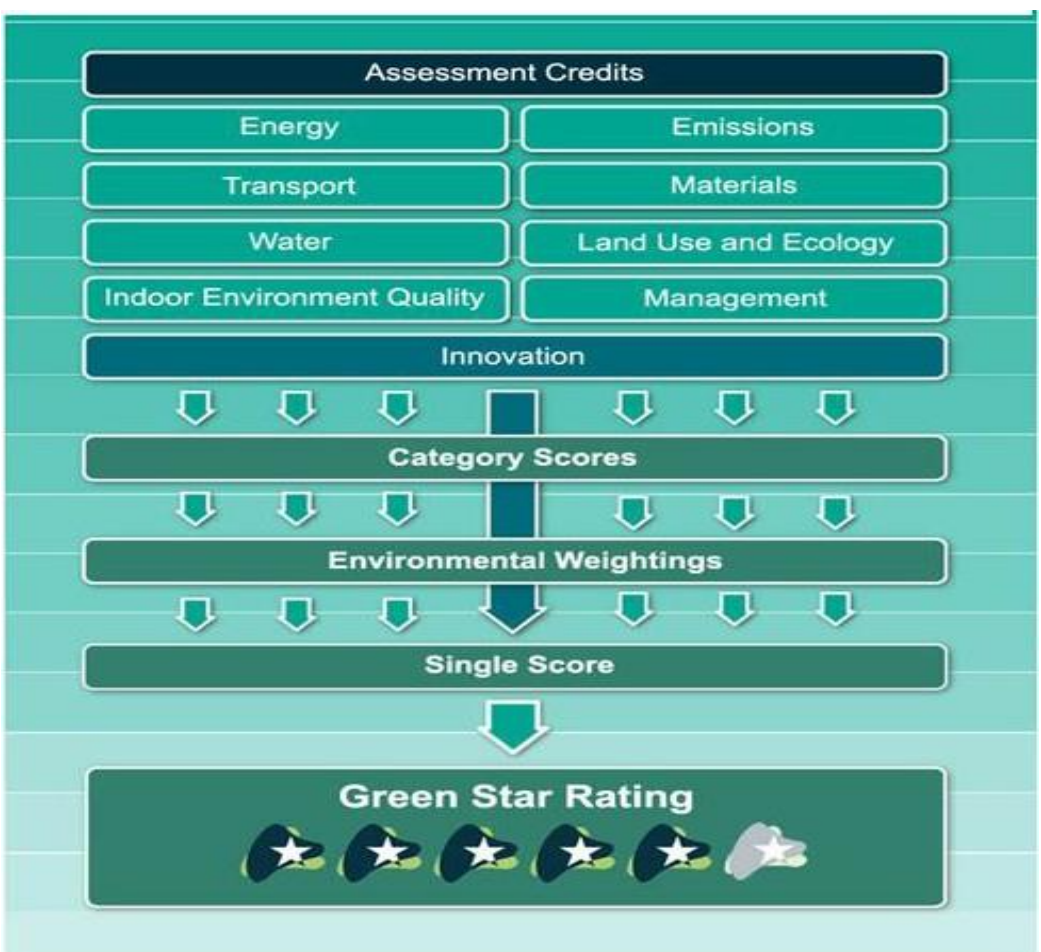



**Figure 2.8: A screen shot from the actual assessment tool**

#### 2.3.4.1 Green Star SA

The Green Star South Africa framework is a holistic and comprehensive rating system developed by the Green Building Council South Africa (GBCSA) to evaluate the sustainability performance of buildings and construction projects in South Africa (Agbajor & Mewomo 2024: 12). It provides a structured approach to assessing and certifying the environmental, economic, and social sustainability of buildings, with the aim of promoting sustainable design, construction, and operation practices within the South African built environment (Agbajor & Mewomo 2024: 12). The framework encompasses various categories and credits that address key sustainability considerations, including energy efficiency, water conservation, materials selection, indoor environmental quality, innovation, and the overall environmental impact of the building (Fatoki 2021: 12). By incorporating a wide range of criteria, the Green Star framework encourages a multifaceted approach to sustainability that goes beyond environmental considerations to include social and economic aspects as well.

The Green Star South Africa framework is designed to accommodate diverse building types, such as commercial buildings, residential developments, educational facilities, and industrial buildings, reflecting its adaptability and relevance across different sectors of the built environment (Agbajor & Mewomo 2024: 14; Fatoki 2021: 12). This flexibility allows the framework to be applied to a wide range of building projects, promoting sustainable practices and fostering a culture of environmental responsibility and conscious design and construction within the South African construction industry. Additionally, the framework also emphasizes the importance of stakeholder engagement and collaboration, encouraging the involvement of various parties, including designers, developers, building owners, and occupants, in the pursuit of sustainable building practices. This collaborative approach reflects the framework's recognition of the interconnectedness of sustainability and the need for collective efforts to drive positive change within the built environment.

The Green Star South Africa framework is related to other available rating tools and certification systems in the field of sustainable construction and building sustainability assessment (Söderström, Blake & Odendaal 2021: 23). It shares commonalities and differences with various international and regional rating systems, each contributing to the broader landscape of sustainability assessment in the built environment. One important aspect of its relatedness is its alignment with international sustainability rating systems such as LEED and BREEAM (Venter et al. 2022: 13). These international frameworks share common goals with the Green Star South Africa framework in promoting sustainable building practices, environmental responsibility, and improved building performance. While these systems may vary in specific criteria and rating methodologies, they collectively contribute to the global efforts to enhance the sustainability of buildings and construction projects.

At the regional level, the Green Star South Africa framework is closely related to other African sustainability rating tools and certification systems that aim to address sustainability challenges specific to the African context (Venter et al.

2022: 17). These regional frameworks often incorporate considerations for local environmental, social, and economic priorities, aligning with the contextual relevance and adaptability that characterize the Green Star South Africa framework. Furthermore, within South Africa, the Green Star framework is related to local building regulations, codes, and standards governing construction and design (Venter et al. 2022: 17). They complement and interact with each other, with the Green Star framework often striving to exceed the minimum requirements set by local regulations, thereby contributing to the advancement of sustainable practices beyond baseline compliance.

### 2.3.4 GBI

GBI was introduced by GBI Innovation Sdn Bhd in 2009 and is Malaysia's first complete evaluating system. It covers 14 specific versions based on different building types (residential, non-residential, industrial, data center, retail, hotel, resort, township). The main criteria of GBI are: "Energy Efficiency" (E.E.), "Indoor Environmental Quality (E.Q.)," "Sustainable Site Planning and Management (S.S.P.M.)," "Material and Resources (M.R.)," "Water Efficiency (WE)" and "Innovation (IN)." This GBI categorizes buildings as Platinum, Gold, Silver, and Certified classes (Jede et.al. 2020: 298). Table 2.2 shows the various building sustainability assessment tools available globally.

## 2.4 Overview of BREEAM, LEED, CASBEE, and GREEN STAR NZ

Non-profit third parties established BREEAM, LEED, and Green Star N.Z., while the government plays a dominant role in CASBEE besides the industry and academia. Due to the collaborations among various parties, CASBEE could receive feedback and consider them for future updates more frequently, precisely, and thoroughly. This could be why CASBEE is regarded as a leader in assessing comprehensive area development projects. This includes a group of buildings or a city with the release of *CASBEE Urban Development CASBEE City,* even though CASBEE was established after the leading global rating systems BREEAM and LEED a decade and half of a decade, respectively. Green Star N.Z. is the latest established rating system compared to BREEAM, LEED, and CASBEE. Consequently, though it could evaluate the majority of the whole life cycle of a project, operation stage assessment is still not covered (see Figure 2.9 above).

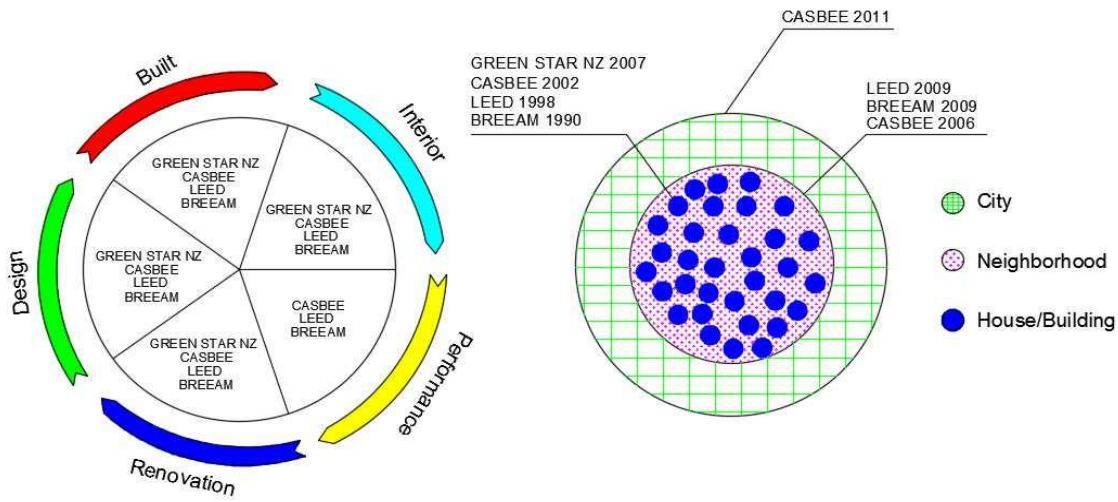



**Figure 2.9: An overview of building sustainability assessment rating tools**

The main features of BREEAM, LEED, CASBEE, and Green Star N.Z. are shown in Table 1. It is clear from this table that these four rating schemes just released their latest versions recently. Although the latest version of LEED was released four years ago, it has a new update in 2017. This proves that all rating systems are trying to revise and update their criteria more frequently to follow immediately with the rapid development of sustainable construction.

***Table 2.1:*** **An overview of *BREEAM, LEED, CASBEE, and Green Star NZ***

| | BREEAM | LEED | CASBEE | Green Star N.Z. |
|---|---|---|---|---|
| Country | U.K. | The U.S. | Japan | N.Z. |
| Organizations | BRE | USGBC | JSBC | NZGBC |
| Flexibility | 77 countries | 160 countries | 1 country | 1 country |
| First version | 1990 | 1998 | 2002 | 2007 |
| Latest version | 2016 | 2013 | 2015 | 2016 |

**Table 2.2: Globally known sustainability assessment tools**

| Sustainable building rating systems development basis | Country of origin | Continent |
|---|---|---|
| Breeam (Building Research Establishment's environmental assessment method) | UK | EUROPE |
| The German Sustainable Building Certificate (DGNBSeal) | Germany | |
| The haute qualite´ environnementale (HQE) | France | |
| Innovation and transparency of the contracts – protocol (Itaca) | Italy | |
| Promise | Finland | |
| Verde (and Breeam derivative) | Spain | |
| Breeam Netherlands | Netherlands | |
| Green Globes$^{TM}$ US | USA | America |
| Leed (leadership in environmental and energy design) | USA | |

| | | |
|---|---|---|
| Sustainable building challenge (SBC – formerly known as the 'green building challenge' (GBC)) | Canada | |
| Aqua/Leed Brazil (and Breeam derivative) | Brazil | |
| Consejo Mexicano de edificacio'n sustentable | Mexico | |
| Building environmental assessment method (HK-Beam) | Hong Kong | Asia |
| Green building rating system | South Korea | |
| Green mark and construction quality assessment system (Conquas) | Singapore | |
| Comprehensive assessment system for building environmental efficiency (Casbee) | Japan | |
| Estidama | United Arab Emirates | |
| GRIHA (green rating for integrated habitat assessment) and Leed India | India | |
| GB evaluation standard for green building | China | |
| Green Star S.A. | South Africa | Africa |
| The National Australian Built Environment Rating system | Australia | Australia |
| Green Star | Australia | |
| Green Star Z.N. | New Zealand | |

#### 2.4.1 Challenges of sustainability assessment

According to Ayarkwa *et al.* (2022a: 7), the lack of sustainability assessment practices in developing countries was due to several factors. Findings from (Ayarkwa *et al.* 2022b: p.7) and (Hawang and Tan 2012: 9) outlined higher costs of sustainable building processes and materials, construction process technicalities, long bureaucratic processes, unfamiliarity with sustainable technology, inadequate public education and awareness; and lack of sustainable product information as the major challenges to implementing and embracing sustainability practices in developing countries.

**Inadequate public education and awareness**

The study, according to Kibert (2016b: 15), discussed that the conventional notion of how a building must be constructed exists. However, he goes ahead to stress that due to perceived risks, many builders do not want to engage in sustainable construction. Interestingly, Akhanova *et al.* (2019: 4) highlighted that environmental auditing adoption, a beneficial sustainable building practice, is usually not done because of a lack of understanding. Research by Darko *et al.* (2018: 2) found that due to insufficient knowledge of sustainability studies, there is inadequate public education concerning the advantages of sustainability assessment of buildings. Ayarkwa *et al.* (2022: 3) postulated that this lack of awareness is a major challenge in adopting sustainability assessments.

**Construction process technicalities**

Constructing sustainable buildings can be a challenging process, as it involves the implementation of complex technologies and construction procedures *(Wu et al.* 2019: 3). Moreover, Robichaud and Anantatmula (2011: 5) postulated that project's objectives are hard to achieve, especially when the construction complexities are not communicated early.

**Higher costs of sustainable building processes and materials**

Various researchers (Dwaikat and Ali 2016: 7) and Tagaza and Wilson (2004: 19) contend that the estimated cost for sustainable building might range from 1% to 25% higher than conventional building. Wu *et al.* (2019: 3) suggest that the higher cost of sustainable building is due to the complexity of the design layout, coupled with modeling and green practices. Furthermore, sustainable building materials tend to be priced 3-4% more than traditional building materials (Zhang, Platten and Shen 2011: 22).

**Long bureaucratic processes**

Research conducted by Salah *et al.* (2023: 3) revealed that the process of bureaucratic approval for new and modern technologies in construction projects could lead to an increase in project completion time. Additionally, Zhang et al. (2011: 2159) noted that the approval process for construction processes in projects can be lengthy and challenging for management. Svensson and Dollerup (2020:18) also emphasized the difficulties faced by project management due to these time-consuming approval procedures.

**Unfamiliarity with sustainable technology**

According to Silvius, Schipper and Planko (2012: 5), construction industry practitioners appear to have very little knowledge about sustainable construction materials and processes and are unfamiliar with the products, materials, system, or design; this is in agreement with the reasons advanced by Eisenberg, Done and Ishida (2002: 34). Darko *et al.* (2018: 697) emphasized that unfamiliarity with sustainable technologies adversely affects project outcomes and performance.

**Lack of sustainable product information**

Studies by Ma, Yang, Li, Chi and Chen (2023: 120); Maqbool et al. (2023a: 3); Ali and Al Nsairat (2009c: 2-3) suggest that project team players lack information concerning sustainable materials and construction processes. Builders frequently need to work with specialists who possess specialized knowledge. Some of the challenges that arise in the construction industry include managing risks associated with different types of project delivery (Koolwijk, *et al.* 2018: 11), a lack of policies, and the need for extra time to implement sustainable building practices on construction sites (Tagaza and Wilson 2004: 14).

### 2.4.2 Limitations of the assessment tools

In relation to the existing tools used in developed and developing countries, several issues were identified as part of the problems associated with such an existing Decision Support System (DSS).

**Regional Variation:** One of the weaknesses identified with those tools is that most of them were developed for local use and, hence, do not allow for international, national, or regional variations.

Complexity: Assessment tools typically require the collection and analysis of significant amounts of detailed information. However, due to the complexity of the data presented and calculated, it can often be challenging to understand. This can pose a problem in finding a balance between completeness in data coverage and simplicity of use. To address this issue, the suggested framework proposes splitting databases into smaller, modular units or compartments. This approach would facilitate the evaluation process and make it easier to manage.

**Life cycle approach:** The literature suggests that some tools are only used at a specific point in time and fail to consider the entire life cycle of a building. These tools usually focus on conditions during the final design or operation phase. To address this issue, a new framework is being proposed that will take into account decision-making factors from the earliest stages of the design process. It is important to note that decisions made during the initial stages of design have a greater impact on the building's performance than decisions made during the final design phase.

**Financial and socio-cultural issues:** Many building material assessment tools, including BREEAM, BEPAC, and LEED, tend to evaluate building products based solely on their environmental criteria. However, they often fail to consider the cost and socio-cultural aspects of the evaluation framework. This approach contradicts the basic principle of building projects, which involves minimizing the cost of materials, an essential aspect of all building projects. Therefore, it is crucial to consider both the economic and socio-cultural dimensions of the S.D. principles, as a building project that is environmentally sound may be very expensive to construct and not compatible with the lifestyle of its users.

**To assess quantitative and qualitative data**, one can easily evaluate quantitative criteria, like energy and water consumption, by considering the total consumption level and awarding points accordingly. However, when using systems such as BREEAM and LEED, it becomes challenging to evaluate qualitative criteria, such as aesthetics, health, and safety.

The current methods of evaluating quantitative and qualitative data in existing tools are feature-specific, which involves awarding points for the presence or absence of desired features. However, this approach often undermines the importance of qualitative criteria in the decision-making process. Therefore, this study aims to explore different assessment techniques that can handle both quantitative and qualitative elements of the material selection process and select the most suitable material assessment technique.

**Weighting alteration:** Most building material selection frameworks typically offer a default weighting system that requires users to adjust the weights based on regional differences. However, teams in individual countries often establish scoring weights subjectively when assessing building products, which can be problematic when applied to other regions. Users may manipulate the results to suit their specific requirements, as the default weighting system can be changed. The criteria weighting is determined on a project-by-project basis and reflects the objectives of the potential users and relevant stakeholders. Although some argue that the available building assessment tools offer little more than pre-processed rules of thumb (Dos Santos *et al.* 2023: 9; Bragança *et al.* 2010c: 2), it is still widely acknowledged that these tools provide valuable advantages to the housing construction industry.

## 2.5 Methods for weighting, aggregating, and determination of indices

According to literature by Krylovas *et al.* (2019: 4); and Wang and Lee (2009: 4), the weighting methods are classified into two distinct groups. These are subjective and objective methods. According to Deng, Yeh and Willis (2000: 11), subjective weight determination methods necessitate the decision-makers to provide initial information based on their knowledge or experience. Some popular subjective weighting methods are pairwise-comparison-based (Hovanov, Kolari and Sokolov 2008: 7), SWARA, KEMIRA (Krylovas *et al.* (2014: 24), SIMOS (Simos 1990: 30), P-SWING (Danielson and Ekenberg 2019a: 4), PIPRECIA (Stanujkic, *et al.* 2017: 6), FUCOM (Pamučar, Stević and Sremac 2018: 4), and DEMATEL (Fontela and Gabus 1974: 54), among others. Subjective methods offer the benefit of incorporating insights from experienced decision-makers (Odu, 2019a: 4). Nonetheless, these insights may sometimes exhibit a preference for a particular criterion due to decision-makers' prior beliefs, resulting in biased outcomes. Besides, according to Ma, Fan and Huang (1999: 26), decision-makers who do not have complete knowledge about the decision problem under consideration may be unable to furnish the needed initial information. In addition, delivering such information may become complex when the MCDM problem involves many criteria.

In contrast to subjective methods, Vanolya and Niaraki (2021: 4-5) discussed that objective methods do not require any initial information or judgment from the decision-makers; they merely assess the structure of the data available in the decision matrix to determine the weights (Alemi-*Ardakani et al.* (2016: 3); (Liu, Chan and Ran 2016: 2); (Podvezko, Kildienė and Zavadskas 2017: 4). According to a research by Krishnan, Mat Kasim and Hamid (2020: 3), all these methods are known for eliminating possible bias associated with subjective evaluation, thus increasing objectivity. As mentioned in the literature, the following are some examples of objective methods: CRiteria Importance Through Inter-criteria Correlation (CRITIC) (Diakoulaki, Mavrotas and Papayannakis 1995: 45), entropy-based methods (Zeleny and Cochrane 1982: 103-104), and the recent CILOS and IDOCRIW methods (Zavadskas and Podvezko 2016: 3).

Literature suggests that entropy-based methods and CRITIC are the most widely applied objective methods for weighting criteria. However, Peng, Zhang and Luo (2020: 3; Krishnan et al. (2020: 5) opined that CRITIC was found to have extra merit as it considered both the contrast intensity and the conflicting relationship held by each decision criterion, unlike the Shannon entropy method, which addresses only the contrast intensity (Li and Mo 2015: 4). A detailed description of the two aspects is given below.

a. The degree of variability associated with the local scores of each criterion is known as the contrast intensity of decision criteria. The CRITIC method, which was developed by Danielson and Ekenberg (2019b: 3), uses standard deviation to measure the contrast intensity of each criterion. The method ensures that a higher contrast intensity or standard deviation criterion is assigned with a higher weight. According to Pinochet *et al.* (2023: 7), when a criterion’s scores show greater variability across different alternatives, it is considered to provide more significant or interesting information.. Thus, from a decision-making viewpoint, more attention or weight should be given to such a criterion than to criteria with homogeneous scores.

b. Alternatives that are considered in a multi-criteria decision-making (MCDM) problem may have competing criteria, making it impractical

> for any alternative to fully meet all the predetermined criteria *Júnior et al.* (2023: 7-8). For instance, it is difficult for a buyer to purchase a brand new car with a higher engine capacity and is cheaper simultaneously: generally, the higher the engine capacity, the more expensive the car. In brief, a conflict between criteria refers to a specific type of relationship that can exist between decision criteria. According to Durmaz, Akan and Bakır (2020: 15), the CRITIC method addresses such conflicting relationships by employing the Pearson correlation coefficient, which falls within the range of -1 to 1. A coefficient of zero indicates that the two criteria, $c_j$ and $c_{j'}$, are independent

Statistical analysis shows that when the coefficient is negative, it means that two criteria are moving in opposite directions. Conversely, when the coefficient is positive, it means that both criteria are moving in the same direction. If the coefficient is approaching 1, it suggests that there is a strong conflict between the two criteria. In contrast, when two criteria have a high positive coefficient, it indicates that they share a lot of redundant information. In line with the findings of Odu (2019b: 4), a criterion that has a high positive correlation with other criteria does not provide any additional information and is considered to have a minimal role in the decision-making system. The CRITIC approach ensures that criteria with higher levels of conflict or lower levels of redundancy are given higher weights by using specific formulae that adhere to this principle.

In a study conducted by Hashemkhani *et al.* ((2020: 17), it was found that the CRITIC method assigns greater weight to a criterion that has a higher contrast intensity and a greater degree of conflict with other criteria. This makes CRITIC useful in various practical applications. Previous studies have also shown that CRITIC can be used in combination with other objective or subjective methods for weight determination. For example, in a study conducted by Tabak, Yıldız and Yerlikaya (2019: 4), they employed a combination of pairwise comparison method and CRITIC to assess the weights of logistic location selection criteria. Piasecki and Kostyrko (2020: 2) utilized a combination of an entropy method and CRITIC to determine the weights of indoor air quality criteria.

### 2.6 Sustainability indicators for buildings from a systematic review

Sustainability indicators were identified from the various journals and were placed under social, economic, and environmental categories, as shown in Table 2.3.

Table 2.3 gives a comprehensive list of all the sustainability assessment indicators from the extensive literature review. Land use and impacts on ecology, low-impact site construction, green space, landscape irrigation, building form, and orientation, greening the building, parking capacity, thermal comfort, daylighting and viewing comfort, air quality, natural ventilation, building water conservation, application of innovative water efficient equipment, water recycling, and reuse, among others, were under the environmental category of the sustainability indicators of buildings. Similarly, most of the literature reviewed looked at the environmental factors more than any other categories. Furthermore, annual operating costs, affordability, safety and security, and valuable floor space are the sustainability indicators under the economic indicators' category. The social sustainability category includes access to social, domestic, and socio-economic facilities, visual comfort, education and awareness, safety, inclusiveness of opportunities, acoustic comfort, building architectural appearance quality, and access to public transport indicators.

**Table 2.3: Sustainability indicators from literature review**

| Sustainability indicators | Category | References |
|---|---|---|
| Land use and impacts on ecology | Environmental | Shari and Soebarto (2017), Agyekum et al., (2022), |
| Low-impact site construction | Environmental | (Bragança et al. 2010; Akhanova et al. 2019) |
| Green space | Environmental | Akhanova et al. (2019) |
| Landscape irrigation | Environmental | Akhanova et al. (2019) |
| Building form and orientation | Environmental | Akhanova et al. (2019) |
| Greening the building | Environmental | Akhanova et al. (2019) |
| Parking capacity | Environmental | Akhanova et al. (2019) |
| Thermal comfort | Environmental | (Karji, et al., 2019; Kuriakose, et al., 2014) |
| Day lighting and viewing comfort | Environmental | (Saraiva, et al., 2018; Karji et al. 2019) |
| Isolation level | Environmental | Akhanova et al. (2019) |
| Air Quality | Environmental | (Bragança et al. 2010; Kuriakose et al. 2014) |
| Air pollution monitoring | Environmental | Akhanova et al. (2019) |
| Natural ventilation | Environmental | Akhanova et al. (2019) |
| User health | Environmental | (Shari and Soebarto 2017; Arukala, Pancharathi and Pulukuri 2019) |
| Building water conservation | Environmental | Akhanova et al. (2019) |
| Application of innovative water-efficient equipment | Environmental | AlWaer and Kirk (2012) |
| Leak detection | Environmental | Akhanova et al. (2019) |
| Water-efficient landscaping and irrigation systems | Environmental | Akhanova et al. (2019) |
| Water recycling and reuse | Environmental | (Bragança, Mateus and Koukkari 2010; Agyekum, Goodier and Oppon 2021) |
| Building commissioning | Environmental | Akhanova et al. (2019) |
| Renewable energy sources use | Environmental | (Akhanova et al. 2019; Arukala et al. 2019) |
| Greenhouse gases emission | Environmental | (Mahmoud, Zayed and Fahmy 2019; Kamali and Hewage 2015) |
| Energy-efficient heating and cooling | Environmental | Akhanova et al. (2019) |
| Energy-efficient equipment | Environmental | (Abdel-Basset et al., 2021; Kuriakose et al., 2014) |
| Energy savings-reduction of electricity consumption | Environmental | (Abdel-Basset et al., 2021; Kuriakose et al., 2014) |
| Energy saving-natural gas efficiency | Environmental | (Abdel-Basset et al., 2021; Kuriakose et al., 2014) |
| Local/regional building materials | Environmental | (Heravi, Fathi and Faeghi 2015; Gibberd 2017) |
| Use of Recycled materials in the first place | Environmental | (Akhanova et al. 2019; Arukala et al. 2019) |
| Secondary use of recycled materials | Environmental | (Akhanova et al. 2019; Arukala et al. 2019) |
| Construction and demolition waste management | Environmental | (Arukala et al., 2019; Heravi, Fathi and Faeghi 2015; Agyekum et al., 2021) |
| Building operation and disposal impact | Environmental | (VillarinhoRosa and Haddad 2013; Ahmad and Thaheem 2018) |
| Environmental management certificate | Environmental | (Bragança, Mateus and Koukkari 2010; Agyekum, Goodier and Oppon 2021) |
| Green building Accredited expert | Environmental | Akhanova et al. (2019) |

| | | |
|---|---|---|
| Designer's green building experience | Environmental | Akhanova et al. (2019) |
| Contractor's green building experience | Environmental | Akhanova et al. (2019) |
| Noise protection | Environmental | Akhanova et al. (2019) |
| Building total lifecycle costs | Environmental | Akhanova et al. (2019) |
| Annual operating costs | Economic | (Shari and Soebarto 2017; Aslani, Gholamreza and Ebrahimi 2015) |
| Affordability | Economic | Stender and Walter (2019) |
| Safety and security | Economic | Stender and Walter (2019) |
| Useful floor space | Economic | AlWaer, H., and Sibley, M., 2005, |
| Access to social, domestic, and socio-economic facilities | Social | (Aslani et al. 2015; Olukoya and Atanda 2020) |
| Visual comfort | Social | Akhanova et al. (2019) |
| Education and awareness | Social | (Gibberd 2017; Stender and Walter 2019) |
| Safety and inclusiveness of opportunities | Social | (Karji, et al., 2019; Aslani et al. 2015) |
| Building architectural appearance quality | Social | (Kamali and Hewage 2015; Karji et al. 2019) |
| Access to public transport | Social | (Heravi, Fathi and Faeghi 2015; Olukoya and Atanda 2020) |
| Acoustic comfort<br>Provide a Chapter summary (for every chapter) | Social | (Bragança et al. 2010; Kuriakose, et al.,2014) |

# CHAPTER THREE: RESEARCH METHODOLOGY

## 3.1 Introduction

In this section, I discussed the research methodology that was utilized for collecting and analyzing data to answer the research questions and enhance the theoretical and practical knowledge concerning construction sustainability. I provided details on data collection techniques, quantitative data analysis, the consensus-based method, and the MCDA method that were chosen for the study.

## 3.2 Research philosophies

The research philosophy for this study is predominantly constructivist in nature. The constructivist approach acknowledges that there are multiple realities and seeks to understand the perceptions and interpretations of different stakeholders involved in the case study (Wong *et al.* 2024: 25). For the case of construction industry, it recognizes that sustainability is a complex and multifaceted concept, influenced by social, economic, and environmental factors. By adopting a constructivist philosophy, the study explored the diverse perspectives of experts involved in the construction industry, with the belief that their collective understanding will contribute to the development of a more comprehensive and contextually relevant sustainability assessment framework for buildings in Uganda. Additionally, the study incorporated elements of interpretivism, which emphasizes the subjective nature of human understanding. This approach is essential in understanding how individuals perceive and assign meaning to sustainability within the specific context (Johnson *et al.* 2007: 92). By embracing an interpretivist perspective, the research pursued to uncover the relevant indicators towards sustainable construction practices in Uganda.

Moreover, the research philosophy also integrated elements of pragmatism, recognizing the practical implications and applications of the sustainability assessment framework. This perspective acknowledges the importance of incorporating practical solutions that can be implemented within the existing institutional and regulatory frameworks (Faraji Sabokbar *et al.* 2016: 78). It emphasizes the need for the sustainability assessment framework to not only be theoretically sound but also viable and actionable within the local context. Therefore, the research philosophy for this study encompassed constructivist, interpretivist, and pragmatic elements, aiming to capture the multifaceted nature of sustainability, the diverse perspectives of stakeholders, and the practical implementation of the sustainability assessment framework within the Ugandan construction industry.

### 3.3 Research Design approach

As stated by Yin (2003: 84), a research design is a crucial, step-by-step plan that guides the collection and analysis of data in a research project. It specifies the information to be collected, its sources, the collection procedure, and the justification for the procedure used (Creswell, 2003: 22). The process of accurately predicting building materials and components is complex and requires objective and logical reasoning and rigorous evaluation of a wide range of possible alternatives (Ding, 2008: 451). Similarly, sorting alternatives into classes arranged in priority order, ranking alternatives from best to worst, and selecting the most important alternative can only be achieved if proper and adequate information is available (Faraji Sabokbar *et al.* 2016: 88).

However, Hofstede *et al.* (1990: 299) suggest that for research designs, its crucial to start with a qualitative orientation and then be followed up with a quantitative assessment. They noted that, it helps researcher to understand the dimensions that can be used to measure them and gain clarity about the subject from existing theories and research. According to their argument, when data is examined in reverse order, researchers are compelled to impose a theoretical structure on it. This structure may inadvertently exclude some critical or incorporate non-relevant variables.

The research problem at hand is broad and complex, and it requires the development of a sustainability assessment framework. Due to the variability of the information needed to address the different aspects of the research question, and the perceived limitations of each research method, it was necessary to use multiple data collection methods. The combination of qualitative and quantitative methods, known as the mixed-method approach or triangulation of methods, was preferred to obtain as much information as possible from different sources. This approach helped to ensure objectivity, rigor, and logical reasoning, and eliminated any potential sources of bias.

The 4-phase research design adopted for this study is illustrated in Figure 3.1 below, which exemplifies the stages and the tasks each undertakes within the research study.

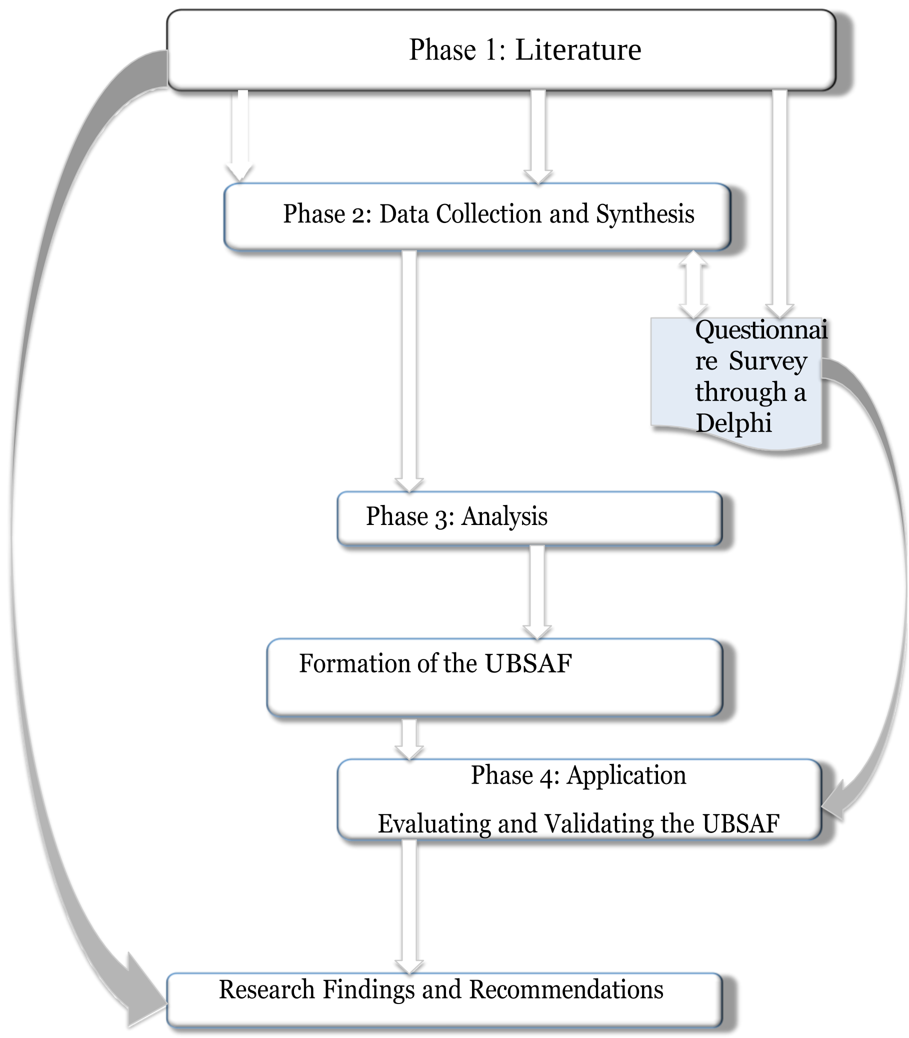



**Figure 3.1: Research methods in phases**

### 3.4 Data collection techniques

This section discusses the overall research methods used for the study and the justification of the reasons for using them. The four stages of the research methodology are broadly discussed as follows:

#### 3.4.1 Crossed referenced analysis

Providing a clear theoretical framework for a relatively new area of study is the basis upon which the desired research could be developed (Yin 2009: 81). Hofstede and Neuijen (1990: 300) note that exploratory review enables the researcher to understand the theme understudy better, assess the feasibility of the study, suggest hypotheses and mechanisms that can serve as the basis for quantitative research, and even determine the best data collection and analytical methods appropriate for the main study.

To address the fundamental issues associated with the objectives, the following steps were undertaken:

**Step 1**

The study explored and examined relevant literature through synthesizing and analyzing recently published data, using various information sources such as books, peer-reviewed journals, articles, and dissemination notes from libraries and internet-based sources.

This task helped to confirm initial observations and develop preliminary ideas on issues specific to the research theme relating to the impacts of decision-making on selecting sustainability indicators and rating tools and their role in sustainable housing. It also provided insights into knowledge deficits of various sustainability rating tools currently available for assessing building performance. This helped the study identify appropriate indicators needed for developing the proposed framework.

**Step 2**

A Delphi study examined further views and current thinking from leading researchers and practicing practitioners of relevant building professional groups who influence sustainability decisions and possess enough industry and product knowledge. The need to include industry views arose due to a lack of academic references and an acknowledgment that the industry often provides more current and insightful information. The respondents, who included mainly building professionals from targeted disciplines such as academia, architecture, civil engineering, urban planning, quantity surveying, and mechanical engineering, were selected because of their long-standing experience, versatility in the building industry and sustainability knowledge.

### 3.4.2 Pretesting the questionnaire

According to Hashim *et al.* (2022: 217), it is argued that carrying out a test run on a questionnaire survey before embarking on the main study is a crucial step necessary to demonstrate the methodological rigour of a survey. To assess the clarity and comprehensiveness of the questionnaire and feasibility, the questionnaire was pretested on a randomly selected sample of four (4) experts (two academicians and two construction industry experts).

Although the results of the pilot study were not used as part of the data required for the development of the proposed model, pretesting the survey enabled the study to:

a) Test whether the questions were clear and understandable;
b) Test the wording, sequence, form, layout, question difficulty, question, and survey instructions;
c) Identify any flaws in the design that were corrected prior to its administration;
d) Test the comprehensibility of the list of proposed decision selection

factors/variables;

e) Ensure that the wording of the questionnaire can be reliably interpreted. This provided an opportunity for checking and correcting potential errors on time so that the data obtained during the main survey fully addressed all aspects of the issues raised and were internally consistent and coherent for analysis;

f) Identify additional variables that broadened the range of decision selection factors.

## 3.5 Identifying sustainability assessment indicators for the assessment of buildings

A systematic literature review was conducted to establish sustainability indicators. The reviewed papers were selected from Scopus, Google Scholar, and PubMed databases using keywords contained in Table 3.1, and the results that came out were 1228 documents. The process of the review is explained in Figure 3.2 below. The inclusive dates for the searches ranged from January 2000 to January 2023, covering a total of 23 years. Only English-language peer-reviewed journal papers and conference papers were included. Furthermore, some sources were rejected based on irrelevancy in terms of context, papers whose full text could not be accessed, duplicates and unpublished materials.

**Table 3.1: Keyword combinations used for the database searches**

| Search no. | Search term |
|---|---|
| 1 | Sustainability indicators AND construction |
| 2 | Sustainability indicators AND environmental |
| 3 | Sustainability indicators AND economic |
| 4 | Sustainability indicators AND social AND construction |
| 5 | Sustainability indicators AND the built environment |
| 6 | Sustainability indicators AND building |

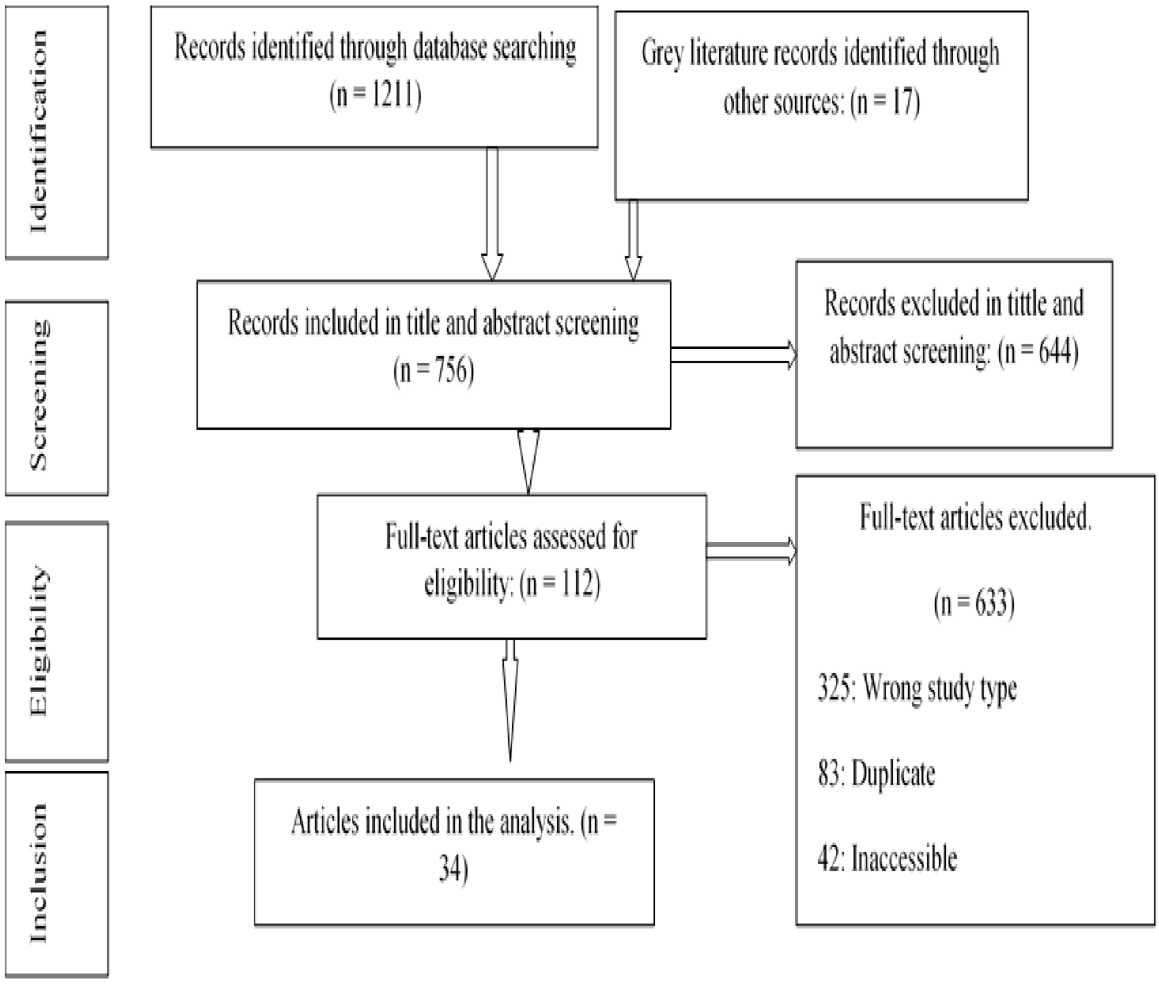



**Figure 3.2: The preferred reporting items for systematic reviews**

### 3.6 Assessing the relevance of building sustainability assessment indicators in Uganda's construction industry

The study's second objective aimed to assess the relevance of sustainability assessment indicators in Uganda's construction industry. To achieve this, the primary research approach utilized was the Delphi technique, known for its effectiveness in achieving consensus in complex or new areas. The Delphi technique was chosen because it allows informed judgments on a given topic to be derived and correlated. Additionally, the study emphasized the significance of the data collection approach in establishing criteria for measuring research findings. Three rounds of Delphi survey with seven respondent groups: academicians, architects, environmentalists, mechanical engineers, quantity surveyors, urban planners, and structural engineers were undertaken to rank the 58 identified sustainability indicators from the literature search. Also, statistical methods such as weighted mean score and standard deviation, Cronbach's alpha reliability test, Shapiro-Wilk test of normality, Kendall's concordance test, Chi-square test, and inter-rater agreement (IRA) were employed.

### 3.6.1 Format of the Delphi technique

Before the launch of the three-round Delphi survey, a review of studies on sustainability indicators in the construction industry was undertaken. A content analysis of extant literature was used, which helped to deduce fifty-eight (58) indicators, then reduced to fifty-two (52) after pretesting the indicators. The summative content analysis approach was adopted in this study's content analysis, as described by Zhang and Wildemuth (2000: 1). A pilot study involving four (4) industry experts was conducted to evaluate and validate the 52 indicators and the survey instrument. Hence, based on feedback from the pilot survey, the finalized Delphi survey comprised forty-nine (49) construction sustainability indicators. The expert team assessed the indicators in the survey form using a 5-point Likert scale (1= Strongly Disagree and 5= Strongly Agree).

One of the critical aspects of a Delphi survey approach is the selection and characteristics of the expert panel member. The sampling technique involves a non-probability sampling technique, and a purposive sampling technique was used in this study to ensure the invited experts are well-informed about sustainability indicators in the construction industry. More so, Aigbavboa (2015: 2) argued that a Delphi survey's success depends on the expert panel's selection and expertise. The following criteria were devised for identifying eligible respondents for the Delphi survey: (1) experts with extensive experience of at least five (5) years in the construction industry and (2) experts with sound knowledge and understanding of the concepts of sustainability indicators in the construction industry.

Some authors claim that the expert panel should consist of a heterogeneous group of members with diversified and expansive knowledge and experience (Belton 2020: 5; Rowe and Wright 2001: 127–128). For this study, thirty (30) experts from the construction industry were used to obtain expert opinions. This agrees with De Villiers, De Villiers and Kent 2005: 306), who found that a panel size greater than 30 may not improve the Delph result. The composition of the expert panel gives the study’s findings a balanced view.

Based on previous studies, 2-3 rounds of Delphi surveys are preferable, and Shang (2023: 2) also utilized a 3-round Delphi survey. Meanwhile, Keeney, Hasson and McKenna (2006: 206) stressed that the expert panel must reach a consensus before the closure of the rounds of the Delphi survey. Moreover, to facilitate the credibility and reliability of the Delphi survey, we ensured the anonymity of the invited experts, iteration, and feedback of results from each Delphi survey round.

### 3.6.2 Dropping criteria

According to Croasmun and Ostrom (2014: 23), research proposed a method for establishing exclusion criteria in research studies using Likert scale responses. The authors suggested that dropping criteria based on the weighted mean score is appropriate. According to the authors, this method can help researchers identify the factors most important to the study outcomes and reduce the potential for bias in the study results, particularly the outlier bias. This approach is relatively easy to implement and uses Likert scale responses in various research studies.

The authors also introduced a scale indicating the significance of the study criteria, with indicators with a weighted mean score of less than 1.5 considered unimportant for the study outcome. The method used for this research is a dropping method for the criteria deemed unimportant by the professionals. Therefore, all sub-criteria whose weighted mean score was less than 1.5 were dropped, as they were considered irrelevant to Uganda's construction sustainability assessment framework.

### 3.6.3 Statistical tools for data analysis

The data collected from the expert panel were analyzed using statistical tools. These tools included several methods like weighted mean score (M) and standard deviation (SD), Cronbach's alpha reliability test, Shapiro-Wilk test of normality, Kendall's concordance test, Chi-square test, and inter-rater agreement (IRA). A comparative analysis was conducted between the experts' groups using these methods.

#### Descriptive statistics

Descriptive statistics are brief descriptive coefficients that summarize a given data set, representing the entire population or a population sample (Kaur, Stoltzfus and Yellapu 2018: 54). Descriptive statistics are broken down into measures of central tendency and measures of variability. This study employed two methods of descriptive statistics: weighted mean score (M) and standard deviation (SD). The weighted mean score and standard deviation of each variable were determined based on the 5-point Likert scale used to collect data to establish the relevance of indicators in each construct. Weighted mean score entails allocating a point to the respondent's ratings of the variables, e.g., extremely important equals 5 points, and not important equals 1 point. The weighted mean score has been used extensively in research with similar variables (Likert data). However, determining their rank can be tricky when dealing with multiple indicators with the same mean value. In such cases, the standard deviation of each factor is considered alongside the mean value. This allows factors with a more minor standard deviation to be given a higher rank, as they are considered more consistent. However, if two or more factors have the same mean and standard deviation, they will be assigned the same rank. This approach ensures a fair and accurate ranking system. The weighted mean score is calculated for each construct using SPSS based on the underlying formula:

$$\boldsymbol{Weighted\ Mean\ Score} = \sum \frac{1n_1+2n_2+3n_3+4n_4+4n_5}{[n_1+n_2+n_3+n_4+n_5]} \text{ ………………………….. Eqn1}$$

where

$n_1$ = number of respondents who strongly disagree, $n_2$ = number of respondents who disagree, $n_3$ = number of respondents not sure, $n_4$ = number of respondents who agree, and $n_5$ = number of respondents who strongly agree.

**Cronbach's (α) Alpha for reliability test**

In research, creating reliable and valid tests and questionnaires is crucial for accurate assessment and evaluation (Tavakol, Mohagheghi and Dennick 2008: 106). The validity and reliability of a measurement instrument are two essential elements. These instruments can be conventional knowledge, skill, or attitude tests, or survey questionnaires and can measure concepts, psychomotor skills, or affective values (Nunnally and Bernstein 1994a: 401). Validity measures the extent to which an instrument measures what it is intended to measure. Reliability measures the ability of an instrument to measure consistently. It is important to note that the reliability of an instrument is closely related to its validity.

An instrument cannot be valid unless it is reliable, but the reliability of an instrument does not depend on its validity (Nunnally and Bernstein 1994a: 410). Cronbach's Alpha is the most widely used objective measure of reliability. It is a statistical measure that assesses the consistency of responses to a set of test items or questions (Cronbach 1951: 95). The value of Cronbach's Alpha ranges from 0 to 1, with higher values indicating greater internal consistency reliability. In this research, Cronbach's Alpha and its significance in measuring the reliability of measurement instrument has been explained .

**What is Cronbach Alpha?**

Alpha, developed by Cronbach in 1951, measures the internal consistency of a test or scale and is expressed as a number between 0 and 1. Reliability estimates show the amount of measurement error in a test, which is important to consider when interpreting results. The weighting of measurement error is produced by squaring the correlation of a test with itself and subtracting it from 1 (Kline 2014: 43). The reliability of a test reveals the effect of measurement error on the observed score of a student cohort. The standard measurement error must be computed to calculate the effect of measurement error on an individual's observed score (Nunnally and Bernstein 1994b: 417).

When the items in a test are correlated with each other, the value of Alpha increases. However, it is important to note that a high coefficient alpha does not necessarily mean a high degree of internal consistency. This is because the test length can also affect the alpha value. The alpha value decreases if the test is too short (Nunnally and Bernstein 1994a: 410); (Streiner 2003: 76). Adding more related items that test the same concept to the test is necessary to increase Alpha. Additionally, Alpha is a property of the scores on a test from a specific sample of test-takers. Therefore, investigators should not rely solely on published alpha estimates and should measure Alpha each time the test is administered (Streiner 2003: 73).

**Use of cronbach's alpha**

The improper use of Alpha can result in wrongly discarded tests or criticized results. To avoid this, one must understand internal consistency, homogeneity, and unidimensionality (Cortina 1993: 306; Green, Lissitz and Mulaik 1977: 202). Reliability assumes unidimensionality exists and violating this assumption can cause a significant underestimate of reliability. Alpha should not be interpreted solely as a weighting for internal consistency, and a multidimensional test does not necessarily have a lower alpha than an unidimensional test (Cortina 1993: 304); Green *et al.* 1977: 411).

Reliability alpha assumes that each test item measures the same latent trait on the same scale. If there are multiple factors or traits underlying the items on a scale or if the number of test items is too small, Alpha will underestimate the reliability of the test (Green and Thompson 2003: 101). When test items meet the assumptions of the tau-equivalent model, Alpha is a better estimate of reliability. Cronbach's Alpha is a lower-bound estimate of reliability since heterogeneous test items would violate the assumptions of the tau-equivalent model. If "standardized item alpha" is higher than "Cronbach's alpha," it may be necessary to examine the tau-equivalent measurement in the data further (Green and Thompson 2003: 221).

**Numerical values of alpha**

Alpha values in testing are influenced by various factors such as the number of test items, item inter-relatedness, and dimensionality. Different opinions exist on the acceptable range of alpha values, with reports suggesting a range between 0.70 to 0.95 (Cortina 1993: 307). A low alpha value could indicate several issues, while a high alpha value could suggest redundant questions (Nunnally and Bernstein 1994b: 312; Bland and Altman 1997: 179; DeVellis and Thorpe 2021:

6). The alpha value of 0.81 was achieved, implying that the research tool had relevant questions for this study .

**Normality test**

It is imperative to determine whether the data follows a normal distribution. If the data follows a normal distribution pattern, the appropriate technique for statistical analysis is parametric well, and nonparametric methods are appropriate for data not following a normal distribution. Though various techniques are used for normality tests (histogram and line graph, box plot, residue plot, stem, and leaf plot, Anderson-Darling, Kolmogorov-Smirnov, Martinez-Iglewicz, D'Agostino Skewness, Shapiro-wilk, D'Agostino Kurtosis, and D'Agostino Omnibus), Shapiro-wilk was used for this study.

**Shapiro-Wilk W test**

This test for normality is the most potent test in most situations. It is the ratio of two estimates of the variance of a normal distribution based on a random sample of n observations. The numerator is proportional to the square of the best linear estimator of the standard deviation. The denominator is the sum of squares of the observations about the sample mean. The test statistic W may be written as the square of the Pearson correlation coefficient between the ordered observations and a set of weights used to calculate the numerator. Since these weights are asymptotically proportional to the corresponding expected normal order statistics, W is roughly a measure of the straightness of the normal quantile plot. Hence, the closer W is to one, the more normal the sample is. The probability values for W are valid for sample sizes greater than 3. The test was developed by Shapiro and Wilk (1965: 434) for sample sizes up to 20. However, Mara (2011: 21–22) approximation allowed unlimited sample sizes, as he checked the results for sample sizes up to 5000 but indicated no reason larger sample sizes should not work.

**Commenting on the Shapiro-Wilk W test**

The purpose of conducting a test to determine whether data were normally distributed is to ensure that statistical analyses performed on the data are valid. A p-value is calculated from the test and used to make conclusions about the normality of the data. Suppose the p-value is greater than the significance level (e.g., 0.05), in that case, the data are not significantly different from a normal distribution and is assumed to be normally distributed.

However, suppose the p-value is less than the significance level, then in that case, the data significantly deviate from a normal distribution and cannot be assumed to be normally distributed. In this case, the data used did not follow a normal distribution, so using parametric methods to analyze the data would not have been appropriate. As a result, nonparametric methods were used to analyze the data. Nonparametric methods do not rely on the assumption of normality and are, therefore, more suitable for analyzing non-normal data.

**Kendall's concordance test (w)**

Kendall's coefficient of concordance, also known as Kendall's W, is a nonparametric statistics tool used to assess agreement between different raters. The coefficient ranges from 0 to 1, where 0 indicates no agreement between raters and 1 indicates perfect agreement. The statistic can be calculated either on an interval or ordinal scale. It was proposed by Kendall and Babington-Smith (1939: 439) to measure the agreement among several quantitative or semi-quantitative variables that assess a set of objects of interest. In the social sciences, these variables often refer to judges who assess different subjects or objects.

In this study, the professionals acted as judges while the sustainability construction indicators were the objects being evaluated. Using the chi-square test, Kendall's W was used to determine the level of agreement among rankers and the level of significance test. A W test statistic of 1 indicates that all survey respondents were unanimous and assigned the same order to the list of concerns. Conversely, a W value 0 suggests no overall agreement trend among the respondents, and their responses may be considered random. Intermediate values of W indicate varying degrees of unanimity among the responses. To determine the degree of agreement among the respondents in their rankings, Kendall’s coefficient of concordance (W) was used. This coefficient provides a measure of agreement between respondents within a survey on a scale of zero to one, with ‘0’ indicating no agreement and ‘1’ indicating perfect agreement or concordance. Using the rankings by each respondent, W was computed using Eqn 2.

$$W = \frac{12S}{m^2\,(n^3 - n)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eqn2$$

Where $m$ is the number of participants (raters) and $n$ is the total number of criteria. $S$ is the sum of squared deviations defined as follows:

$$S = \sum_{i=1}^{n} (R_i - \bar{R})^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eqn3$$

$R_i$ is the total rank given to the factor $i$, and $\bar{R}$ is the mean of these total ranks.

**Chi-square test**

In statistical analysis, a chi-square test is a powerful tool to determine whether two categorical variables are related or associated. It is a nonparametric test, meaning it does not depend on any specific distribution or assumptions about the data. Instead, it can be applied to various data sets, making it a versatile tool for statisticians and researchers. By performing a chi-square test, one can discover valuable information about the relationship between different variables and gain insights into the underlying patterns and trends in the data.

To verify that the degree of agreement did not occur by chance, the significance of W was tested, the null hypothesis being perfect disagreement. With a degree of freedom, the Chi-square approximation of the sampling distribution is used for testing this hypothesis at a given level (5% significant level). The calculated chi-square value, greater than its counterpart table value, implies that the W was significant at the given significance level. As such, the null hypothesis is not supported and thus has to be rejected. To verify that the degree of agreement did not occur by chance, the significance of W was tested, the null hypothesis being perfect disagreement. The Chi-square approximation of the sampling distribution given by equation below with (N-1) as degree of freedom is used for testing this hypothesis at a given level. The calculated Chi-square value, greater than its counterpart table value, implies that the W was significant at the given significance level. As such, the null hypothesis is not supported and thus has to be rejected.

$x = k(N-1)W$………………………………………………………………. Eqn4

**Inter-Rater Agreement (IRA)**

Literature shows that Brown and Hauenstein (2005: 179) proposed and advanced the use of interrater agreement statistics to analyze group agreement. IRA was developed to overcome the limitation of other agreement indices correlated with the extremeness of mean ratings. The closer the mean rating is to the scale endpoint (i.e., the extremity of the group mean), the lower the variance in those ratings, and the greater the agreement. This confounds the above IRA statistics with the group mean, rendering them incomparable across groups with different means.

Brown and Hauenstein (2005) explained that IRA is advantageous because it makes the data independent of the scale and the study's sample size. More so, LeBreton and Senter (2008) provided the interpretation for the IRA statistics, which are: 0.00-0.30 "*lack of agreement*," 0.31-0.50 "*weak agreement*," 0.510.70 "*moderate agreement,"* 0.71-0.90 "*strong agreement*" and 0.91-1.00 "*very strong agreement*." The IRA statistics and the significance level grading were used in this study to check the level of agreement across the three rounds of the Delphi survey and validate the results. Equation 5, the IRA formula, was utilized to analyze and validate the agreement for each factor. However, the IRA statistics cannot accurately measure the agreement for means at the boundary of a scale, such as 1 and 5 on a 5-point Likert scale. Therefore, to calculate the IRA analysis, equations 6 and 7 were employed to establish the mean upper and lower limits.

$$a_{wg} = 1 - \frac{(2 * SD^2)}{\{(A + B)M - (M^2) - (A * B)\} * \frac{n}{n-1}} \ldots\ldots\ldots\ldots Eqn5$$

$$M_{lower} = \frac{B(n-1) + A}{n} \ldots\ldots\ldots\ldots Eqn6$$

$$M_{upper} = \frac{A(n-1) + B}{n} \ldots\ldots\ldots\ldots, \ldots\ldots Eqn7$$

Where $SD$ is the standard deviation, $A$ is the maximum scale value (i.e., 5), $B$ is the minimum scale value (i.e., 1), $M$ is the mean value of that factor, and $n$ is the sample size of respondents.

## 3.7 Determining building sustainability assessment indices for benchmarking the performance of buildings in Uganda

The social, economic, and environmental indicators affecting sustainability - named hereinafter sustainability indicators-were identified, and their relevance was studied in the second objective. The third objective intended to determine the indices for building sustainability indicators. To do this, each indicator's relative weights and magnitude were required to develop a sustainability weighting. To determine the relative weights of these indicators, the Multi-Criteria Decision Analysis (MCDA) technique, named Criteria Importance Through Intercriteria Correlation (CRITIC), was used.

### 3.7.1 CRiteria Importance Through Intercriteria Correlation (CRITIC)

According to Da Silva *et al.* (2023: 170), the CRITIC method is a highly regarded, objective method widely used to evaluate options. A correlation-based method that determines the degree of contrast between different criteria. This is accomplished by using the standard deviation of the ranked criteria values for each option in a given column and calculating all paired columns' correlation coefficients. The CRITIC method comprehensively evaluates the options under consideration by analyzing these factors. The Criteria Importance Through Intercriteria Correlation (CRITIC) methodology is also a powerful tool for developing decision-making indices systematically. By analyzing inter-criteria correlations, CRITIC helps identify the most important criteria influencing the decision-making process. This methodology has been widely used across various domains, including business, finance, and environmental management, to name a few.

The weighting was developed using a comprehensive set of sustainability construction criteria that consider a range of environmental, social, and economic factors. These criteria were carefully selected to ensure that the weighting provides a holistic assessment of sustainability in construction practices. To better understand the relationships between the different criteria, an analysis was conducted to determine their correlation. To accomplish this, a correlation matrix was created, which displays the correlation coefficients between each pair of criteria. This approach provides a clear and concise representation of the connections between the examined factors.

**Step 1: Normalization**

The scores of different criteria are incommensurable as they are expressed in different measurement units or scales. The normalization process in the CRITIC (CRiteria Importance Through Intercriteria Correlation) method involves normalizing the decision matrix in which different criteria for various assessment units or scales are used. When normalized, the scores are converted to scales between zero (0) and one (1). Scores are standardized in the decision matrix. In the proposed method, as a first step, we use Equation 8 to normalize the scores in the decision matrix.

$$\bar{x}_{ij} = \frac{x_{ij} - {x_j}^{Min}}{{x_j}^{Max} - {x_j}^{Min}} \quad \text{eqn8}$$

Where $\bar{x}_{ij}$ is the normalized score of alternative $i$ with respect to criterion $j$, $x_{ij}$ is the actual score of alternative $i$ with respect to criterion $j$, and ${x_j}^{Max}$ is the maximum score of criterion $j$, and ${x_j}^{Min}$ is the minimum score for criterion $j$. Normalization is a critical step in the CRITIC method, ensuring that the correlation coefficients are on the same scale and can be compared. This, in turn, enables the calculation of the Intercriteria weights and overall weights of the criteria.

**Step 2: Standard deviation determination**

Standard deviation measures the amount of variation or dispersion of a set of data values from the mean or average. It is calculated by taking the square root of the variance, which is the average squared differences of each value from the mean. In this step, the standard deviation of each criterion is calculated using equation 9. Note that $\bar{x}_j$ is the mean score of criterion $j$ and that $m$ is the total number of alternatives.

$$s_j = \sqrt{\frac{\left(\sum_{i=1}^{m} x_{ij} - \bar{x}_j\right)^2}{m-1}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eqn9$$

Where $s_j$ is the standard deviation, $\sum_{i=1}^{m} x_{ij}$ is the total criterion weight, $\bar{x}_j$ is the mean, and $m$ is the total number of alternatives.

**Step 3: Interdependency and measure of conflict**

The conflicting correlation between each set of criteria was calculated in this stage to minimize possible errors in the final weights. The conflicting relationships between criteria are captured with the help of the Pearson correlation.

$$r = \frac{n\sum ij - (\sum i \sum j)}{\sqrt{n\sum i^2 - (\sum i)^2}\sqrt{n\sum i^2 - (\sum i)^2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eqn10$$

Where $r$ is the Pearson correlation coefficient, and $ij$ is the pair of criteria compared to each other to determine the relationship's strength and direction. The measure of conflict ($MC$) was then determined from the correlation coefficient matrix table.

**Step 4: Quantity of information**

The quantity of information is considered the amount of information each criterion provides in the decision-making process. To determine how much information is associated with criteria $j$, equation 11 was used:

$I_j = s_j * \sum_{j=1}^{n}(1-r)$………………………………………………………… Eqn11

where $I_j$ denotes the information content of $j$.

**Step 5: Relative weights**

Equation 12 was used to compute the relative weight of criteria $j$.

$w_j = \frac{I_j}{\sum_{j=1}^{n} I_j}$……………………………………………………………………….. Eqn12

Where $w_j$ is the weighted value of criteria $j$

**Step 6: Determination of indices**

Research by Pollesch and Dale (2016: 19) explains that the CRITIC method utilizes a sustainability index determined by multiplying the normalized score with the generated weight. This process yields the weighted normalized score, summed up to arrive at the sustainability index. To be more specific, equation 13 was utilized for the calculation of the index.

$$s_i = \sum (W_{\bar{x}_{ij}}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eqn13$$

Where $s_i$ is the Sustainability index and $W_{\bar{x}_{ij}}$ is the weighted normalized score.

## 3.8 Validating the building sustainability assessment framework in Uganda.

The sustainability index is a critical tool for creating sustainable frameworks and tools. The index was calculated by considering several factors, such as environmental, economic, and social indicators. The index was used to develop a comprehensive sustainability framework outlining the necessary steps and strategies for the construction industry to operate in an environmentally friendly, socially responsible, and economically viable manner that ensures long-term sustainability.

### 3.8.1 Validation of the framework

The plausibility of the proposed framework was tested by applying it to three case studies in Uganda to assess the sustainability of construction projects. The assessment was conducted using a specialized sustainability tool developed for this purpose. This rigorous evaluation process aimed to determine the effectiveness and practicality of the framework in real-life situations and provide valuable insights for future sustainable construction practices. The sustainability assessment tool consisted of three distinct sections: the social indicator section, the environmental section, and the economic indicator section. These sections evaluate the site practices in three key areas of sustainability. Each criterion's possible score is indicated on the questionnaire based on the overall sustainability index, with three suggestions. A score of 1 indicates that the criteria are not practiced; a score of 0 means the site manager is not informed about the criteria. A score of 2 indicates that the criteria are being used. This helps to provide a comprehensive picture of the site's sustainability practices and identify areas for improvement.

Determining the most appropriate site involved a comprehensive evaluation of multiple factors. After examining each criterion, the scores were combined to make a final decision. The grouping criteria used to assess these scores were based on the LEED sustainability framework, a widely recognized and accepted standard for evaluating the environmental impact of any project. This approach allowed for a thorough and reliable assessment of site sustainability, helping to ensure the project's success.

### 3.8.2 Acceptability of the framework

To ensure the plausibility of the proposed framework, experts from the construction industry were approached to evaluate the practicality and reliability of the framework. The verification process involved a limited number of questions structured using the Likert scaling method, with a scale of 1-5. This method commonly gauges' people's attitudes or perceptions towards a particular topic. The questions were designed to address the key aspects of the framework, such as its effectiveness, feasibility, and usability. The experts were asked to rate each question based on their level of agreement or disagreement. The responses were then compiled and analyzed to determine the overall plausibility of the framework.

### 3.9 Ethics clearance approval

Since this research involved human subjects, ethical approval was obtained in advance from the Durban University of Technology Research Ethics Committee. A copy of the Ethics clearance approval is attached in Appendix D under the appendices section.

### 3.10 Data management

Managing primary data is a crucial aspect of conducting research. It involves several steps to ensure the data are reliable, accurate, and secure. This study used primary subject data, which were collected and processed with great care. Firstly, the collected data were entered into Excel, a user-friendly software. It was used due to its simplicity and familiarity to many researchers. Secondly, the Excel data were exported to STATA, a powerful software for scrubbing and coding data. STATA is specifically designed for analyzing large and complex datasets and is a popular choice for many researchers (Todorova-Ekmekci 2021: 15; McClure *et al*. 2014: 24; Gentili 2021: 7).

The scrubbing process involved several steps to ensure data integrity. It included identifying missing values in the dataset, which were replaced with the arithmetic mean. This helped to avoid skewing the data due to missing information. Duplicate records were also removed to avoid overrepresentation and ensure data integrity. Outliers, which are data points that deviate significantly from the majority of the data, were also handled. The data were then converted from string to numerical data to facilitate analysis. This allowed us to perform a statistical analysis of the data. Inconsistencies in the data, such as different representations of the same data, were also corrected to ensure reliability. Irrelevant data, such as data related to the time and date the expert filled out the questionnaire. To ensure the accuracy of the data, the researcher verified that the data adhered to defined constraints, such as unique keys and relationships in a database. Finally, typographical errors were corrected to ensure the data were error-free. By following these steps carefully, the data used in this study were of the highest quality.

## 3.11 Delimitation and limitations

### 3.11.1 Delimitation

The framework that was developed is tailored to address the unique needs of Uganda's construction industry. It is designed to cater for the different types of buildings, including residential, commercial, and industrial structures. The study focused on evaluating the sustainability of construction projects based on three critical construction assessment sustainability criteria: environmental, social, and economic indicators. Nonparametric statistical methods were employed to determine the relevance of these criteria. The sustainability index was computed using the CRITIC method of Multi-Criteria Decision Analysis (MCDA).

### 3.11.2 Limitations

Although the research has generally achieved the objectives stated in the introduction, the study was not conducted without limitations. Firstly, the Covid pandemic affected all businesses and all aspects of life. It was impossible to physically deliver questionnaires because of COVID-19 limitations and the standard operating procedures involved. This affected the time of information collection as it took a lot of time for data collection.

Secondly, the research was confined to the Kampala metropolitan geographical area out of many other business areas in Uganda. Even though Uganda has different climatic zones, certain parts of the country are drier or wetter than others, depending on the months of the year. Other variations include nature, socio-economic background and priorities, and technological achievements. Therefore, the weightings developed in this survey may apply only to cities/towns similar to the investigated ones. Otherwise, further research needs to be conducted to generate appropriate weightings for other cities/towns.

Thirdly, the research is targeted at all building projects. However, the findings from this study could be considered a guide to assessing and developing sustainable building criteria for different buildings like office projects, hospitals, and schools. This is because these different building projects have differing requirements to be implemented/achieved to operate such projects properly. Finally, the study only tested the applicability of the criteria relevant to the design phase of the assessment.

### 3.12 Anonymity and confidentiality

Anonymity and confidentiality were assured by assigning codes to study participants.

### 3.13 Statement of voluntariness

Ethical clearance was required before the commencement of data collection. No participants were forced to participate. A respondent had the right to withdraw from the study at any time without a penalty.

CHAPTER FOUR: RESULTS, ANALYSIS AND DISCUSSION

## 4.1 Introduction

In Uganda, there is currently no framework available to assess the sustainability of construction practices in the industry. To address this gap, a study was conducted to develop a comprehensive framework for this purpose. The framework was developed by selecting the most relevant indicators from an international framework and adapting them to the specific context of Ugandan industry. The study objectives required statistical analysis and the use of CRITIC, a method of Multiple Criteria Decision Analysis (MCDA), to develop the framework. This section presents the results of the study, which include the statistical analysis and the details of the framework developed using CRITIC.

## 4.2 Background information for study participants

The background characteristics of the respondents were:

### 4.2.1 Gender

Figure 4.1 shows that respondents were majorly males (90%) and only 3 (10%) were females. From the selected 40 Delphi participants (30 males and 10 females), only 27 males and 3 females accepted to participate.

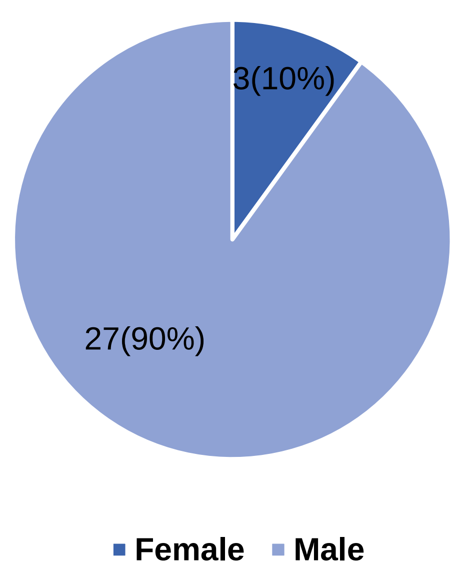



**Figure 4.1: Gender of experts**

### 4.2.2 Profession of experts

The respondents comprised of Urban planners (03), Structural engineers (03), Quantity surveyors (10), mechanical engineers (05), environmentalists (02), architects (04) and academicians (03) that were purposively selected from the academia, consultancies and the construction industry. The variation in numbers is due to the ease or difficulty in accessing the different professionals. For instance, it was difficult to get environmentalists to participate as most of the contacted members were either unwilling or busy with projects, similarly, the same was true for structural engineers, urban planners and academicians.

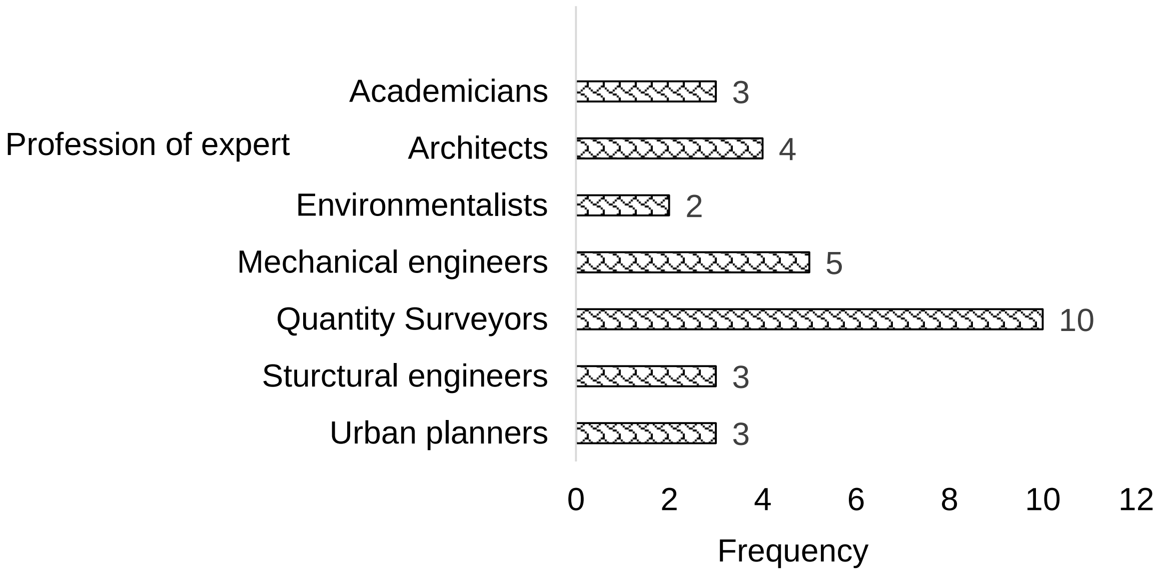



**Figure 4.2: Profession of experts**

### 4.2.3 Education level

The education level of the respondents is as indicated in the graph above. Two (2) respondents held a bachelor's degree representing percentage of 6.7, while 15 respondents and 12 respondents hold masters and doctorate degrees representing 50% and 40% respectively. One (1) respondent declined to disclose the academic level. It's therefore evident that the respondents had an advanced level of academic standard and knowledge and were therefore expected to have a high-level understanding of the concepts of sustainability assessment in the Ugandan construction industry and this was paramount for the quality of research outcomes.

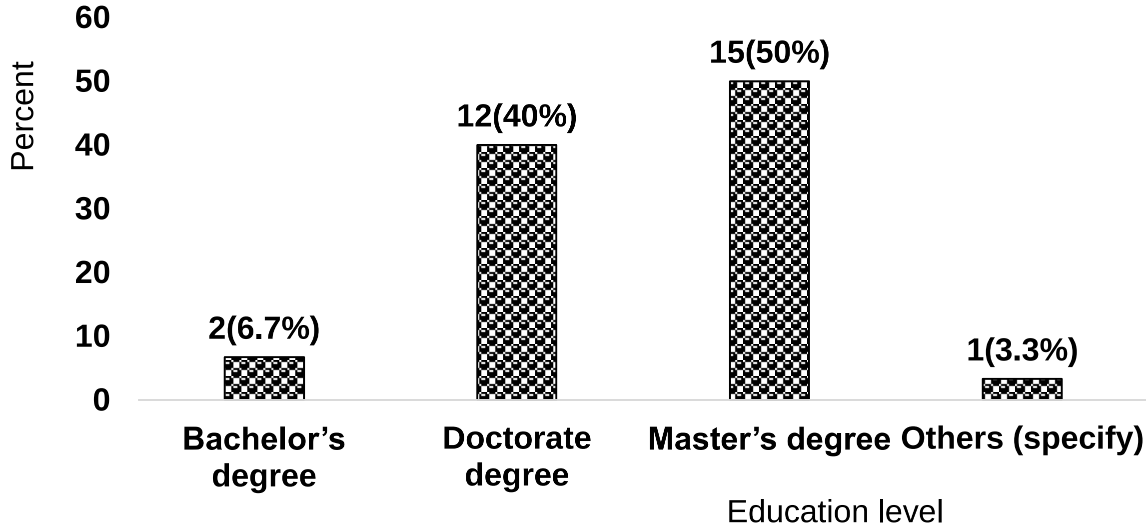



**Figure 4.3: Education level of experts**

#### 4.2.4 Age bracket

From Figure 4.4, it's evident that the respondents are mature and of the age capable of articulating the concepts of sustainability and giving good feedback in relation to the topic.

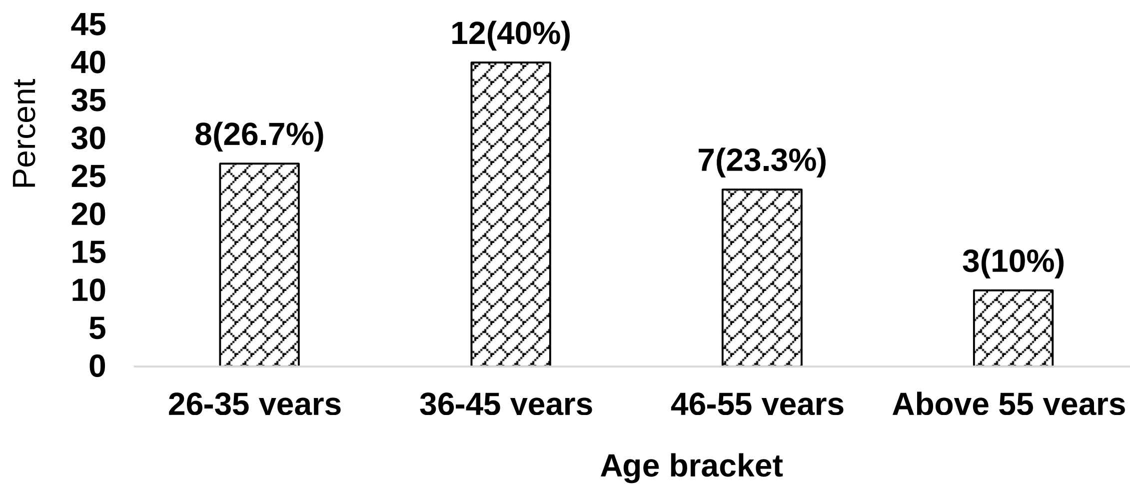



**Figure 4.4: Age bracket of experts**

#### 4.2.5 Field experience

According to the Figure 4.5, the respondents exhibited a good level of working experience in the construction industry with seven (7) experts having at least 20 years of experience, seven (7) experts within the range of 16 and 20 years of working experience, four (4) experts within the range of 11 and 15 years of working experience, ten (10) experts within the range of 6 and 10 years of working experience and another two (2) respondents within the range of 0 and 5 years of working experience.

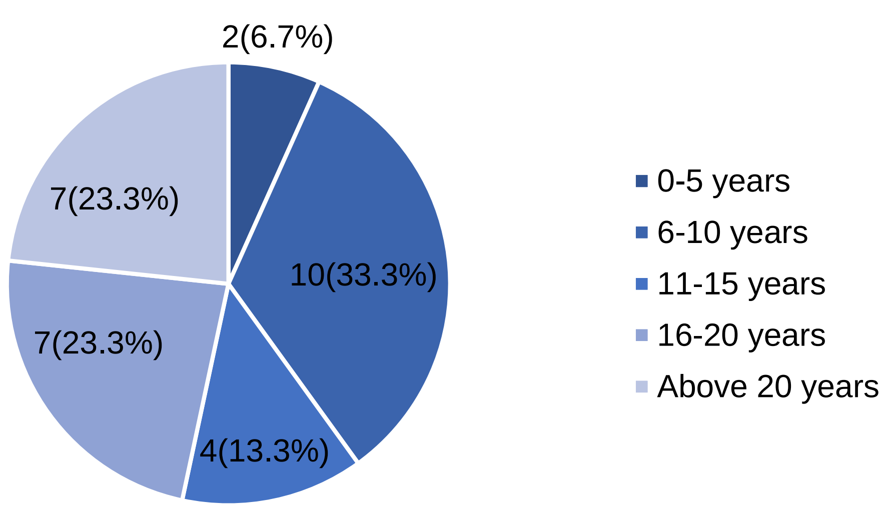



**Figure 4.5: Field experience of experts**

It can be concluded that with experts of such vast field experience, the articulation of the research requirements would be easy and the results would be an output of a well experienced team of experts. This increased the reliability of the output.

**4.3 Relevant UBSA indicators based on expert`s opinion**

The data referenced for analysis are based on the mean score values of the 36 identified factors after the second round of Delphi survey. More so, in prioritizing the factors based on their significance levels, the scale of 1-5 interval interpretation proposed by Li, Ng and Skitmore (2013: 7) was adopted as follows: “not important” ($M < 1.5$), “somewhat important” ($1.51 \leq M \leq 2.5$), “important” ($2.51 \leq M \leq 3.5$), “very important” ($3.51 \leq M \leq 4.5$) and “extremely important” ($M \geq 4.51$). More so, of the 48 sustainability indicators, 14 sustainability indicators fell in $M < 1.5$ (see table 4.1) and according to Li, Ng and Skitmore (2013: 9), indicators having a mean of 1.5 and below, should be dropped. Therefore, isolation level ENV19, air quality ENV16, low-impact site construction ENV11, noise protection ENV38, greenhouse gases emission ENV29, Environmental management certificate ENV12, contractors green building experience ENV33, water recycling and reuse ENV28, building commissioning ENV22, designers green building experience ENV37, green space ENV14, use of recycled materials ENV13, green building accredited expert ENV30, greening the building ENV18, were all dropped as they fell in the category of “not important” with a mean of 1.5 and below.

Meanwhile, eleven (11) of the factors were considered “extremely important” by the respondents after the first round and these indicators include indicator ECO4, ENV2, SOC2, ENV4, ENV23, ECO2, SOC1, ENV1, ENV10, SOC5, ENV7. Three (3) indicators ENV17, SOC6, ENV25 were graded as “important” while the remaining 17 indicators were considered “very important” by the expert panel.

**Table 4.1: Relevant UBSAF indicators**

| Criterion | Code | N | Mean | Significance level |
|---|---|---|---|---|
| Safety and security | ECO4 | 30 | 4.73 | Extremely Important |
| Land use and impacts on ecology | ENV2 | 30 | 4.70 | Extremely Important |
| Access to public transport | SOC2 | 30 | 4.67 | Extremely Important |
| Building form and orientation | ENV4 | 30 | 4.67 | Extremely Important |
| Building total lifecycle costs | ENV23 | 30 | 4.67 | Extremely Important |
| Annual operating costs | ECO2 | 30 | 4.60 | Extremely Important |
| Access to social, domestic, and socio- economic facilities | SOC1 | 30 | 4.60 | Extremely Important |
| Day lighting and viewing comfort | ENV1 | 30 | 4.60 | Extremely Important |
| Parking capacity | ENV10 | 30 | 4.57 | Extremely Important |
| Safety and inclusiveness of opportunities | SOC5 | 30 | 4.57 | Extremely Important |
| Local/regional building materials | ENV7 | 30 | 4.53 | Extremely Important |
| Building architectural appearance quality | SOC4 | 30 | 4.50 | Very Important |
| Natural ventilation | ENV5 | 30 | 4.50 | Very Important |
| Energy-efficient equipment | ENV34 | 30 | 4.50 | Very Important |
| Energy saving-Reduction of electricity consumption | ENV36 | 30 | 4.50 | Very Important |
| Useful floor space | ECO1 | 30 | 4.47 | Very Important |
| Building water conservation | ENV6 | 30 | 4.37 | Very Important |
| Application of innovative technologies | ENV24 | 30 | 4.37 | Very Important |
| Water-efficient equipment | ENV24 | 30 | 4.37 | Very Important |
| Energy-efficient heating and cooling | ENV32 | 30 | 4.33 | Very Important |
| Construction and demolition waste management | ENV8 | 30 | 4.33 | Very Important |
| Renewable energy sources use | ENV35 | 30 | 4.33 | Very Important |
| Education and awareness | SOC7 | 30 | 4.30 | Very Important |
| Leak detection | ENV21 | 30 | 4.27 | Very Important |
| Water-efficient landscaping and irrigation systems | ENV26 | 30 | 4.23 | Very Important |
| Affordability | ECO3 | 30 | 4.00 | Very Important |
| User health | ENV27 | 30 | 3.90 | Very Important |
| Air pollution monitoring | ENV15 | 30 | 3.77 | Very Important |
| Visual comfort | SOC3 | 30 | 3.77 | Very Important |
| Landscape irrigation | ENV17 | 30 | 3.17 | Important |
| Acoustic comfort | SOC6 | 30 | 3.00 | Important |
| Secondary use of recycled materials | ENV25 | 30 | 2.67 | Important |
| Building operation and disposal impact | ENV20 | 30 | 2.50 | Somewhat important |
| Energy saving Natural gas efficiency | ENV31 | 30 | 2.47 | Somewhat important |
| Thermal comfort | ENV3 | 30 | 2.30 | Somewhat important |
| Isolation level | ENV19 | 30 | 1.50 | Not Important |
| Air Quality | ENV16 | 30 | 1.50 | Not Important |
| Low-impact site construction | ENV11 | 30 | 1.43 | Not Important |
| Noise protection | ENV38 | 30 | 1.43 | Not Important |
| Greenhouse gases emission | ENV29 | 30 | 1.40 | Not Important |
| Environmental management certificate | ENV12 | 30 | 1.40 | Not Important |
| Contractors green building experience | ENV33 | 30 | 1.40 | Not Important |
| Water recycling and reuse | ENV28 | 30 | 1.37 | Not Important |
| Building commissioning | ENV22 | 30 | 1.37 | Not Important |
| Designers green building experience | ENV37 | 30 | 1.37 | Not Important |
| Green space | ENV14 | 30 | 1.33 | Not Important |
| Use of Recycled materials | ENV13 | 30 | 1.33 | Not Important |
| Green building Accredited expert | ENV30 | 30 | 1.30 | Not Important |
| Greening the building | ENV18 | 30 | 1.23 | Not Important |

## 4.4 Delph study findings

The research methodology employed in the study consisted of three rounds of Delphi technique, which involved gathering input from a group of diverse professionals with expertise in different fields. The insights and opinions gathered from the selected experts were used to generate the results presented in this study.

### 4.4.1 Round one of Delphi

The first Delphi round asked the participants to rate the sustainability indicators, on a scale of one (1) to five (5) in the construction industry of Uganda. The level of concordance was deduced with Kendall's W.

**Academicians**

The level of agreement among the academicians (3 participants in Table 4.2) to sustainability indicators was moderately high (W=0.611). The agreement between the opinions of the raters (academicians) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.002) at 0.05 and 0.01 level of significance with a degree of freedom 33. The academicians in Delphi round one ranked land use and impacts on ecology, safety and inclusiveness of opportunity, and building total lifecycle cost as the most essential sustainability indicators scoring a mean value of 5.00 on average. The least ranked included: thermal comfort, secondary use of recycled materials, and building operation and disposal with a mean score value of 2.00 on average. The difference in the mean score was 3.00, indicating a wide variation in the ranks of the indicators.

**Table 4.2: Level of agreement among academicians round one of Delph**

| Criterion | Mean | SD | RK |
|---|---|---|---|
| Land use and impacts on ecology | 5.00 | 0.000 | 1 |
| Safety and inclusiveness of opportunities | 5.00 | 0.000 | 1 |
| Building total lifecycle costs | 5.00 | 0.000 | 1 |
| Access to public transport | 4.67 | 0.577 | 4 |
| Building form and orientation | 4.67 | 0.577 | 4 |
| Parking capacity | 4.67 | 0.577 | 4 |
| Building water conservation | 4.67 | 0.577 | 4 |
| Energy-efficient equipment | 4.67 | 0.577 | 4 |
| Energy saving Reduction of electricity | 4.67 | 0.577 | 4 |
| Local/regional building materials | 4.67 | 0.577 | 4 |
| Construction and demolition waste management) | 4.67 | 0.577 | 4 |
| Annual operating costs | 4.67 | 0.577 | 4 |
| Building architectural appearance | 4.33 | 0.577 | 13 |
| Useful floor space | 4.33 | 0.577 | 13 |
| Natural ventilation | 4.33 | 0.577 | 13 |
| User health | 4.33 | 0.577 | 13 |
| Application of innovative water | 4.33 | 0.577 | 13 |
| Leak detection | 4.33 | 0.577 | 13 |

| | | | |
|---|---|---|---|
| Safety and security | 4.33 | 0.577 | 13 |
| Education and awareness | 4.33 | 0.577 | 13 |
| Access to social, domestic, and socio-economic facilities | 4.00 | 0.000 | 21 |
| Water-efficient landscaping and | 4.00 | 0.000 | 21 |
| Renewable energy sources use | 4.00 | 1.000 | 21 |
| Energy-efficient heating and cooling | 4.00 | 0.000 | 21 |
| Affordability | 4.00 | 1.000 | 21 |
| Visual comfort | 3.67 | 0.577 | 26 |
| Day lighting and viewing comfort | 3.67 | 1.155 | 26 |
| Air pollution monitoring | 3.67 | 1.155 | 26 |
| Acoustic comfort | 3.33 | 1.155 | 29 |
| Energy saving-natural gas efficient | 3.33 | 1.155 | 29 |
| Landscape irrigation | 2.67 | 1.155 | 31 |
| Thermal comfort | 2.33 | 0.577 | 32 |
| Secondary use of recycled material | 2.00 | 0.000 | 33 |
| Building operation and disposal impacts | 2.00 | 0.000 | 33 |
| **Number of respondents** | **3** | | |
| **Kendall`s coefficient of Concordance** | **0.611** | | |
| **Chi-square** | **60.53** | | |
| **Degree of Freedom** | **33** | | |
| **One tailed significance level** | **0.002** | | |
| **$H_0$: No agreement** | **Reject $H_0$** | | |

### Architects

The level of agreement among the architects (4 participants) to sustainability indicators was moderate (W=0.506). The agreement between the opinions of the raters (architects) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.000) at 0.05 and 0.01 level of significance with a degree of freedom 33 as indicated in Table 4.3. The architects in Delphi round one ranked education and awareness scoring a mean value of 5.00 as the first most essential sustainability indicator. More so, sustainability indicators including Land use and impacts on ecology, access to public transport, building form and orientation, useful floor space, parking capacity, day lighting, renewable energy sources use and safety and security as the other most essential sustainability indicators scoring a mean value of 4.75 on average. The least ranked included: thermal comfort, energy saving-natural gas efficiency with a mean score value of 2.50 on average, and landscape irrigation with a mean score value of 2.25 on average. The difference in the mean score was 2.75, indicating a reduced variation in the ranks of the indicators. The reduction in the variation is due to the fact that the respondents ranking of the indicators improved.

**Table 4.3: Level of agreement among architects round one of Delph**

| Criterion | Mean | SD | RK |
|---|---|---|---|
| Education and awareness | 5.00 | 0.000 | 1 |
| Land use and impacts on ecology | 4.75 | 0.500 | 2 |
| Access to public transport | 4.75 | 0.500 | 2 |
| Building form and orientation | 4.75 | 0.500 | 2 |
| Useful floor space | 4.75 | 0.500 | 2 |
| Parking capacity | 4.75 | 0.500 | 2 |
| Day lighting and viewing comfort | 4.75 | 0.500 | 2 |

| | | | |
|---|---|---|---|
| Renewable energy sources use | 4.75 | 0.500 | 2 |
| Safety and security | 4.75 | 0.500 | 2 |
| Access to social, domestic, and socio-economic facilities | 4.50 | 0.577 | 10 |
| Building architectural appearance | 4.5 | 0.577 | 10 |
| Air pollution monitoring | 4.5 | 0.577 | 10 |
| Natural ventilation | 4.5 | 0.577 | 10 |
| Building water conservation | 4.5 | 0.577 | 10 |
| Application of innovative water | 4.5 | 0.577 | 10 |
| Water-efficient landscaping and | 4.5 | 0.577 | 10 |
| Energy-efficient heating and coo | 4.5 | 0.577 | 10 |
| Energy-efficient equipment | 4.5 | 0.577 | 10 |
| Energy saving Reduction of electricity | 4.5 | 0.577 | 10 |
| Local/regional building materials | 4.5 | 0.577 | 10 |
| Building total lifecycle costs | 4.5 | 0.577 | 10 |
| Affordability | 4.5 | 0.577 | 10 |
| Safety and inclusiveness of opportunities | 4.25 | 0.500 | 23 |
| Leak detection | 4.25 | 0.500 | 23 |
| Construction and demolition waste management) | 4.25 | 0.500 | 23 |
| Annual operating costs | 4.25 | 0.500 | 23 |
| User health | 4.00 | 1.414 | 27 |
| Acoustic comfort | 3.50 | 1.000 | 28 |
| Secondary use of recycled materials | 3.50 | 1.000 | 28 |
| Visual comfort | 3.00 | 1.155 | 30 |
| Building operation and disposal impacts | 3.00 | 1.155 | 30 |
| Thermal comfort | 2.50 | 0.577 | 32 |
| Energy saving - natural gas efficiency | 2.50 | 1.000 | 32 |
| Landscape irrigation | 2.25 | 1.258 | 34 |
| **Number of respondents** | | | **4** |
| **Kendall`s coefficient of Concordance** | | | **0.506** |
| **Chi-square** | | | **66.791** |
| **Degree of Freedom** | | | **33** |
| **Significance level** | | | **0** |
| **$H_0$: No agreement** | | | **Reject $H_0$** |

**Environmentalists**

The level of agreement among the environmentalists (2 participants) to sustainability indicators was very high (W=0.707). The agreement between the opinions of the raters (environmentalists) was statistically not significant as the chi-square value computed is greater than tabulated statistical value (p=0.058) at 0.05 and 0.01 level of significance with a degree of freedom 33. The environmentalists in Delphi round one ranked access to social, domestic, and socio-economic facilities, access to public transport, building total lifecycle costs and safety and security as the most essential sustainability indicators scoring a mean value of 5.00 on average. The least ranked included; thermal comfort, acoustic comfort, energy saving-natural gas efficiency, secondary use of recycled materials, with a mean score value of 2.00 on average while building operation and disposal impacts had the lowest mean score of 1.50. The difference in the mean score was 3.50, indicating a wide variation in the ranks of the indicators.

**Table 4.4: Level of agreement among environmentalists round one of Delph**

| Criterion | Mean | SD | RK |
|---|---|---|---|
| Access to social, domestic, and socio-economic facilities | 5.00 | 0.000 | 1 |
| Access to public transport | 5.00 | 0.000 | 1 |
| Building total lifecycle costs | 5.00 | 0.000 | 1 |
| Safety and security | 5.00 | 0.000 | 1 |
| Land use and impacts on ecology | 4.50 | 0.707 | 5 |
| Building architectural appearance | 4.50 | 0.707 | 5 |
| Useful floor space | 4.50 | 0.707 | 5 |
| Parking capacity | 4.50 | 0.707 | 5 |
| Safety and inclusiveness of opportunities | 4.50 | 0.707 | 5 |
| Day lighting and viewing comfort | 4.50 | 0.707 | 5 |
| User health | 4.50 | 0.707 | 5 |
| Energy-efficient equipment | 4.50 | 0.707 | 5 |
| Energy saving Reduction of electricity | 4.50 | 0.707 | 5 |
| Local/regional building materials | 4.50 | 0.707 | 5 |
| Annual operating costs | 4.50 | 0.707 | 5 |
| Landscape irrigation | 4.00 | 0.000 | 16 |
| Building form and orientation | 4.00 | 0.000 | 16 |
| Natural ventilation | 4.00 | 0.000 | 16 |
| Building water conservation | 4.00 | 0.000 | 16 |
| Application of innovative water | 4.00 | 0.000 | 16 |
| Leak detection | 4.00 | 0.000 | 16 |
| Water-efficient landscaping and | 4.00 | 0.000 | 16 |
| Renewable energy sources use | 4.00 | 1.414 | 16 |
| Energy-efficient heating and cooling | 4.00 | 0.000 | 16 |
| Construction and demolition waste management | 4.00 | 0.000 | 16 |
| Affordability | 4.00 | 1.414 | 16 |
| Education and awareness | 4.00 | 0.000 | 16 |
| Visual comfort | 3.00 | 1.414 | 28 |
| Air pollution monitoring | 3.00 | 1.414 | 28 |
| Thermal comfort | 2.50 | 0.707 | 30 |
| Acoustic comfort | 2.00 | 0.000 | 31 |
| Energy saving Natural gas efficiency | 2.00 | 0.000 | 31 |
| Secondary use of recycled materials | 2.00 | 0.000 | 31 |
| Building operation and disposal impacts | 1.50 | 0.707 | 34 |
| **Number of respondents** | | | **2** |
| **Kendall`s coefficient of Concordance** | | | **0.707** |
| **Chi-square** | | | **46.63** |
| **Degree of Freedom** | | | **33** |
| **Significance level** | | | **0.058** |
| **$H_0$: No agreement** | | | **Accept $H_0$** |

**Mechanical engineers**

The level of agreement among the mechanical engineers (5 participants in Table 4.5) to sustainability indicators was very high (W=0.619). The agreement between the opinions of the raters (mechanical engineers) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.000) at 0.05 and 0.01 level of significance with a degree of freedom 33. The mechanical engineers in Delphi round one ranked land use, access to social, domestic, and socio-economic facilities, access to public transport, building total lifecycle costs, as the most essential sustainability indicators scoring a mean value of 5.00 on average. The least ranked included: energy saving-natural gas efficiency, building operation and disposal impacts, with a mean score value of 2.00 on average. The difference in the mean score was 3.00, indicating a wide variation in the ranks of the indicators.

**Table 4.5: Level of agreement among mechanical engineers round one of Delph**

| Criterion | Mean | SD | RK |
|---|---|---|---|
| Land use and impacts on ecology | 5.00 | 0.000 | 1 |
| Access to social, domestic, and socio-economic facilities | 5.00 | 0.000 | 1 |
| Access to public transport | 5.00 | 0.000 | 1 |
| Building total lifecycle costs | 5.00 | 0.00 | 1 |
| Day lighting and viewing comfort | 4.80 | 0.447 | 5 |
| Local/regional building materials | 4.80 | 0.447 | 5 |
| Annual operating costs | 4.80 | 0.447 | 5 |
| Useful floor space | 4.60 | 0.548 | 8 |
| Safety and inclusiveness of opportunities | 4.60 | 0.548 | 8 |
| Natural ventilation | 4.60 | 0.548 | 8 |
| Energy-efficient equipment | 4.60 | 0.548 | 8 |
| Building architectural appearance | 4.40 | 0.548 | 12 |
| Building form and orientation | 4.40 | 0.548 | 12 |
| Parking capacity | 4.40 | 0.548 | 12 |
| Leak detection | 4.40 | 0.548 | 12 |
| Energy saving Reduction of electricity | 4.40 | 0.548 | 12 |
| Construction and demolition waste management | 4.40 | 0.548 | 12 |
| Affordability | 4.40 | 0.548 | 12 |
| Safety and security | 4.40 | 0.548 | 12 |
| Education and awareness | 4.40 | 0.548 | 12 |
| Visual comfort | 4.20 | 0.837 | 21 |
| Building water conservation | 4.20 | 0.447 | 21 |
| Application of innovative water | 4.20 | 0.447 | 21 |
| Water-efficient landscaping and irrigation | 4.20 | 0.447 | 21 |
| Energy-efficient heating and cooling | 4.20 | 0.447 | 21 |
| Air pollution monitoring | 4.00 | 0.707 | 26 |
| User health | 4.00 | 1.225 | 26 |
| Landscape irrigation | 3.80 | 0.447 | 28 |
| Renewable energy sources use | 3.80 | 0.837 | 28 |
| Acoustic comfort | 3.20 | 1.095 | 30 |
| Secondary use of recycled materials | 2.80 | 1.095 | 31 |
| Thermal comfort | 2.20 | 0.447 | 32 |
| Energy saving Natural gas efficiency | 2.00 | 0.000 | 33 |
| Building operation and disposal impacts | 2.00 | 1.225 | 33 |
| **Number of respondents** | | | **5** |
| **Kendall`s coefficient of Concordance** | | | **0.619** |
| **Chi-square** | | | **102.097** |
| **Degree of Freedom** | | | **33** |
| **Significance level** | | | **0** |
| **$H_0$: No agreement** | | | **Reject $H_0$** |

### Quantity surveyors

The level of agreement among the quantity surveyors (10 participants) to sustainability indicators was moderate (W=0.48). The agreement between the opinions of the raters (quantity surveyors) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.000) at 0.05 and 0.01 level of significance with a degree of freedom 33. The quantity surveyors in Delphi round one ranked building form and orientation, building total lifecycle costs, safety and security, as the most essential sustainability indicators scoring a mean value of 4.80 on average. The least ranked included building operation and disposal impacts, energy saving-natural gas efficiency, with a mean score value of 2.40 on average while thermal comfort, with a mean score value of 2.3 on average is the lowest ranked indicator according to quantity surveyors. The difference in the mean score was 2.50, indicating a wide variation in the ranks of the indicators. As the number of participants increases, Kendall`s coefficient of Concordance values become lower (Gisev, Bell and Chen 2013). This is true as seen in Table 4.6. With ten (10) experts in the quantity surveying group, the W value was 0.482, which is low in comparison with the other expert groups.

**Table 4.6: Level of agreement among quantity surveyors round one of Delph**

| Criterion | Mean | SD | RK |
|---|---|---|---|
| Building form and orientation | 4.80 | 0.422 | 1 |
| Building total lifecycle costs | 4.80 | 0.422 | 1 |
| Safety and security | 4.80 | 0.422 | 1 |
| Day lighting and viewing comfort | 4.70 | 0.675 | 4 |
| Land use and impacts on ecology | 4.60 | 0.516 | 5 |
| Building architectural appearance | 4.60 | 0.516 | 5 |
| Access to social, domestic, and socio-economic facilities | 4.50 | 0.707 | 7 |
| Access to public transport | 4.50 | 0.527 | 8 |
| Parking capacity | 4.50 | 0.527 | 8 |
| Energy-efficient heating and cooling | 4.50 | 0.527 | 8 |
| Energy-efficient equipment | 4.50 | 0.527 | 8 |
| Energy saving Reduction of electricity | 4.50 | 0.527 | 8 |
| Construction and demolition waste management | 4.50 | 0.527 | 8 |
| Annual operating costs | 4.50 | 0.527 | 8 |
| Building water conservation | 4.40 | 0.516 | 15 |
| Application of innovative water | 4.40 | 0.516 | 15 |
| Safety and inclusiveness of opportunities | 4.40 | 0.699 | 17 |
| Useful floor space | 4.30 | 0.483 | 18 |
| Water-efficient landscaping and irrigation | 4.30 | 0.483 | 18 |
| Natural ventilation | 4.30 | 0.483 | 20 |
| Local/regional building materials | 4.30 | 0.483 | 20 |
| Renewable energy sources use | 4.30 | 0.823 | 22 |
| Education and awareness | 4.20 | 0.422 | 23 |
| Leak detection | 4.10 | 0.316 | 24 |
| Visual comfort | 3.70 | 1.252 | 25 |
| Affordability | 3.60 | 0.843 | 26 |
| Landscape irrigation | 3.30 | 1.160 | 27 |
| Air pollution monitoring | 3.30 | 1.059 | 27 |
| User health | 3.30 | 1.160 | 27 |
| Acoustic comfort | 2.80 | 1.033 | 30 |
| Secondary use of recycled materials | 2.80 | 1.033 | 30 |
| Building operation and disposal impacts | 2.40 | 1.174 | 32 |
| Energy saving Natural gas efficiency | 2.40 | 0.843 | 33 |
| Thermal comfort | 2.30 | 0.483 | 34 |
| **Number of respondents** | | | **10** |
| **Kendall`s coefficient of Concordance** | | | **0.482** |
| **Chi-square** | | | **159.031** |
| **Degree of Freedom** | | | **33** |
| **Significance level** | | | **0** |
| **$H_0$: No agreement** | | | **Reject $H_0$** |

### Structural engineers

The level of agreement among the structural engineers (3 participants) to sustainability indicators was moderately high (W=0.607). The agreement between the opinions of the raters (structural engineers) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.003) at 0.05 and 0.01 level of significance with a degree of freedom 33. The structural engineers in Delphi round one ranked access to social, domestic, and socio-economic facilities, natural ventilation and safety and security as the most essential sustainability indicators scoring a mean value of 5.00 on average. The least ranked included secondary use of recycled materials with a mean score value of 2.00 on average with thermal comfort, with a mean score value of 1.67 on average was the lowest ranked sustainability indicator according to structural engineers. The difference in the mean score was 3.33, indicating a wider variation in the ranks of the indicators.

**Table 4.7: Level of agreement among structural engineers round one of Delph**

| Criterion | Mean | SD | RK |
|---|---|---|---|
| Access to social, domestic, and socio-economic facilities | 5.00 | 0.000 | 1 |
| Natural ventilation | 5.00 | 0.000 | 1 |
| Safety and security | 5.00 | 0.000 | 1 |
| Building form and orientation | 4.67 | 0.577 | 4 |
| Useful floor space | 4.67 | 0.577 | 4 |
| Parking capacity | 4.67 | 0.577 | 4 |
| Safety and inclusiveness of opportunities | 4.67 | 0.577 | 4 |
| Day lighting and viewing comfort | 4.67 | 0.577 | 4 |
| Renewable energy sources use | 4.67 | 0.577 | 4 |
| Local/regional building materials | 4.67 | 0.577 | 4 |
| Annual operating costs | 4.67 | 0.577 | 4 |
| Land use and impacts on ecology | 4.33 | 0.577 | 12 |
| Access to public transport | 4.33 | 0.577 | 12 |
| Visual comfort | 4.33 | 0.577 | 12 |
| Building architectural appearance | 4.33 | 0.577 | 12 |
| Air pollution monitoring | 4.33 | 0.577 | 12 |
| Building water conservation | 4.33 | 0.577 | 12 |
| Application of innovative water | 4.33 | 0.577 | 12 |
| Water-efficient landscaping and irrigation | 4.33 | 0.577 | 12 |
| Energy-efficient heating and coo | 4.33 | 0.577 | 12 |
| Affordability | 4.33 | 1.155 | 12 |
| Leak detection | 4.00 | 0.000 | 22 |
| Energy-efficient equipment | 4.00 | 0.000 | 22 |
| Energy saving Reduction of electricity | 4.00 | 0.000 | 22 |
| Construction and demolition waste management | 4.00 | 0.000 | 22 |
| Education and awareness | 4.00 | 0.000 | 22 |
| User health | 3.67 | 1.528 | 27 |
| Building total lifecycle costs | 3.67 | 1.528 | 27 |
| Acoustic comfort | 3.33 | 1.155 | 29 |
| Building operation and disposal impacts | 3.33 | 1.155 | 29 |
| Landscape irrigation | 2.67 | 1.155 | 31 |
| Energy saving Natural gas efficiency | 2.67 | 1.155 | 31 |
| Secondary use of recycled materials | 2.00 | 0.000 | 33 |
| Thermal comfort | 1.67 | 0.577 | 34 |
| **Number of respondents** | | | **3** |
| **Kendall`s coefficient of Concordance** | | | **0.607** |
| **Chi-square** | | | **60.084** |
| **Degree of Freedom** | | | **33** |
| **Significance level** | | | **0.003** |
| **$H_0$: No agreement** | | | **Reject $H_0$** |

**Urban planners**

The level of agreement among the urban planners (3 participants) to sustainability indicators was very high (W=0.70). The agreement between the opinions of the raters (urban planners) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.003) at 0.05 and 0.01 level of significance with a degree of freedom 33. The urban planners in Delphi round one ranked building form and orientation, safety and inclusiveness of opportunities, natural ventilation, user health, leak detection, renewable energy sources use, energy saving-reduction of electricity, annual operating costs and safety and security, as the most essential sustainability indicators scoring a mean value of 5.00 on average. The least ranked included thermal comfort, Acoustic comfort, energy saving-natural gas efficiency, and secondary use of recycled material, with a mean score value of 2.67 on average. The difference in the mean score was 2.33, indicating a less wide variation in the ranks of the indicators.

**Table 4.8: Level of agreement among urban planners round one of Delph**

| Criterion | Mean | SD | RK |
|---|---|---|---|
| Building form and orientation | 5.0 | 0.000 | 1 |
| Safety and inclusiveness of opportunities | 5.0 | 0.000 | 1 |
| Natural ventilation | 5.0 | 0.000 | 1 |
| User health | 5.0 | 0.000 | 1 |
| Leak detection | 5.0 | 0.000 | 1 |
| Renewable energy sources use | 5.0 | 0.000 | 1 |
| Energy saving Reduction of electricity | 5.0 | 0.000 | 1 |
| Annual operating costs | 5.0 | 0.000 | 1 |
| Safety and security | 5.0 | 0.000 | 1 |
| Land use and impacts on ecology | 4.67 | 0.577 | 10 |
| Access to public transport | 4.67 | 0.577 | 10 |
| Building architectural appearance | 4.67 | 0.577 | 10 |
| Parking capacity | 4.67 | 0.577 | 10 |
| Day lighting and viewing comfort | 4.67 | 0.577 | 10 |
| Application of innovative water | 4.67 | 0.577 | 10 |
| Energy-efficient equipment | 4.67 | 0.577 | 10 |
| Local/regional building materials | 4.67 | 0.577 | 10 |
| Access to social, domestic, and socio-economic facilities | 4.33 | 1.155 | 18 |
| Visual comfort | 4.33 | 0.577 | 18 |
| Useful floor space | 4.33 | 0.577 | 18 |
| Building water conservation | 4.33 | 0.577 | 18 |
| Energy-efficient heating and cooling | 4.33 | 0.577 | 18 |
| Building total lifecycle costs | 4.33 | 0.577 | 18 |
| Air pollution monitoring | 4.0 | 1.000 | 24 |
| Water-efficient landscaping and | 4.0 | 0.000 | 24 |
| Construction and demolition waste management | 4.0 | 0.000 | 24 |
| Education and awareness | 4.0 | 0.000 | 24 |
| Affordability | 3.67 | 1.155 | 28 |
| Landscape irrigation | 3.33 | 1.155 | 29 |
| Building operation and disposal impacts | 3.33 | 1.155 | 29 |
| Thermal comfort | 2.67 | 0.577 | 31 |
| Acoustic comfort | 2.67 | 1.155 | 31 |
| Energy saving Natural gas efficiency | 2.67 | 1.155 | 31 |
| Secondary use of recycled material | 2.67 | 1.155 | 31 |
| **Number of respondents** | | | **3** |
| **Kendall`s coefficient of Concordance** | | | **0.7** |
| **Chi-square** | | | **69.317** |
| **Degree of Freedom** | | | **33** |

| Significance level | 0 |
|---|---|
| $H_0$: No agreement | Reject $H_0$ |

**All experts**

The level of agreement among the experts (30 participants) to sustainability indicators was moderate (W=0.444). The agreement between the opinions of the raters (all experts) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.000) at 0.05 and 0.01 level of significance with a degree of freedom 33. All experts in Delphi round one ranked safety and security, land use, access to public transport, building total lifecycle costs and building form and orientation as the most essential sustainability indicators scoring a mean value of 4.73, 4.70, 4.67, 4.67, 4.67 on average respectively. The least ranked included secondary use of recycled materials, building operation and disposal impacts, energy saving-natural gas efficiency, and thermal comfort, with a mean score value of 2.67, 2.50, 2.47 and 2.30 on average respectively. The difference in the mean score was 2.43, indicating a less wide variation in the ranks of the indicators.

**Table 4.9: Level of agreement among all experts for round one of Delphi**

| Criterion | Mean | SD | RK |
|---|---|---|---|
| Safety and security | 4.73 | 0.45 | 1 |
| Land use and impacts on ecology | 4.70 | 0.466 | 2 |
| Access to public transport | 4.67 | 0.479 | 3 |
| Building total lifecycle costs | 4.67 | 0.661 | 3 |
| Building form and orientation | 4.67 | 0.479 | 3 |
| Annual operating costs | 4.60 | 0.498 | 6 |
| Access to social, domestic, and socio-economic facilities | 4.60 | 0.621 | 7 |
| Day lighting and viewing comfort | 4.60 | 0.675 | 7 |
| Parking capacity | 4.57 | 0.504 | 9 |
| Safety and inclusiveness of opportunities | 4.57 | 0.568 | 9 |
| Local/regional building materials | 4.53 | 0.507 | 11 |
| Building architectural appearance | 4.50 | 0.509 | 12 |
| Energy saving Reduction of electricity | 4.50 | 0.509 | 12 |
| Natural ventilation | 4.50 | 0.509 | 14 |
| Energy-efficient equipment | 4.50 | 0.509 | 14 |
| Useful floor space | 4.47 | 0.507 | 16 |
| Building water conservation | 4.37 | 0.49 | 17 |
| Application of innovative water | 4.37 | 0.49 | 18 |
| Renewable energy sources use | 4.33 | 0.802 | 19 |
| Energy-efficient heating and cooling | 4.33 | 0.479 | 19 |
| Construction and demolition waste management | 4.33 | 0.479 | 19 |
| Education and awareness | 4.30 | 0.466 | 22 |
| Leak detection | 4.27 | 0.45 | 23 |
| Water-efficient landscaping and irrigation | 4.23 | 0.43 | 24 |
| Affordability | 4.00 | 0.871 | 25 |
| User health | 3.90 | 1.155 | 26 |
| Visual comfort | 3.77 | 1.04 | 27 |
| Air pollution monitoring | 3.77 | 0.971 | 28 |
| Landscape irrigation | 3.17 | 1.085 | 29 |
| Acoustic comfort | 3.00 | 1.017 | 30 |
| Secondary use of recycled materials | 2.67 | 0.959 | 31 |
| Building operation and disposal impacts | 2.50 | 1.137 | 32 |
| Energy saving Natural gas efficiency | 2.47 | 0.86 | 33 |
| Thermal comfort | 2.30 | 0.535 | 34 |
| **Number of respondents** | | **30** | |

| | |
|---|---|
| **Kendall`s coefficient of Concordance** | **0.444** |
| **Chi-square** | **439.322** |
| **Degree of Freedom** | **33** |
| **Significance level** | **0** |
| **$H_0$: No agreement** | **Reject $H_0$** |

### 4.4.2 Validation of expert`s agreement with IRA and ANOVA

One-way ANOVA was performed to compare the mean differences among the expert groups with construction sustainability indicators. The ANOVA results revealed that there was not a significant difference ($P<0.05$) in mean ranks for the expert`s groups with most of the indicators, apart from education and awareness where mean difference was found to be statistically significant. The absence of difference in the mean scores for the groups shows that expert`s opinions were in the same interval. Moreover, the Inter-Rater Agreement results deduced that the level of agreement among experts with particular indicator ranged between 0.35 (weak agreement) to 0.82 (strong agreement); it was found that the level of consensus among the experts was strong for nine (9) indicators, moderate agreement for fourteen (14) indicators, weak agreement for eight (8) indicators, and three (3) indicators where participants did not have agreement.

**Table 4.10: Validation of expert`s level of agreement for Delphi one**

| | | | ANOVA | |
|---|---|---|---|---|
| **Criterion** | **IRA** | **Agreement level** | **F** | **Sig.** |
| Land use and impacts on ecology | 0.595 | Moderate Agreement | 1.273 | 0.308 |
| Access to social, domestic, and socio-economic facilities | 0.445 | Weak Agreement | 1.167 | 0.36 |
| Access to public transport | 0.611 | Moderate Agreement | 0.848 | 0.561 |
| Landscape irrigation | 0.386 | Weak Agreement | 1.044 | 0.43 |
| Visual comfort | 0.344 | Weak Agreement | 1.162 | 0.363 |
| Building architectural appearance | 0.694 | Moderate Agreement | 0.429 | 0.874 |
| Building form and orientation | 0.611 | Moderate Agreement | 1.148 | 0.371 |
| Useful floor space | 0.712 | Strong Agreement | 0.736 | 0.644 |
| Parking capacity | 0.660 | Moderate Agreement | 0.447 | 0.862 |
| Safety and inclusiveness of opportunity | 0.568 | Moderate Agreement | 1.053 | 0.425 |
| Thermal comfort | 0.831 | Strong Agreement | 1.278 | 0.306 |
| Day lighting and viewing comfort | 0.346 | Weak Agreement | 1.156 | 0.366 |
| Acoustic comfort | 0.465 | Weak Agreement | 0.569 | 0.773 |
| Air pollution monitoring | 0.428 | Weak Agreement | 1.523 | 0.211 |
| Natural ventilation | 0.694 | Moderate Agreement | 1.603 | 0.187 |
| User health | 0.134 | Lack of Agreement | 0.989 | 0.464 |
| Building water conservation | 0.767 | Strong Agreement | 0.389 | 0.899 |
| Application of innovative water | 0.767 | Strong Agreement | 0.389 | 0.899 |
| Leak detection | 0.825 | Strong Agreement | 2.100 | 0.087 |
| Water-efficient landscaping and | 0.846 | Strong Agreement | 0.551 | 0.787 |
| Renewable energy sources use | 0.401 | Weak Agreement | 1.620 | 0.182 |
| Energy-efficient heating and coo | 0.786 | Strong Agreement | 0.577 | 0.767 |
| Energy-efficient equipment | 0.694 | Moderate Agreement | 0.764 | 0.623 |
| Energy saving-reduction of electricity | 0.694 | Moderate Agreement | 1.249 | 0.319 |
| Energy saving Natural gas efficiency | 0.588 | Moderate Agreement | 0.735 | 0.645 |
| Local/regional building materials | 0.677 | Moderate Agreement | 0.835 | 0.57 |
| Secondary use of recycled material | 0.511 | Moderate Agreement | 1.034 | 0.436 |
| Construction and demolition waste management) | 0.786 | Strong Agreement | 0.952 | 0.488 |

| | | | | |
|---|---|---|---|---|
| Building operation and disposal impact | 0.287 | Lack of Agreement | 1.107 | 0.393 |
| Building total lifecycle costs | 0.261 | Lack of Agreement | 1.875 | 0.123 |
| Annual operating costs | 0.643 | Moderate Agreement | 1.061 | 0.42 |
| Affordability | 0.477 | Weak Agreement | 1.197 | 0.345 |
| Safety and security | 0.580 | Moderate Agreement | 1.230 | 0.329 |
| Education and awareness | 0.805 | Strong Agreement | 2.569 | 0.043 |

Experts had a moderate consensus on Land use and impacts on ecology being sustainability indicator in Ugandan construction industry (IRA=0.595), with no differences in the mean ranks of expert's groups (F=1.273, p-value=0.308), weak consensus on access to social, domestic and socio-economic facilities (IRA=0.445) with no differences in the mean ranks (F=1.167, p-value=0.360), moderate agreement on access to public transport (IRA=0.611), with no differences in the mean ranks (F=0.848, p-value=0.561), weak agreement on landscape irrigation (IRA=0.386), with no differences in the mean ranks (F=1.044, p-value=0.430), weak agreement on visual comfort (IRA=0.344), with no differences in the mean ranks (F=1.162, p-value=0.363), moderate agreement on building architectural appearance (IRA=0.694), with no differences in the mean ranks (F=0.429, p-value=0.874), moderate agreement on building form and orientation (IRA=0.611), with no differences in the mean ranks (F=1.148, p-value=0.371), strong agreement on useful floor space (IRA=0.712), with no differences in the mean ranks (F=0.736, p-value=0.644), moderate agreement on parking capacity (IRA=0.660), with no differences in the mean ranks (F=0.447, p-value=0.862), moderate agreement on safety and inclusiveness of opportunity (IRA=0.568), with no differences in the mean ranks (F=1.053, p-value=0.425), strong agreement on thermal comfort (IRA=0.831), with no differences in the mean ranks (F=1.278, p-value=0.306), weak agreement on Day lighting and viewing comfort(IRA=0.346), with no differences in the mean ranks (F=1.156, p-value=0.366), weak agreement on acoustic comfort (IRA=0.465), with no differences in the mean ranks (F=0.569, p-value=0.773), weak agreement on air pollution monitoring (IRA=0.428), with no differences in the mean ranks (F=1.523, p-value=0.211).

Moderate agreement on natural ventilation (IRA=0.694), with no differences in the mean ranks (F=1.603, p-value=0.187), lack of agreement on user health (IRA=0.134), with no differences in the mean ranks (F=0.989, p-value=0.464), strong agreement on building water conservation (IRA=0.767), with no differences in the mean ranks (F=0.389, p-value=0.899), strong agreement on application of innovative water (IRA=0.767), with no differences in the mean ranks (F=0.389, p-value=0.899), strong agreement on leak detection (IRA=0.825), with no differences in the mean ranks (F=2.100, p-value=0.087), strong agreement on water-efficient landscaping and irrigation (IRA=0.846), with no differences in the mean ranks (F=0.551, p-value=0.787), weak agreement on renewable energy sources use (IRA=0.401), with no differences in the mean ranks (F=1.620, p-value=0.182), strong agreement on Energy-efficient heating and cooling (IRA=0.786), with no differences in the mean ranks (F=0.577, p-value=0.767), moderate agreement on Energy-efficient equipment (IRA=0.694), with no differences in the mean ranks (F=0.764, p-value=0.623), moderate agreement on energy saving (IRA=0.694), with no differences in the mean ranks (F=1.249, p-value=0.645), moderate agreement on energy saving-reduction of electricity (IRA=0.694), with no differences in the mean ranks (F=1.249, p-value=0.645), moderate agreement on energy saving-natural gas efficiency (IRA=0.588), with no differences in the mean ranks (F=0.735, p-value=0.645), moderate agreement on Local/regional building materials (IRA=0.677), with no differences in the mean ranks (F=0.835, p-value=0.570).

Moderate agreement on secondary use of recycled materials(IRA=0.786), with no differences in the mean ranks (F=1.034, p-value=0.436), strong agreement on construction and demolition waste management (IRA=0.786), with no differences in the mean ranks (F=0.952, p-value=0.488), lack of agreement on building operation and disposal impact(IRA=0.287), with no differences in the mean ranks (F=1.107, p-value=0.393), moderate agreement on building total lifecycle costs (IRA=0.261), with no differences in the mean ranks (F=1.875, p-value=0.123), moderate agreement on annual operating costs (IRA=0.643), with no differences in the mean ranks (F=1.061, p-value=0.420), weak agreement on affordability (IRA=0.477), with no differences in the mean ranks (F=1.197, p-value=0.345), moderate agreement on safety and security (IRA=0.580), with no differences in the mean ranks (F=1.230, p-value=0.329), and, strong agreement on education and awareness (IRA=0.805), with no differences in the mean ranks (F=2.569, p-value=0.043).

#### 4.4.3 Ranking based on significance grading and IRA analysis

The indicators were ranked on the basis of significance level; from the extremely important to somewhat important. The first eleven indicators were extremely important, however, the experts had moderate consensus among the 1$^{st}$-4$^{th}$ indicators, no agreement among the experts for the 5$^{th}$ indicator irrespective of it being extremely important, moderate consensus for the 6$^{th}$ indicator, weak consensus for the 7$^{th}$ – 8$^{th}$ indicator. For the 9$^{th}$ 11$^{th}$ indicator, the experts had moderate consensus, and three indicators were considered to be somewhat important in the last positions. These findings are presented in Table 4.11.

**Table 4.11: Ranking of Criteria for round one of Delphi**

| Criterion | RK | Agreement Level | Significance grade |
|---|---|---|---|
| Safety and security | 1 | Moderate Agreement | Extremely Important |
| Land use and impacts on ecology | 2 | Moderate Agreement | Extremely Important |
| Access to public transport | 3 | Moderate Agreement | Extremely Important |
| Building form and orientation | 3 | Moderate Agreement | Extremely Important |
| Building total lifecycle costs | 5 | Lack of Agreement | Extremely Important |
| Annual operating costs | 6 | Moderate Agreement | Extremely Important |
| Access to social, domestic, and socio-economic facilities | 7 | Weak Agreement | Extremely Important |
| Day lighting and viewing comfort | 8 | Weak Agreement | Extremely Important |
| Parking capacity | 9 | Moderate Agreement | Extremely Important |
| Safety and inclusiveness of opportunity | 10 | Moderate Agreement | Extremely Important |
| Local/regional building materials | 11 | Moderate Agreement | Extremely Important |
| Building architectural appearance | 12 | Moderate Agreement | Very Important |
| Natural ventilation | 12 | Moderate Agreement | Very Important |
| Energy-efficient equipment | 12 | Moderate Agreement | Very Important |
| Energy saving Reduction of electricity | 12 | Moderate Agreement | Very Important |
| Useful floor space | 16 | Strong Agreement | Very Important |
| Building water conservation | 17 | Strong Agreement | Very Important |
| Application of innovative water | 17 | Strong Agreement | Very Important |
| Energy-efficient heating and cooling | 19 | Strong Agreement | Very Important |
| Construction and demolition waste management | 19 | Strong Agreement | Very Important |
| Renewable energy sources use | 21 | Weak Agreement | Very Important |
| Education and awareness | 22 | Strong Agreement | Very Important |
| Leak detection | 23 | Strong Agreement | Very Important |
| Water-efficient landscaping and irrigation | 24 | Strong Agreement | Very Important |
| Affordability | 25 | Weak Agreement | Very Important |
| User health | 26 | Lack of Agreement | Very Important |
| Air pollution monitoring | 27 | Weak Agreement | Very Important |
| Visual comfort | 28 | Weak Agreement | Very Important |
| Landscape irrigation | 29 | Weak Agreement | Important |
| Acoustic comfort | 30 | Weak Agreement | Important |
| Secondary use of recycled material | 31 | Moderate Agreement | Important |
| Building operation and disposal impacts | 32 | Lack of Agreement | Somewhat important |
| Energy saving Natural gas efficiency | 33 | Moderate Agreement | Somewhat important |
| Thermal comfort | 34 | Strong Agreement | Somewhat important |

From the analysis, safety and security were extremely important with moderate consensus among the experts, Land use and impacts on ecology was ranked second with extreme importance and moderate agreement among the experts, access to public transport in the third position with extreme importance and moderate agreement. Building form and orientation followed with extreme importance and moderate agreement among the experts. Building total lifecycle costs were extremely important but with no agreement among the experts. Annual operating costs were of extreme importance with moderate agreement among the experts. Access to social, domestic, and socio-economic facilities and Day lighting and viewing comfort indicators were extremely important despite the weak agreement among the experts. Indicators including parking capacity, safety and inclusiveness of opportunity, local/regional building materials were extremely important with moderate agreement by the experts. Building architectural appearance, natural ventilation, energy-efficient equipment, energy saving-reduction of electricity, occupied the 12$^{th}$ position and were all very important with a moderate level of agreement by the experts. Useful floor space, building water conservation, application of innovative water, energy-efficient heating and cooling, and construction and demolition waste management followed closely and were very important with strong agreement among the experts. Renewable energy sources use indicator had a weak level of agreement among the experts but of very important significance.

Furthermore, education and awareness, leak detection and water-efficient landscaping and irrigation indicators were very important with a strong level of agreement among the experts. However, the affordability indicator was very important with a weak level of agreement among the experts. Additionally, from the analysis, user health was very important but lacked agreement from the experts. More so, air pollution monitoring and visual comfort indicators had a weak agreement among the experts but with a very important significance. Three indicators were graded important including landscape irrigation, acoustic comfort and secondary use of recycled materials. However, landscape irrigation, and acoustic comfort had a weak level of agreement while secondary use of recycled materials had a moderate level of agreement among the experts. Building operation and disposal impacts, energy saving-natural gas efficiency and thermal comfort were graded somewhat important with thermal comfort having a strong level of agreement among the experts' while energy saving-natural gas efficiency had a moderate agreement and building operation and disposal impacts indicator had no agreement among the experts.

After Delphi study round one, the experts suggested additional sustainability indicators, including building height (social), Rewarding sustainability points and incentivising compliant buildings (environmental), Building regulations and bye laws (environmental), Geo-technical aspects of the construction site (environmental), and Universal design thinking (social). These five sustainability assessment indicators were included in Delph round two as shown in the next tables.

### 4.4.4 Round two of Delphi

**Academicians**

The level of agreement among the academicians shown in table 4.12 (3 participants) to sustainability indicators was very high (W=0.675). The level of agreement improved from 0.611 in round one to 0.675 in round two as participants got a better understanding of the indicators. The agreement between the opinions of the raters (academicians) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.000) at 0.05 and 0.01 level of significance with a degree of freedom 38. The academicians in Delphi round two ranked ENV-1 (land use), ENV-3 (Building form and orientation), ENV-4 (Parking capacity), SOC-6 (Safety and inclusiveness of opportunity), ENV-22 (Building total lifecycle costs), as the most essential sustainability indicators scoring a mean value of 5.00 on average. In round two, indicators like ENV-3, ENV-4 improved in ranking and the mean for both improved from 4.67 to 5. The least ranked included; ENV-19 (Secondary use of recycled materials), ENV-21 (Building operation and disposal impacts), ENV-25 (Rewarding sustainability points and incentivising compliant buildings). ENV-25 came up as a result of additional indicators that participants added after round one. Indicators like secondary use of recycled materials and building operation and disposal with a mean score value of 2.00 on average remained ranked the least with the exception of thermal comfort whose mean improved from 2 in round one to 2.33 in round 2. The difference in the mean score was 3.00, indicating a wide variation in the ranks of the indicators.

**Table 4.12: Level of agreement among academicians round two of Delphi**

| Criterion | Code | Mean | Std. Deviation | RK |
|---|---|---|---|---|
| Land use | ENV-1 | 5.00 | 0.000 | 1 |
| Building form and orientation | ENV-3 | 5.00 | 0.000 | 1 |
| Parking capacity | ENV-4 | 5.00 | 0.000 | 1 |
| Safety and inclusiveness of opportunities | SOC-6 | 5.00 | 0.000 | 1 |
| Building total lifecycle costs | ENV-22 | 5.00 | 0.000 | 1 |
| Access to public transport | SOC-2 | 4.67 | 0.577 | 6 |
| Natural ventilation | ENV-8 | 4.67 | 0.577 | 6 |
| Building water conservation | ENV-10 | 4.67 | 0.577 | 6 |
| Energy-efficient equipment | ENV-15 | 4.67 | 0.577 | 6 |
| Construction and demolition waste management | ENV-20 | 4.67 | 0.577 | 6 |
| Annual operating costs | ECO-1 | 4.67 | 0.577 | 6 |
| Safety and security | ECO-3 | 4.67 | 0.577 | 6 |
| Education and awareness | ECO-4 | 4.67 | 0.577 | 6 |
| Access to social, domestic and socio-economic facilities | SOC-1 | 4.33 | 0.577 | 14 |
| Useful floor space | SOC-5 | 4.33 | 0.577 | 14 |
| Day lighting | ENV-6 | 4.33 | 0.577 | 14 |
| User health | ENV-9 | 4.33 | 0.577 | 14 |
| Application of innovative water | ENV-11 | 4.33 | 0.577 | 14 |
| Leak detection | ENV-12 | 4.33 | 0.577 | 14 |
| Saving energy-reduction of electricity | ENV-16 | 4.33 | 0.577 | 14 |
| Local/regional building materials | ENV-18 | 4.33 | 0.577 | 14 |
| Affordability | ECO-2 | 4.33 | 0.577 | 14 |
| Visual comfort | SOC-3 | 4.00 | 0.000 | 23 |
| Building architecture and appearance | SOC-4 | 4.00 | 0.000 | 23 |
| Water-efficient landscaping and irrigation | ENV-12 | 4.00 | 0.000 | 23 |
| Renewable energy sources use | ENV-13 | 4.00 | 1.000 | 23 |
| Energy-efficient heating and cooling | ENV-14 | 4.00 | 0.000 | 23 |
| Building heights | SOC-8 | 4.00 | 0.000 | 23 |
| Universal design thinking | SOC-9 | 4.00 | 0.000 | 23 |
| Air pollution monitoring | ENV-7 | 3.67 | 1.155 | 30 |
| Geo-technical aspects of the construction site | ENV-23 | 3.67 | 0.577 | 30 |
| Building regulations and bye laws | ENV-24 | 3.67 | 0.577 | 30 |
| Acoustic comfort | SOC-7 | 3.33 | 1.155 | 33 |
| Energy saving-natural gas efficiency | ENV-17 | 3.33 | 1.155 | 33 |
| Landscape irrigation | ENV-2 | 2.67 | 1.155 | 35 |
| Thermal comfort | ENV-5 | 2.33 | 0.577 | 36 |
| Secondary use of recycled materials | ENV-19 | 2.00 | 0.000 | 37 |
| Building operation and disposal impacts | ENV-21 | 2.00 | 0.000 | 37 |
| Rewarding sustainability points and incentivising compliant buildings | ENV-25 | 2.00 | 0.000 | 37 |
| **N** | | | **3** | |
| **Kendall's W** | | | **0.675** | |
| **Chi-Square** | | | **76.985** | |
| **Df** | | | **38** | |
| **Significance** | | | **0** | |
| **H0: No agreement** | | | **Reject H0** | |

### Architects

The level of agreement among the architects (4 participants) to sustainability indicators was moderately high (W=0.592). The level of agreement improved from 0.506 in round one to 0.592 in round two as participants got a better understanding of the indicators. The agreement between the opinions of the raters (architects) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.000) at 0.05 and 0.01 level of significance with a degree of freedom 38. The architects in Delphi round two ranked education and awareness scoring a mean value of 5.00 as the first most essential sustainability indicator as is in round one. More so, sustainability indicators including: ENV-1 (Land use), SOC-1 (Access to social, domestic, and socio-economic facilities), SOC-2 (Access to public transport), ENV-3 (Building form and orientation), ENV-4 (Parking capacity), ENV-6 (Day lighting), ENV-13 (Renewable energy sources use), as the other most essential sustainability indicators scoring a mean value of 4.75 on average. Indicators including useful floor space, safety and security, that had a mean of 4.75 in round one, dropped in ranking to 4.50, and Access to social, domestic, and socio-economic facilities that had an average mean score of 4.50 improved to 4.75 in round two, hence its inclusion in the indicators ranked number 2. The least ranked included; ENV-5 (Thermal comfort) with average mean 2.50, ENV-17 (Energy saving-natural gas efficiency) with average mean 2.50, ENV-25 (Rewarding sustainability points and incentivising compliant buildings) with average mean 2.50, ENV-2 (Landscape irrigation) with average mean 2.25, ENV-23 (Geo-technical aspects of the construction site) with average mean 2.00, were the lowest ranked sustainability indicators by architects in round two. Rewarding sustainability points and incentivising compliant buildings and Geo-technical aspects of the construction site were added after round one. The difference in the mean score was 3.00, indicating a wide variation in the ranks of the indicators.

**Table 4.13: Level of agreement among architects round two of Delphi**

| Criterion | Code | Mean | Std. Deviation | RK |
|---|---|---|---|---|
| Education and awareness | ECO-4 | 5.00 | 0.000 | 1 |
| Land use | ENV-1 | 4.75 | 0.500 | 2 |
| Access to social, domestic and socio-economic facilities | SOC-1 | 4.75 | 0.500 | 2 |
| Access to public transport | SOC-2 | 4.75 | 0.500 | 2 |
| Building form and orientation | ENV-3 | 4.75 | 0.500 | 2 |
| Parking capacity | ENV-4 | 4.75 | 0.500 | 2 |
| Day lighting | ENV-6 | 4.75 | 0.500 | 2 |
| Renewable energy sources use | ENV-13 | 4.75 | 0.500 | 2 |
| Building architecture and appearance | SOC-4 | 4.50 | 0.577 | 9 |
| Useful floor space | SOC-5 | 4.50 | 0.577 | 9 |
| Air pollution monitoring | ENV-7 | 4.50 | 0.577 | 9 |
| Natural ventilation | ENV-8 | 4.50 | 0.577 | 9 |
| User health | ENV-9 | 4.50 | 0.577 | 9 |
| Building water conservation | ENV-10 | 4.50 | 0.577 | 9 |
| Application of innovative water | ENV-11 | 4.50 | 0.577 | 9 |
| Leak detection | ENV-12 | 4.50 | 0.577 | 9 |
| Energy-efficient heating and cooling | ENV-14 | 4.50 | 0.577 | 9 |
| Energy-efficient equipment | ENV-15 | 4.50 | 0.577 | 9 |
| Local/regional building materials | ENV-18 | 4.50 | 0.577 | 9 |
| Building total lifecycle costs | ENV-22 | 4.50 | 0.577 | 9 |
| Affordability | ECO-2 | 4.50 | 0.577 | 9 |
| Safety and security | ECO-3 | 4.50 | 0.577 | 9 |
| Water-efficient landscaping and irrigation | ENV-12 | 4.25 | 0.500 | 23 |

| | | | | |
|---|---|---|---|---|
| Saving energy-reduction of electricity | ENV-16 | 4.25 | 0.500 | 23 |
| Construction and demolition waste management | ENV-20 | 4.25 | 0.500 | 23 |
| Annual operating costs | ECO-1 | 4.25 | 0.500 | 23 |
| Visual comfort | SOC-3 | 4.0 | 0.000 | 27 |
| Building Regulation and bye laws | ENV-24 | 3.75 | 0.500 | 28 |
| Safety and inclusiveness of opportunities | SOC-6 | 3.50 | 1.000 | 29 |
| Acoustic comfort | SOC-7 | 3.50 | 1.000 | 29 |
| Secondary use of recycled materials | ENV-19 | 3.50 | 1.000 | 29 |
| Building heights | SOC-8 | 3.50 | 1.000 | 29 |
| Building operation and disposal impacts | ENV-21 | 3.00 | 1.155 | 33 |
| Universal design thinking | SOC-9 | 3.00 | 1.155 | 33 |
| Thermal comfort | ENV-5 | 2.50 | 0.577 | 35 |
| Energy saving-natural gas efficiency | ENV-17 | 2.50 | 1.000 | 35 |
| Rewarding sustainability points and incentivising compliant buildings | ENV-25 | 2.50 | 1.000 | 35 |
| Landscape irrigation | ENV-2 | 2.25 | 1.258 | 38 |
| Geo-technical aspects of the construction site | ENV-23 | 2.00 | 1.155 | 39 |
| **N** | | | **4** | |
| **Kendall's W** | | | **0.592** | |
| **Chi-Square** | | | **89.99** | |
| **Df** | | | **38** | |
| **Significance** | | | **0** | |
| **H0: No agreement** | | | **Reject H0** | |

### Environmentalists

The level of agreement among the environmentalists (2 participants) to sustainability indicators was perfect (W=0.802). The level of agreement improved from 0.707 in round one to 0.802 in round two as participants' understanding of the indicators improved as more discussions of the indicators were carried out with the respondents. The agreement between the opinions of the raters (environmentalists) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.011) at 0.05 and 0.01 level of significance with a degree of freedom 38. The opinions of the environmentalists in round one were not significant as it resulted from the fact that the ranking by the experts differed a lot. With proper understanding and improved ranking by the experts, the statistical significance improved in Delph round two. The environmentalists in Delphi round two ranked; SOC-1 (Access to social, domestic, and socio-economic facilities), SOC-2 (Access to public transport), ENV-22 (Building total lifecycle costs), ECO-2 (Affordability), as the most essential sustainability indicators scoring a mean value of 5.00 on average. Three of the above indicators were also the most essential sustainability indicators in round one with the exception of the safety and security indicator whose average mean reduced from 5.00 to 4.00 in round two. It was replaced by affordability whose average mean improved from 4.00 in round one to 5.00 in round two. The least ranked included ENV-21 (Building operation and disposal impacts) with the average mean of 1.50, ENV-23 (Geo-technical aspects of the construction site) with the average mean of 1.00. Geo-technical aspects of the construction site indicator was one of the other indicators suggested by the respondents after Delphi round one, however, it was ranked lowest by environmentalists. The Building operation and disposal impacts indicator maintained its mean score of 1.50 in round one and two. The difference in the mean score was 4.00, indicating a wider variation in the ranks of the indicators.

**Table 4.14: Level of agreement among environmentalists round two of Delphi**

| Criterion | Code | Mean | Std. Deviation | RK |
|---|---|---|---|---|
| Access to social, domestic and socio-economic facilities | SOC-1 | 5.00 | 0.000 | 1 |
| Access to public transport | SOC-2 | 5.00 | 0.000 | 1 |
| Building total lifecycle costs | ENV-22 | 5.00 | 0.000 | 1 |
| Affordability | ECO-2 | 5.00 | 0.000 | 1 |
| Land use | ENV-1 | 4.50 | 0.707 | 5 |
| Parking capacity | ENV-4 | 4.50 | 0.707 | 5 |
| Safety and inclusiveness of opportunities | SOC-6 | 4.50 | 0.707 | 5 |
| Day lighting | ENV-6 | 4.50 | 0.707 | 5 |
| Natural ventilation | ENV-8 | 4.50 | 0.707 | 5 |
| User health | ENV-9 | 4.50 | 0.707 | 5 |
| Energy-efficient equipment | ENV-15 | 4.50 | 0.707 | 5 |
| Saving energy-reduction of electricity | ENV-16 | 4.50 | 0.707 | 5 |
| Construction and demolition waste management | ENV-20 | 4.50 | 0.707 | 5 |
| Annual operating costs | ECO-1 | 4.50 | 0.707 | 5 |
| Landscape irrigation | ENV-2 | 4.00 | 0.000 | 15 |
| Building architecture and appearance | SOC-4 | 4.00 | 0.000 | 15 |
| Building form and orientation | ENV-3 | 4.00 | 0.000 | 15 |
| Useful floor space | SOC-5 | 4.00 | 0.000 | 15 |
| Building water conservation | ENV-10 | 4.00 | 0.000 | 15 |
| Application of innovative water | ENV-11 | 4.00 | 0.000 | 15 |
| Leak detection | ENV-12 | 4.00 | 0.000 | 15 |
| Water-efficient landscaping and irrigation | ENV-12 | 4.00 | 0.000 | 15 |
| Renewable energy sources use | ENV-13 | 4.00 | 1.414 | 15 |
| Energy-efficient heating and cooling | ENV-14 | 4.00 | 0.000 | 15 |
| Local/regional building materials | ENV-18 | 4.00 | 0.000 | 15 |
| Safety and security | ECO-3 | 4.00 | 0.000 | 15 |
| Education and awareness | ECO-4 | 4.00 | 0.000 | 15 |
| Building Regulation and bye laws | ENV-24 | 4.00 | 0.000 | 15 |
| Visual comfort | SOC-3 | 3.00 | 1.414 | 29 |
| Air pollution monitoring | ENV-7 | 3.00 | 1.414 | 29 |
| Universal design thinking | SOC-9 | 3.00 | 1.414 | 29 |
| Thermal comfort | ENV-5 | 2.50 | 0.707 | 32 |
| Acoustic comfort | SOC-7 | 2.00 | 0.000 | 33 |
| Energy saving-natural gas efficiency | ENV-17 | 2.00 | 0.000 | 33 |
| Secondary use of recycled materials | ENV-19 | 2.00 | 0.000 | 33 |
| Rewarding sustainability points and incentivising compliant buildings | ENV-25 | 2.00 | 0.000 | 33 |
| Building heights | SOC-8 | 2.00 | 0.000 | 33 |
| Building operation and disposal impacts | ENV-21 | 1.50 | 0.707 | 38 |
| Geo-technical aspects of the construction site | ENV-23 | 1.00 | 0.000 | 39 |
| **N** | | | **2** | |
| **Kendall's W** | | | **0.802** | |
| **Chi-Square** | | | **60.914** | |
| **Df** | | | **38** | |
| **Significance** | | | **0.011** | |
| **H0: No agreement** | | | **Reject H0** | |

**Mechanical engineers**

The level of agreement among the mechanical engineers (5 participants) to sustainability indicators was very high (W=0.680). The level of agreement improved from 0.619 in round one to 0.680 in round two as participants' understanding of the indicators improved as more discussions of the indicators were carried out with the respondents. The agreement between the opinions of the raters (mechanical engineers) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.000) at 0.05 and 0.01 level of significance with a degree of freedom 38. The mechanical engineers in Delphi round two ranked; ENV-1 (Land use), SOC-1 (Access to social, domestic, and socio-economic facilities), SOC-2 (Access to public transport), and ENV-22 (Building total lifecycle costs), as the most essential sustainability indicators scoring a mean value of 5.00 on average. The same sustainability indicators were ranked the most essential in rounds one and two showing great consistency. The least ranked included Geo-technical aspects of the construction site with a mean score value of 1.80 on average. Energy saving-natural gas efficiency, building operation and disposal impacts, indicators maintained the mean score value of 2.00 on average and were slightly above the lowest ranked ENV-23 indicator. The difference in the mean score was 3.20, indicating a wide variation in the ranks of the indicators.

**Table 4.15: Level of agreement among mechanical engineers round two of Delphi**

| Criterion | Code | Mean | Std. Deviation | RK |
|---|---|---|---|---|
| Land use | ENV-1 | 5.00 | 0 | 1 |
| Access to social, domestic and socio-economic facilities | SOC-1 | 5.00 | 0 | 1 |
| Access to public transport | SOC-2 | 5.00 | 0 | 1 |
| Building total lifecycle costs | ENV-22 | 5.00 | 0 | 1 |
| Day lighting | ENV-6 | 4.80 | 0.447 | 5 |
| Annual operating costs | ECO-1 | 4.80 | 0.447 | 5 |
| Building form and orientation | ENV-3 | 4.60 | 0.548 | 7 |
| Parking capacity | ENV-4 | 4.60 | 0.548 | 7 |
| Natural ventilation | ENV-8 | 4.60 | 0.548 | 7 |
| Energy-efficient equipment | ENV-15 | 4.60 | 0.548 | 7 |
| Safety and security | ECO-3 | 4.60 | 0.548 | 7 |
| Education and awareness | ECO-4 | 4.60 | 0.548 | 7 |
| Visual comfort | SOC-3 | 4.40 | 0.548 | 13 |
| Useful floor space | SOC-5 | 4.40 | 0.548 | 13 |
| User health | ENV-9 | 4.40 | 0.548 | 13 |
| Leak detection | ENV-12 | 4.40 | 0.548 | 13 |
| Construction and demolition waste management | ENV-20 | 4.40 | 0.548 | 13 |
| Affordability | ECO-2 | 4.40 | 0.548 | 13 |
| Building architecture and appearance | SOC-4 | 4.20 | 0.447 | 19 |
| Safety and inclusiveness of opportunities | SOC-6 | 4.20 | 0.837 | 19 |
| Building water conservation | ENV-10 | 4.20 | 0.447 | 19 |
| Application of innovative water | ENV-11 | 4.20 | 0.447 | 19 |
| Water-efficient landscaping and irrigation | ENV-12 | 4.20 | 0.447 | 19 |
| Energy-efficient heating and cooling | ENV-14 | 4.20 | 0.447 | 19 |
| Saving energy-reduction of electricity | ENV-16 | 4.20 | 0.447 | 19 |
| Local/regional building materials | ENV-18 | 4.20 | 0.447 | 19 |
| Air pollution monitoring | ENV-7 | 4.00 | 0.707 | 27 |

| | | | | |
|---|---|---|---|---|
| Landscape irrigation | ENV-2 | 3.80 | 0.447 | 28 |
| Renewable energy sources use | ENV-13 | 3.80 | 0.837 | 28 |
| Building Regulation and bye laws | ENV-24 | 3.80 | 0.447 | 28 |
| Universal design thinking | SOC-9 | 3.80 | 1.095 | 28 |
| Acoustic comfort | SOC-7 | 3.20 | 1.095 | 32 |
| Secondary use of recycled materials | ENV-19 | 2.80 | 1.095 | 33 |
| Rewarding sustainability points and incentivising compliant buildings | ENV-25 | 2.40 | 0.894 | 34 |
| Building heights | SOC-8 | 2.40 | 0.894 | 34 |
| Thermal comfort | ENV-5 | 2.20 | 0.447 | 36 |
| Energy saving-natural gas efficiency | ENV-17 | 2.00 | 0 | 37 |
| Building operation and disposal impacts | ENV-21 | 2.00 | 1.225 | 37 |
| Geo-technical aspects of the construction site | ENV-23 | 1.80 | 0.447 | 39 |
| **N** | | | **5** | |
| **Kendall's W** | | | **0.68** | |
| **Chi-Square** | | | **129.173** | |
| **Df** | | | **38** | |
| **Significance** | | | **0** | |
| **H0: No agreement** | | | **Reject H0** | |

### Quantity surveyors

The level of agreement among the quantity surveyors (10 participants) to sustainability indicators was moderately high (W=0.558). The level of agreement improved from 0.480 in round one to 0.558 in round two as participants' understanding of the indicators improved as more discussions of the indicators were carried out with the respondents. The agreement between the opinions of the raters (quantity surveyors) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.000) at 0.05 and 0.01 level of significance with a degree of freedom 38. The quantity surveyors in Delphi round two ranked ENV-3 (Building form and orientation), ENV-6 (Day lighting), ENV-22 (Building total lifecycle costs), as the most essential sustainability indicators scoring a mean value of 4.78 on average. Day lighting and viewing comfort indicator's ranking improved from 4$^{th}$ in round one to 3$^{rd}$ in round two. The mean slightly changed from 4.70 in round one to 4.78 in round two replacing the safety and security sustainability indicator in round two. The slight change in the average mean manifests the consistency in the respondents' agreements. The least ranked indicator was ENV-23 (Geo-technical aspects of the construction site) with a mean score value of 1.56 on average. ENV17 (Energy saving-natural gas efficiency) indicator is slightly above the lowest ranked indicator with a mean score value of 2.22 on average. The difference in the mean score was 3.44, indicating a wide variation in the ranks of the indicators. These findings are presented in Table 4.16.

**Table 4.16: Level of agreement among quantity surveyors round two of Delphi**

| Criterion | Code | Mean | Std. Deviation | RK |
|---|---|---|---|---|
| Building form and orientation | ENV-3 | 4.78 | 0.441 | 1 |
| Day lighting | ENV-6 | 4.78 | 0.441 | 1 |
| Building total lifecycle costs | ENV-22 | 4.78 | 0.441 | 1 |
| Land use | ENV-1 | 4.67 | 0.500 | 4 |
| Access to social, domestic and socio-economic facilities | SOC-1 | 4.67 | 0.500 | 4 |
| Energy-efficient heating and cooling | ENV-14 | 4.56 | 0.527 | 6 |
| Energy-efficient equipment | ENV-15 | 4.56 | 0.527 | 6 |
| Construction and demolition waste management | ENV-20 | 4.56 | 0.527 | 6 |
| Annual operating costs | ECO-1 | 4.56 | 0.527 | 6 |
| Safety and security | ECO-3 | 4.56 | 0.527 | 6 |
| Access to public transport | SOC-2 | 4.44 | 0.527 | 11 |
| Building architecture and appearance | SOC-4 | 4.44 | 0.527 | 11 |
| Parking capacity | ENV-4 | 4.44 | 0.527 | 11 |
| Natural ventilation | ENV-8 | 4.44 | 0.527 | 11 |
| Building water conservation | ENV-10 | 4.44 | 0.527 | 11 |
| Application of innovative water | ENV-11 | 4.44 | 0.527 | 11 |
| Affordability | ECO-2 | 4.44 | 0.527 | 11 |
| Education and awareness | ECO-4 | 4.44 | 0.527 | 11 |
| Visual comfort | SOC-3 | 4.33 | 0.500 | 19 |
| Leak detection | ENV-12 | 4.22 | 0.441 | 20 |
| Local/regional building materials | ENV-18 | 4.22 | 0.441 | 21 |
| Renewable energy sources use | ENV-13 | 4.22 | 0.833 | 22 |
| Useful floor space | SOC-5 | 4.11 | 0.333 | 23 |
| Safety and inclusiveness of opportunities | SOC-6 | 4.11 | 0.782 | 23 |
| User health | ENV-9 | 4.11 | 0.333 | 23 |
| Water-efficient landscaping and irrigation | ENV-12 | 4.11 | 0.333 | 23 |
| Saving energy-reduction of electricity | ENV-16 | 4.11 | 0.333 | 23 |
| Building Regulation and bye laws | ENV-24 | 3.78 | 0.441 | 28 |
| Universal design thinking | SOC-9 | 3.33 | 1.323 | 29 |
| Landscape irrigation | ENV-2 | 3.22 | 1.202 | 30 |
| Air pollution monitoring | ENV-7 | 3.22 | 1.093 | 30 |
| Acoustic comfort | SOC-7 | 2.89 | 1.054 | 32 |
| Secondary use of recycled materials | ENV-19 | 2.89 | 1.054 | 32 |
| Building heights | SOC-8 | 2.89 | 1.364 | 32 |
| Building operation and disposal impacts | ENV-21 | 2.44 | 1.236 | 35 |
| Rewarding sustainability points and incentivising compliant buildings | ENV-25 | 2.44 | 0.882 | 35 |
| Thermal comfort | ENV-5 | 2.33 | 0.500 | 37 |
| Energy saving-natural gas efficiency | ENV-17 | 2.22 | 0.667 | 38 |
| Geo-technical aspects of the construction site | ENV-23 | 1.56 | 0.527 | 39 |
| **N** | | | **9** | |
| **Kendall's W** | | | **0.558** | |
| **Chi-Square** | | | **190.986** | |
| **df** | | | **38** | |
| **Significance** | | | **0** | |
| **H0: No agreement** | | | **Reject H0** | |

### Structural engineers

The level of agreement among the structural engineers (3 participants) to sustainability indicators was moderately high (W=0.690). The level of agreement improved from 0.607 in round one to 0.690 in round two as participants' understanding of the indicators improved as more discussions of the indicators were carried out with the respondents. The agreement between the opinions of the raters (structural engineers) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.000) at 0.05 and 0.01 level of significance with a degree of freedom 38. The structural engineers in Delphi round two ranked; SOC-1 (Access to social, domestic, and socio-economic facilities), ENV-8 (Natural ventilation), ECO-2 (Affordability), and ECO-3 (Safety and security), as the most essential sustainability indicators scoring a mean value of 5.00 on average. Affordability (ECO-2) joined the most essential sustainability indicators in group two after its average mean improved from 4.33 in round one to 5.00 in round two with the improvement in its ranking by the experts. The least ranked included ENV-5 (Thermal comfort), and ENV-23 (Geo-technical aspects of the construction site), with a mean score value of 1.67 on average. Secondary use of recycled materials (ENV-19), whose average mean was 1.67 in round one, improved to 2.00. An additional sustainability indicator ENV-23 was obtained after round one, it became the lowest ranked together with indicator ENV-5 that was amongst the lowest in round one. The difference in the mean score was 3.33, indicating wider variation in the ranks of the indicators.

**Table 4.17: Level of agreement among Structural engineers round two of Delphi 2**

| Criterion | Code | Mean | Std. Deviation | RK |
|---|---|---|---|---|
| Access to social, domestic and socio-economic facilities | SOC-1 | 5.00 | 0.000 | 1 |
| Natural ventilation | ENV-8 | 5.00 | 0.000 | 1 |
| Affordability | ECO-2 | 5.00 | 0.000 | 1 |
| Safety and security | ECO-3 | 5.00 | 0.000 | 1 |
| Building form and orientation | ENV-3 | 4.67 | 0.577 | 5 |
| Useful floor space | SOC-5 | 4.67 | 0.577 | 5 |
| Parking capacity | ENV-4 | 4.67 | 0.577 | 5 |
| Day lighting | ENV-6 | 4.67 | 0.577 | 5 |
| Renewable energy sources use | ENV-13 | 4.67 | 0.577 | 5 |
| Construction and demolition waste management | ENV-20 | 4.67 | 0.577 | 5 |
| Annual operating costs | ECO-1 | 4.67 | 0.577 | 5 |
| Land use | ENV-1 | 4.33 | 0.577 | 12 |
| Access to public transport | SOC-2 | 4.33 | 0.577 | 12 |
| Visual comfort | SOC-3 | 4.33 | 0.577 | 12 |
| Building architecture and appearance | SOC-4 | 4.33 | 0.577 | 12 |
| Safety and inclusiveness of opportunities | SOC-6 | 4.33 | 0.577 | 12 |
| Air pollution monitoring | ENV-7 | 4.33 | 0.577 | 12 |
| User health | ENV-9 | 4.33 | 0.577 | 12 |
| Building water conservation | ENV-10 | 4.33 | 0.577 | 12 |
| Application of innovative water | ENV-11 | 4.33 | 0.577 | 12 |
| Leak detection | ENV-12 | 4.33 | 0.577 | 12 |
| Energy-efficient heating and cooling | ENV-14 | 4.33 | 0.577 | 12 |
| Local/regional building materials | ENV-18 | 4.33 | 0.577 | 12 |
| Education and awareness | ECO-4 | 4.33 | 0.577 | 12 |
| Water-efficient landscaping and irrigation | ENV-12 | 4.00 | 0.000 | 25 |
| Energy-efficient equipment | ENV-15 | 4.00 | 0.000 | 25 |
| Saving energy-reduction of electricity | ENV-16 | 4.00 | 0.000 | 25 |
| Building total lifecycle costs | ENV-22 | 3.67 | 1.528 | 28 |
| Building Regulation and bye laws | ENV-24 | 3.67 | 0.577 | 28 |
| Acoustic comfort | SOC-7 | 3.33 | 1.155 | 30 |
| Building operation and disposal impacts | ENV-21 | 3.33 | 1.155 | 30 |
| Universal design thinking | SOC-9 | 3 | 1.732 | 32 |
| Landscape irrigation | ENV-2 | 2.67 | 1.155 | 33 |
| Energy saving-natural gas efficiency | ENV-17 | 2.67 | 1.155 | 33 |
| Building heights | SOC-8 | 2.33 | 1.528 | 35 |
| Secondary use of recycled materials | ENV-19 | 2.00 | 0.000 | 36 |

| | | | | |
|---|---|---|---|---|
| Rewarding sustainability points and incentivising compliant buildings | ENV-25 | 2.00 | 0.000 | 36 |
| Thermal comfort | ENV-5 | 1.67 | 0.577 | 38 |
| Geo-technical aspects of the construction site | ENV-23 | 1.67 | 0.577 | 38 |
| **N** | | | **3** | |
| **Kendall's W** | | | **0.69** | |
| **Chi-Square** | | | **78.705** | |
| **df** | | | **38** | |
| **Significance** | | | **0** | |
| **H0: No agreement** | | | **Reject H0** | |

### Urban planners

The level of agreement among the structural engineers (3 participants) to sustainability indicators was very high (W=0.712). The level of agreement improved from 0.700 in round one to 0.712 in round two with more clarity on the indicators given to the respondents. The agreement between the opinions of the raters (urban planners) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.000) at 0.05 and 0.01 level of significance with a degree of freedom 38. The urban planners in Delphi round two ranked; SOC-1 (Access to social, domestic, and socio-economic facilities), ENV-3 (Building form and orientation), ENV-8 (Natural ventilation), ENV-9 (User health), ENV-12 (Leak detection), ENV-13 (Renewable energy sources use), ECO-1 (Annual operating costs) and ECO-2 (Affordability), as the most essential sustainability indicators scoring a mean value of 5.00 on average. In round two, the average means for; safety and inclusiveness of opportunities (SOC-6), energy saving-reduction of electricity (ENV-17), and safety and security (EC0-3), dropped to 4.33, 2.67 and 4.67 respectively. The least ranked included ENV-23 (Geo-technical aspects of the construction site), and ENV-25 (Rewarding sustainability points and incentivising compliant buildings), with a mean score value of 2.00 on average. These two indicators were additional sustainability indicators that were suggested by the experts at the end of Delphi round one. They replaced thermal comfort, Acoustic comfort, energy saving-natural gas efficiency, and secondary use of recycled material, as the least ranked indicators by urban planners during round two. The difference in the mean score was 3.00, indicating a wide variation in the ranks of the indicators.

**Table 4.18: Level of agreement among urban planners round two of Delphi**

| Criterion | Code | Mean | Std. Deviation | RK |
|---|---|---|---|---|
| Access to social, domestic and socio-economic facilities | SOC-1 | 5.00 | 0.000 | 1 |
| Building form and orientation | ENV-3 | 5.00 | 0.000 | 1 |
| Natural ventilation | ENV-8 | 5.00 | 0.000 | 1 |
| User health | ENV-9 | 5.00 | 0.000 | 1 |
| Leak detection | ENV-12 | 5.00 | 0.000 | 1 |
| Renewable energy sources use | ENV-13 | 5.00 | 0.000 | 1 |

| | | | | |
|---|---|---|---|---|
| Annual operating costs | ECO-1 | 5.00 | 0.000 | 1 |
| Affordability | ECO-2 | 5.00 | 0.000 | 1 |
| Land use | ENV-1 | 4.67 | 0.577 | 9 |
| Access to public transport | SOC-2 | 4.67 | 0.577 | 9 |
| Parking capacity | ENV-4 | 4.67 | 0.577 | 9 |
| Day lighting | ENV-6 | 4.67 | 0.577 | 9 |
| Application of innovative water | ENV-11 | 4.67 | 0.577 | 9 |
| Energy-efficient equipment | ENV-15 | 4.67 | 0.577 | 9 |
| Safety and security | ECO-3 | 4.67 | 0.577 | 9 |
| Education and awareness | ECO-4 | 4.67 | 0.577 | 9 |
| Visual comfort | SOC-3 | 4.33 | 0.577 | 17 |
| Safety and inclusiveness of opportunities | SOC-6 | 4.33 | 0.577 | 17 |
| Building water conservation | ENV-10 | 4.33 | 0.577 | 17 |
| Energy-efficient heating and cooling | ENV-14 | 4.33 | 0.577 | 17 |
| Saving energy-reduction of electricity | ENV-16 | 4.33 | 0.577 | 17 |
| Local/regional building materials | ENV-18 | 4.33 | 0.577 | 17 |
| Construction and demolition waste management | ENV-20 | 4.33 | 0.577 | 17 |
| Building total lifecycle costs | ENV-22 | 4.33 | 0.577 | 17 |
| Building architecture and appearance | SOC-4 | 4.00 | 0.000 | 25 |
| Useful floor space | SOC-5 | 4.00 | 0.000 | 25 |
| Air pollution monitoring | ENV-7 | 4.00 | 1.000 | 25 |
| Water-efficient landscaping and irrigation | ENV-12 | 4.00 | 0.000 | 25 |
| Building Regulation and bye laws | ENV-24 | 4.00 | 0.000 | 25 |
| Landscape irrigation | ENV-2 | 3.33 | 1.155 | 30 |
| Building operation and disposal impacts | ENV-21 | 3.33 | 1.155 | 30 |
| Universal design thinking | SOC-9 | 3.00 | 1.732 | 32 |
| Thermal comfort | ENV-5 | 2.67 | 0.577 | 33 |
| Acoustic comfort | SOC-7 | 2.67 | 1.155 | 33 |
| Energy saving-natural gas efficiency | ENV-17 | 2.67 | 1.155 | 33 |
| Secondary use of recycled materials | ENV-19 | 2.67 | 1.155 | 33 |
| Building heights | SOC-8 | 2.33 | 1.528 | 37 |
| Geo-technical aspects of the construction site | ENV-23 | 2.00 | 0.000 | 38 |
| Rewarding sustainability points and incenticising compliant buildings | ENV-25 | 2.00 | 0.000 | 38 |
| **N** | | | **3** | |
| **Kendall's W** | | | **0.712** | |
| **Chi-Square** | | | **81.118** | |
| **df** | | | **38** | |
| **Significance** | | | **0** | |
| **H0: No agreement** | | | **Reject H0** | |

### All experts

The level of agreement among the experts (30 participants) to sustainability indicators was moderate (W=0.547). The agreement between the opinions of the raters (all experts) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.000) at 0.05 and 0.01 level of significance with a degree of freedom 38. All experts in Delphi round two ranked; Access to social, domestic, and socio-economic facilities, building form and orientation, land use, day lighting, access to public transport, building total lifecycle costs, parking capacity, annual operating costs, natural ventilation, and affordability, as the most essential (top ten) sustainability indicators scoring a mean value of 4.80, 4.73, 4.70, 4.70, 4.67, 4.67, 4.63, 4.60, 4.60, and 4.57, on average, respectively as indicated in Table 4.19. The least ranked included

Building operation and disposal impacts, energy saving-natural gas efficiency, thermal comfort, rewarding sustainability points and incentivising compliant buildings, geo-technical aspects of the construction site, with a mean score value of 2.50, 2.47, 2.30, 2.27, and 1.90 on average respectively. The difference in the mean score was 2.90, indicating a wide variation in the ranks of the indicators.

**Table 4.19: Level of agreement among all experts round two of Delphi**

| Criterion | Mean | SD | RK |
|---|---|---|---|
| Access to social, domestic, and socio-economic facilities | 5.00 | 0.000 | 1 |
| Access to public transport | 5.00 | 0.000 | 1 |
| Building total lifecycle costs | 5.00 | 0.000 | 1 |
| Safety and security | 5.00 | 0.000 | 1 |
| Land use and impacts on ecology | 4.50 | 0.707 | 5 |
| Building architectural appearance | 4.50 | 0.707 | 5 |
| Useful floor space | 4.50 | 0.707 | 5 |
| Parking capacity | 4.50 | 0.707 | 5 |
| Safety and inclusiveness of opportunities | 4.50 | 0.707 | 5 |
| Day lighting and viewing comfort | 4.50 | 0.707 | 5 |
| User health | 4.50 | 0.707 | 5 |
| Energy-efficient equipment | 4.50 | 0.707 | 5 |
| Energy saving Reduction of electricity | 4.50 | 0.707 | 5 |
| Local/regional building materials | 4.50 | 0.707 | 5 |
| Annual operating costs | 4.50 | 0.707 | 5 |
| Landscape irrigation | 4.00 | 0.000 | 16 |
| Building form and orientation | 4.00 | 0.000 | 16 |
| Natural ventilation | 4.00 | 0.000 | 16 |
| Building water conservation | 4.00 | 0.000 | 16 |
| Application of innovative water | 4.00 | 0.000 | 16 |
| Leak detection | 4.00 | 0.000 | 16 |
| Water-efficient landscaping and | 4.00 | 0.000 | 16 |
| Renewable energy sources use | 4.00 | 1.414 | 16 |
| Energy-efficient heating and cooling | 4.00 | 0.000 | 16 |
| Construction and demolition waste management | 4.00 | 0.000 | 16 |
| Affordability | 4.00 | 1.414 | 16 |
| Education and awareness | 4.00 | 0 | 16 |
| Visual comfort | 3.00 | 1.414 | 28 |
| Air pollution monitoring | 3.00 | 1.414 | 28 |
| Thermal comfort | 2.50 | 0.707 | 30 |
| Acoustic comfort | 2.00 | 0.000 | 31 |
| Energy saving Natural gas efficiency | 2.00 | 0.000 | 31 |
| Secondary use of recycled materials | 2.00 | 0.000 | 31 |
| Building operation and disposal impacts | 1.50 | 0.707 | 34 |
| Number of respondents | | | **2** |
| Kendall`s coefficient of Concordance | | | **0.707** |
| Chi-square | | | **46.63** |
| Degree of Freedom | | | **33** |
| Significance level | | | **0.058** |
| H0: No agreement | | | **Accept H0** |

### 4.4.5 Validation of expert`s agreement with IRA and ANOVA for round two of Delphi

One-way ANOVA was performed to compare the mean differences among the expert groups with construction sustainability indicators. The ANOVA results revealed that there was not a significant difference in mean ranks for the expert`s groups with most of the indicators. The absence of difference in the mean scores for the groups shows that expert`s opinions were in the same interval. Moreover, the Inter-Rater Agreement results deduced that the level of agreement among experts with particular indicator ranged between 0.222 (lack of agreement) to 0.899 (strong agreement); it was found that the level of consensus among the experts was strong for fourteen (14) indicators in Delphi round two. This represented an improved consensus among experts in round two, with an addition of 5 more indicators, where in round one, they were nine (9) indicators, moderate agreement for sixteen (16) indicators, 2 more than in round one which had fourteen (14) indicators with moderate agreement, weak agreement for four (4) indicators in round two, 4 less than the eight (8) indicators in round one, and three (4) indicators where participants did not have agreement unlike the 3 indicators in round one where there was no agreement among the experts.

**Table 4.20: Validation of expert`s level of agreement round two of Delphi**

| Criterion | Code | IRA | Agreement level | F | Sig. |
|---|---|---|---|---|---|
| Land use and impacts on ecology | ENV-1 | 0.598 | Moderate agreement | 1.013 | 0.441 |
| Access to social, domestic, and socio-economic facilities | SOC-1 | 0.553 | Moderate agreement | 1.399 | 0.257 |
| Access to public transport | SOC-2 | 0.614 | Moderate agreement | 1.034 | 0.429 |
| Landscape irrigation | ENV-2 | 0.391 | Weak agreement | 5.465 | 0.001 |
| Visual comfort | SOC-3 | 0.727 | Strong agreement | 0.271 | 0.945 |
| Building architectural appearance | SOC-4 | 0.827 | Strong agreement | 0.385 | 0.881 |
| Building form and orientation | ENV-3 | 0.583 | Moderate agreement | 1.273 | 0.308 |
| Useful floor space | SOC-5 | 0.827 | Strong agreement | 2.042 | 0.101 |
| Parking capacity | ENV-4 | 0.63 | Moderate agreement | 0.788 | 0.589 |
| Safety and inclusiveness of opportunity | SOC-6 | 0.504 | Moderate agreement | 1.109 | 0.387 |
| Thermal comfort | ENV-5 | 0.833 | Strong agreement | 1.500 | 0.222 |
| Day lighting and viewing comfort | ENV-6 | 0.598 | Moderate agreement | 1.239 | 0.323 |
| Acoustic comfort | SOC-7 | 0.469 | Weak agreement | 0.389 | 0.878 |
| Air pollution monitoring | ENV-7 | 0.432 | Weak agreement | 0.417 | 0.86 |
| Natural ventilation | ENV-8 | 0.646 | Moderate agreement | 1.197 | 0.343 |
| User health | ENV-9 | 0.769 | Strong agreement | 1.138 | 0.372 |
| Building water conservation | ENV-10 | 0.769 | Strong agreement | 0.441 | 0.844 |
| Application of innovative water | ENV-11 | 0.769 | Strong agreement | 0.694 | 0.657 |
| Leak detection | ENV-12 | 0.827 | Strong agreement | 1.301 | 0.296 |
| Water-efficient landscaping and irrigation | ENV-12 | 0.847 | Strong agreement | 0.953 | 0.478 |
| Renewable energy sources use | ENV-13 | 0.405 | Weak agreement | 1.58 | 0.198 |
| Energy-efficient heating and cooling | ENV-14 | 0.788 | Strong agreement | 0.474 | 0.821 |
| Energy-efficient equipment | ENV-15 | 0.697 | Moderate agreement | 0.474 | 0.821 |
| Energy saving Reduction of electricity | ENV-16 | 0.847 | Strong agreement | 2.562 | 0.048 |
| Energy saving Natural gas efficiency | ENV-17 | 0.591 | Moderate agreement | 0.672 | 0.674 |
| Local/regional building materials | ENV-18 | 0.827 | Strong agreement | 1.165 | 0.359 |
| Secondary use of recycled materials | ENV-19 | 0.515 | Moderate agreement | 0.703 | 0.65 |
| Construction and demolition waste management | ENV-20 | 0.697 | Moderate agreement | 0.567 | 0.752 |

| | | | | | |
|---|---|---|---|---|---|
| Building operation and disposal impacts | ENV-21 | 0.292 | Lack of agreement | 0.295 | 0.933 |
| Building total lifecycle costs | ENV-22 | 0.266 | Lack of agreement | 0.896 | 0.514 |
| Annual operating costs | ECO-1 | 0.646 | Moderate agreement | 0.331 | 0.913 |
| Affordability | ECO-2 | 0.663 | Moderate agreement | 1.261 | 0.313 |
| Safety and security | ECO-3 | 0.663 | Moderate agreement | 0.364 | 0.894 |
| Education and awareness | ECO-4 | 0.679 | Moderate agreement | 1.258 | 0.315 |
| Geo-technical aspects of the construction site | ENV-23 | 0.475 | Weak agreement | 2.287 | 0.071 |
| Building Regulation and bye laws | ENV-24 | 0.899 | Strong agreement | 0.858 | 0.54 |
| Rewarding sustainability points and incentivizing compliant buildings | ENV-25 | 0.717 | Strong agreement | 1.528 | 0.213 |
| Building heights | SOC-8 | 0.222 | Lack of agreement | 0.847 | 0.547 |
| Universal design thinking | SOC-9 | 0.234 | Lack of agreement | 1.278 | 0.306 |

Experts had a moderate consensus on Land use and impacts on ecology being sustainability indicator in Ugandan construction industry (IRA=0.598), with no differences in the mean ranks of expert`s groups (F=1.013, p-value=0.441), moderate consensus on access to social, domestic and socio-economic facilities (IRA=0.553) with no differences in the mean ranks (F=1.399, p-value=0.257), moderate agreement on access to public transport (IRA=0.614), with no differences in the mean ranks (F=1.034, p-value=0.429), weak agreement on landscape irrigation (IRA=0.391), with no differences in the mean ranks (F=5.465, p-value=0.001), strong agreement on visual comfort (IRA=0.727), with no differences in the mean ranks (F=0.271, p-value=0.945), strong agreement on building architectural appearance (IRA=0.827), with no differences in the mean ranks (F=0.385, p-value=0.881)

Moderate agreement on building form and orientation (IRA=0.583), with no differences in the mean ranks (F=1.273, p-value=0.308), strong agreement on useful floor space (IRA=0.827), with no differences in the mean ranks (F=2.042, p-value=0.101), moderate agreement on parking capacity (IRA=0.630), with no differences in the mean ranks (F=0.788, p-value=0.589), moderate agreement on safety and inclusiveness of opportunity (IRA=0.504), with no differences in the mean ranks (F=1.109, p-value=0.389), strong agreement on thermal comfort (IRA=0.833), with no differences in the mean ranks (F=1.500, p-value=0.222), moderate agreement on Day lighting and viewing comfort (IRA=0.598), with no differences in the mean ranks (F=1.239, p-value=0.323), weak agreement on acoustic comfort (IRA=0.469), with no differences in the mean ranks (F=0.389, p-value=0.878), weak agreement on air pollution monitoring (IRA=0.432), with no differences in the mean ranks (F=0.417, p-value=0.860), moderate agreement on natural ventilation (IRA=0.646), with no differences in the mean ranks (F=1.197, p-value=0.343), strong agreement on user health (IRA=0.769), with no differences in the mean ranks (F=1.138, p-value=0.372), strong agreement on building water conservation (IRA=0.769), with no differences in the mean ranks (F=0.441, p-value=0.844), strong agreement on application of innovative water (IRA=0.769), with no differences in the mean ranks (F=0.694, p-value=0.657), strong agreement on leak detection (IRA=0.827), with no differences in the mean ranks (F=1.301, p-value=0.296).

Strong agreement on water-efficient landscaping and irrigation (IRA=0.847), with no differences in the mean ranks (F=0.953, p-value=0.478), weak agreement on renewable energy sources use (IRA=0.405), with no differences in the mean ranks (F=1.580, p-value=0.198), strong agreement on Energy-efficient heating and cooling (IRA=0.788), with no differences in the mean ranks (F=0.474, p-value=0.821), moderate agreement on Energy-efficient equipment (IRA=0.697), with no differences in the mean ranks (F=0.474, p-value=0.821), strong agreement on energy saving-reduction of electricity (IRA=0.847), with no differences in the mean ranks (F=2.562, p-value=0.048), moderate agreement on energy saving-natural gas efficiency (IRA=0.591), with no differences in the mean ranks (F=0.672, p-value=0.674), strong agreement on Local/regional building materials (IRA=0.827), with no differences in the mean ranks (F=1.165, p-value=0.359), moderate agreement on secondary use of recycled materials (IRA=0.515), with no differences in the mean ranks (F=0.703, p-value=0.650), strong agreement on construction and demolition waste management (IRA=0.697), with no differences in the mean ranks (F=0.567, p-value=0.752), lack of agreement on building operation and disposal impact (IRA=0.292), with no differences in the mean ranks (F=0.295, p-value=0.933).

Lack of agreement on building total lifecycle costs (IRA=0.266), with no differences in the mean ranks (F=0.896, p-value=0.514), moderate agreement on annual operating costs (IRA=0.646), with no differences in the mean ranks (F=0.331, p-value=0.913), moderate agreement on affordability (IRA=0.663), with no differences in the mean ranks (F=1.261, p-value=0.313), moderate agreement on safety and security (IRA=0.663), with no differences in the mean ranks (F=0.364, p-value=0.894), moderate agreement on education and awareness (IRA=0.679), with no differences in the mean ranks (F=1.258, p-value=0.315), weak agreement on geo-technical aspects of the construction site (IRA=0.475), with no differences in the mean ranks (F=2.287, p-value=0.071), strong agreement on building regulation and bye laws (IRA=0.899), with no differences in the mean ranks (F=0.858, p-value=0.540), strong agreement on rewarding sustainability points and incentivising compliant buildings (IRA=0.717), with no differences in the mean ranks (F=1.528, p-value=0.213), lack of agreement on building heights (IRA=0.222), with no differences in the mean ranks (F=0.847, p-value=0.547), and lack of agreement on universal design thinking (IRA=0.234), with no differences in the mean ranks (F=1.278, p-value=0.306).

#### 4.4.6 Ranking based on significance grading and IRA analysis for round two of Delphi

In Table…..the indicators were ranked on the basis of significance level; from the extremely important to somewhat important. The first five indicators were extremely important with a moderate consensus among all the indicators, no agreement among the experts for the 5th indicator irrespective of it being important, moderate consensus for the 7th-13th indicators, strong consensus for the 15th – 16th, 18th - 24th, 25th-28th, 37th-38th, indicators. For the 22nd indicator, the experts had no agreement but the indicator was important. The 30th and 33rd indicators were somewhat important with no agreement among the experts. Indicator number 35 was very important with no level of agreement. The 39th indicator had a weak agreement level and somewhat important. The 32nd and the 29th indicators were very important but with a weak level of agreement and lastly, the 31st indicator that was extremely important, had a weak level of agreement among the experts.

**Table 4.21: Ranking of criteria for round two of Delphi**

| Criterion | Code | RK | Agreement level | Significance level |
|---|---|---|---|---|
| Access to social, domestic, and socio-economic facilities | SOC-1 | 1 | Moderate agreement | Extremely Important |
| Building form and orientation | ENV-3 | 2 | Moderate agreement | Extremely Important |
| Land use | ENV-1 | 3 | Moderate agreement | Extremely Important |
| Day lighting | ENV-6 | 3 | Moderate agreement | Extremely Important |
| Access to public transport | SOC-2 | 5 | Moderate agreement | Extremely Important |
| Building total lifecycle costs | ENV-22 | 5 | Lack of agreement | Important |
| Parking capacity | ENV-4 | 7 | Moderate agreement | Extremely Important |
| Annual operating costs | ECO-1 | 8 | Moderate agreement | Important |
| Natural ventilation | ENV-8 | 9 | Moderate agreement | Very Important |
| Affordability | ECO-2 | 10 | Moderate agreement | Important |
| Safety and security | ECO-3 | 10 | Moderate agreement | Important |
| Education and awareness | ECO-4 | 12 | Moderate agreement | Important |
| Energy-efficient equipment | ENV-15 | 13 | Moderate agreement | Very Important |
| Construction and demolition waste management | ENV-20 | 13 | Moderate agreement | Very Important |
| Building water conservation | ENV-10 | 15 | Strong agreement | Very Important |
| User health | ENV-9 | 16 | Strong agreement | Very Important |
| Application of innovative water | ENV-11 | 16 | Strong agreement | Very Important |
| Renewable energy sources use | ENV-13 | 18 | Weak agreement | Very Important |
| Energy-efficient heating and cooling | ENV-14 | 18 | Strong agreement | Very Important |
| Building architectural appearance | SOC-4 | 20 | Strong agreement | Extremely Important |
| Useful floor space | SOC-5 | 21 | Strong agreement | Extremely Important |
| Leak detection | ENV-12 | 21 | Strong agreement | Very Important |
| Local/regional building materials | ENV-18 | 23 | Strong agreement | Very Important |
| Energy saving-reduction of electricity | ENV-16 | 24 | Strong agreement | Very Important |

| | | | | |
|---|---|---|---|---|
| Safety and inclusiveness of opportunity | SOC-6 | 25 | Moderate agreement | Extremely Important |
| Water-efficient landscaping and irrigation | ENV-12 | 25 | Strong agreement | Very Important |
| Visual comfort | SOC-3 | 27 | Strong agreement | Extremely Important |
| Building Regulation and bye laws | ENV-24 | 28 | Strong agreement | Somewhat important |
| Air pollution monitoring | ENV-7 | 29 | Weak agreement | Very Important |
| Universal design thinking | SOC-9 | 30 | Lack of agreement | Somewhat important |
| Landscape irrigation | ENV-2 | 31 | Weak agreement | Extremely Important |
| Acoustic comfort | SOC-7 | 32 | Weak agreement | Very Important |
| Building heights | SOC-8 | 33 | Lack of agreement | Somewhat important |
| Secondary use of recycled materials | ENV-19 | 34 | Moderate agreement | Very Important |
| Building operation and disposal impacts | ENV-21 | 35 | Lack of agreement | Very Important |
| Energy saving-natural gas efficiency | ENV-17 | 36 | Moderate agreement | Very Important |
| Thermal comfort | ENV-5 | 37 | Strong agreement | Extremely Important |
| Rewarding sustainability points and incentivising compliant buildings | ENV-25 | 38 | Strong agreement | Somewhat important |
| Geo-technical aspects of the construction site | ENV-23 | 39 | Weak agreement | Somewhat important |

From the analysis, Access to social, domestic, and socio-economic facilities (ranked first) was extremely important with moderate consensus among the experts, building form and orientation was ranked second, extremely important and with moderate agreement among the experts, Land use and impacts on ecology in the third position with extreme importance and moderate agreement among the experts. Day lighting and viewing comfort and access to public transport followed with extreme importance and moderate agreement among the experts. Building total lifecycle costs was important but with no agreement among the experts. Parking capacity was of extreme importance with moderate agreement among the experts. Affordability, annual operating costs, safety and security and education and awareness were all important with a moderate level of agreement by the experts.

Energy-efficient equipment, energy saving-natural gas efficiency, secondary use of recycled materials, natural ventilation, and construction and demolition waste management were both very important with a moderate level of agreement by the experts. Building water conservation, user health, application of innovative water, water-efficient landscaping and irrigation, leak detection, local/regional building materials, energy saving-reduction of electricity, and energy-efficient heating and cooling, had a strong level of agreement among the experts, and were all very Important, however, renewable energy sources use, air pollution monitoring and acoustic comfort, had a weak level of agreement, although, they were very Important. Similarly, geo-technical aspects of the construction site had a weak level of agreement among the experts and was somewhat important. Indicators including building architectural appearance, visual comfort, thermal comfort, and useful floor space were all extremely important with a strong level of agreement among the experts.

Additionally, from the analysis, building regulations and bye laws and rewarding sustainability points and incentivising compliant buildings had a strong level of agreement, although they were somewhat important. More so, landscape irrigation indicator had a weak agreement among the experts but with an extremely important significance. Two indicators were graded somewhat important with no agreement among the experts including universal design thinking, and building heights. However, building operation and disposal impacts indicator was very important with no agreement among the experts.

#### 4.4.7 Round three of Delphi

**Academicians**

The level of agreement among the academicians (3 participants) to sustainability indicators was very high (W=0.675). The level of agreement improved from 0.675 in round two to 0.703 in round three as participants got a better understanding of the indicators. The W value kept on improving from round one to round three indicating an improved consensus among the experts' rankings. The agreement between the opinions of the raters (academicians) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.000) at 0.05 and 0.01 level of significance with a degree of freedom 38. The academicians in Delphi round three ranked; land use, access to social, domestic, and socio-economic facilities, building form and orientation, parking capacity, safety and inclusiveness of opportunities, construction and demolition waste management, as the most essential sustainability indicators scoring a mean value of 5.00 on average. In round three, indicators like access to social, domestic, and socio-economic facilities, and construction and demolition waste management, improved in ranking and the average means improved from 4.33 and 4.67 to 5 respectively. The least ranked included secondary use of recycled materials, building operation and disposal impacts, rewarding sustainability points and incentivising compliant buildings, maintained their ranks and mean of 2. The difference in the mean score was 3.00, indicating a wide variation in the ranks of the indicators.

**Table 4.22: Level of agreement among academicians round three of Delphi**

| Criterion | Mean | Std. Deviation | RK |
|---|---|---|---|
| Land use | 5.00 | 0.000 | 1 |
| Access to social, domestic, and socio-economic facilities | 5.00 | 0.000 | 1 |
| Building form and orientation | 5.00 | 0.000 | 1 |
| Parking capacity | 5.00 | 0.000 | 1 |
| Safety and inclusiveness of opportunities | 5.00 | 0.000 | 1 |
| Construction and demolition waste management | 5.00 | 0.000 | 1 |
| Building total lifecycle costs | 5.00 | 0.000 | 1 |
| Access to public transport | 4.67 | 0.577 | 8 |
| Natural ventilation | 4.67 | 0.577 | 8 |
| Building water conservation | 4.67 | 0.577 | 8 |
| Energy-efficient equipment | 4.67 | 0.577 | 8 |
| Annual operating costs | 4.67 | 0.577 | 8 |
| Safety and security | 4.67 | 0.577 | 8 |
| Education and awareness | 4.67 | 0.577 | 8 |
| Useful floor space | 4.33 | 0.577 | 15 |
| Day lighting and viewing comfort | 4.33 | 0.577 | 15 |
| User health | 4.33 | 0.577 | 15 |
| Application of innovative water | 4.33 | 0.577 | 15 |
| Leak detection | 4.33 | 0.577 | 15 |
| Energy saving Reduction of electricity | 4.33 | 0.577 | 15 |
| Local/regional building materials | 4.33 | 0.577 | 15 |
| Affordability | 4.33 | 0.577 | 15 |
| Geo-technical aspects of the construction site | 4.00 | 0.000 | 23 |
| Visual comfort | 4.00 | 0.000 | 23 |
| Building architectural appearance | 4.00 | 0.000 | 23 |
| Building heights | 4.00 | 0.000 | 23 |
| Universal design thinking | 4.00 | 0.000 | 23 |
| Water-efficient landscaping and irrigation | 4.00 | 0.000 | 23 |
| Renewable energy sources use | 4.00 | 1.000 | 23 |
| Energy-efficient heating and cooling | 4.00 | 0.000 | 23 |
| Building Regulation and bye laws | 3.67 | 0.577 | 31 |
| Air pollution monitoring | 3.67 | 1.155 | 31 |
| Acoustic comfort | 3.33 | 1.155 | 33 |
| Energy saving-natural gas efficient | 3.33 | 1.155 | 33 |
| Landscape irrigation | 2.67 | 1.155 | 35 |
| Thermal comfort | 2.33 | 0.577 | 36 |
| Rewarding sustainability points and incentivizing compliant buildings | 2.00 | 0.000 | 37 |
| Secondary use of recycled material | 2.00 | 0.000 | 37 |
| Building operation and disposal impacts | 2.00 | 0.000 | 37 |
| **N** | | **3** | |
| **Kendall's W** | | **0.703** | |
| **Chi-Square** | | **80.179** | |
| **df** | | **38** | |
| **Significance** | | **0** | |
| **H0: No agreement** | | **Reject H0** | |

### Architects

The level of agreement among the architects (4 participants) to sustainability indicators was moderately high (W=0.610). The level of agreement improved from 0.592 in round two to 0.610 in round three as participants got a better understanding of the indicators. The agreement between the opinions of the raters (architects) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.000) at 0.05 and 0.01 level of significance with a degree of freedom 38. The architects in Delphi round three ranked education and awareness, Land use and impacts on ecology and access to social, domestic, and socio-economic facilities, scoring a mean value of 5.00 as the first most essential sustainability indicators. More so, sustainability indicators including land use, access to social, domestic, and socio-economic facilities, improved in ranking from 2 to 1. Furthermore, access to public transport, building form and orientation, parking capacity, day lighting, natural ventilation, renewable energy sources use, affordability and safety and security, were all ranked fourth after the third round with an average mean of 4.75. The least ranked included; geo-technical aspects of the construction site, rewarding sustainability points and incentivizing compliant buildings, thermal comfort, energy saving-natural gas efficiency, all with a mean of 2.5 and the very last ranked was landscape irrigation with an average mean of 2.25 after Delphi round three. The least ranked indicators after round three were and round two were the same, only that in round three, geo-technical aspects of the construction site improved from an average mean of 2 (in round 2) to 2.5, while landscape irrigation maintained its average mean of 2.25 in both round three and round two. The difference in the mean score was 3.00, indicating a wide variation in the ranks of the indicators.

**Table 4.23: Level of agreement among architects round three of Delphi**

| Criterion | Mean | Std. Deviation | RK |
|---|---|---|---|
| Land use | 5.00 | 0.000 | 1 |
| Access to social, domestic, and socio-economic facilities | 5.00 | 0.000 | 1 |
| Education and awareness | 5.00 | 0.000 | 1 |
| Access to public transport | 4.75 | 0.500 | 4 |
| Building form and orientation | 4.75 | 0.500 | 4 |
| Parking capacity | 4.75 | 0.500 | 4 |
| Day lighting and viewing comfort | 4.75 | 0.500 | 4 |
| Natural ventilation | 4.75 | 0.500 | 4 |
| Renewable energy sources use | 4.75 | 0.500 | 4 |
| Affordability | 4.75 | 0.500 | 4 |
| Safety and security | 4.75 | 0.500 | 4 |
| Building architectural appearance | 4.50 | 0.577 | 12 |
| Useful floor space | 4.50 | 0.577 | 12 |
| Air pollution monitoring | 4.50 | 0.577 | 12 |
| User health | 4.50 | 0.577 | 12 |
| Building water conservation | 4.50 | 0.577 | 12 |
| Application of innovative water | 4.50 | 0.577 | 12 |
| Water-efficient landscaping and irrigation | 4.50 | 0.577 | 12 |
| Energy-efficient heating and cooling | 4.50 | 0.577 | 12 |
| Energy-efficient equipment | 4.50 | 0.577 | 12 |
| Local/regional building materials | 4.50 | 0.577 | 12 |
| Construction and demolition waste management | 4.50 | 0.577 | 12 |
| Building total lifecycle costs | 4.50 | 0.577 | 12 |
| Annual operating costs | 4.50 | 0.577 | 12 |
| Leak detection | 4.25 | 0.500 | 25 |
| Energy saving-reduction of electricity | 4.25 | 0.500 | 25 |
| Visual comfort | 4.00 | 0.000 | 27 |
| Building Regulation and bye laws | 3.75 | 0.500 | 28 |
| Building heights | 3.50 | 1.000 | 29 |
| Safety and inclusiveness of opportunity | 3.50 | 1.000 | 29 |
| Acoustic comfort | 3.50 | 1.000 | 29 |
| Secondary use of recycled material | 3.50 | 1.000 | 29 |
| Universal design thinking | 3.00 | 1.155 | 33 |

| | | | |
|---|---|---|---|
| Building operation and disposal impacts | 3.00 | 1.155 | 33 |
| Geo-technical aspects of the construction site | 2.50 | 1.732 | 35 |
| Rewarding sustainability points and incentivizing compliant buildings | 2.50 | 1.000 | 35 |
| Thermal comfort | 2.50 | 0.577 | 35 |
| Energy saving-natural gas efficiency | 2.50 | 1.000 | 35 |
| Landscape irrigation | 2.25 | 1.258 | 39 |
| **N** | | **4** | |
| **Kendall's W** | | **0.61** | |
| **Chi-Square** | | **92.762** | |
| **df** | | **38** | |
| **Significance** | | **0** | |
| **H0: No agreement** | | **Reject H0** | |

**Environmentalists**

The level of agreement among the environmentalists (2 participants) to sustainability indicators was perfect (W=0.769). The level of agreement improved from 0.802 in round two to 0.769 in round three. The agreement between the opinions of the raters (environmentalists) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.018) at 0.05 and 0.01 level of significance with a degree of freedom 38. The environmentalists in Delphi round three ranked; land use, access to social, domestic, and socio-economic facilities, access to public transport, building form and orientation, building total lifecycle costs and affordability, as the most essential sustainability indicators scoring a mean value of 5.00 on average. Four of the above indicators were also the most essential sustainability indicators in round two. Two indicators namely, Land use and impacts on ecology and building form and orientation improved from average mean 4.50 and 4.00 respectively to 5.00. The least ranked included rewarding sustainability points and incentivizing compliant buildings, building heights, acoustic comfort, energy saving-natural gas efficient, secondary use of recycled material, all with an average mean of 2.00 and building operation and disposal impacts with an average mean of 1.5. The majority of the least ranked indicators were similar in both rounds two and three. However, it should be noted that geo-technical aspects of the construction site improved in ranking and mean position 39 with an average mean of 1.00 in round two to position 32 with an average mean of 2.50 in round three, while building operation and disposal impacts indicator maintained its average mean of 1.50 in both rounds 2 and 3. The difference in the mean score was 3.50, indicating a wide variation in the ranks of the indicators.

**Table 4.24: Level of agreement among environmentalists round three of Delphi**

| Criterion | Mean | Std. Deviation | RK |
|---|---|---|---|
| Land use | 5.00 | 0.000 | 1 |
| Access to social, domestic, and socio-economic facilities | 5.00 | 0.000 | 1 |
| Access to public transport | 5.00 | 0.000 | 1 |
| Building form and orientation | 5.00 | 0.000 | 1 |
| Building total lifecycle costs | 5.00 | 0.000 | 1 |
| Affordability | 5.00 | 0.000 | 1 |
| Parking capacity | 4.50 | 0.707 | 7 |
| Safety and inclusiveness of opportunities | 4.50 | 0.707 | 7 |
| Day lighting and viewing comfort | 4.50 | 0.707 | 7 |
| Natural ventilation | 4.50 | 0.707 | 7 |
| User health | 4.50 | 0.707 | 7 |
| Building water conservation | 4.50 | 0.707 | 7 |
| Energy-efficient equipment | 4.50 | 0.707 | 7 |
| Energy saving Reduction of electricity | 4.50 | 0.707 | 7 |
| Construction and demolition waste management | 4.50 | 0.707 | 7 |
| Annual operating costs | 4.50 | 0.707 | 7 |
| Safety and security | 4.50 | 0.707 | 7 |
| Education and awareness | 4.50 | 0.707 | 7 |
| Building Regulation and bye laws | 4.00 | 0.000 | 19 |
| Landscape irrigation | 4.00 | 0.000 | 19 |
| Building architectural appearance | 4.00 | 0.000 | 19 |
| Useful floor space | 4.00 | 0.000 | 19 |
| Application of innovative water | 4.00 | 0.000 | 19 |
| Leak detection | 4.00 | 0.000 | 19 |
| Water-efficient landscaping and irrigation | 4.00 | 0.000 | 19 |
| Renewable energy sources use | 4.00 | 1.414 | 19 |
| Energy-efficient heating and coo | 4.00 | 0.000 | 19 |
| Local/regional building materials | 4.00 | 0.000 | 19 |
| Visual comfort | 3.00 | 1.414 | 29 |
| Universal design thinking | 3.00 | 1.414 | 29 |
| Air pollution monitoring | 3.00 | 1.414 | 29 |
| Geo-technical aspects of the construction site | 2.50 | 2.121 | 32 |
| Thermal comfort | 2.50 | 0.707 | 32 |
| Rewarding sustainability points and incentivizing compliant buildings | 2.00 | 0.000 | 34 |
| Building heights | 2.00 | 0.000 | 34 |
| Acoustic comfort | 2.00 | 0.000 | 34 |
| Energy saving-natural gas efficient | 2.00 | 0.000 | 34 |
| Secondary use of recycled material | 2.00 | 0.000 | 34 |
| Building operation and disposal impacts | 1.50 | 0.707 | 39 |
| **N** | | **2** | |
| **Kendall's W[a]** | | **0.769** | |
| **Chi-Square** | | **58.412** | |
| **df** | | **38** | |
| **Significance** | | **0.018** | |
| **H0: No agreement** | | **Reject H0** | |

### Mechanical engineers

The level of agreement among the mechanical engineers (5 participants) to sustainability indicators was very high (W=0.655). The level of agreement reduced from 0.680 in round two to 0.655 in round two. The agreement between the opinions of the raters (mechanical engineers) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.000) at 0.05 and 0.01 level of significance with a degree of freedom 38. The mechanical engineers in Delphi round two ranked; land use, access to social, domestic, and socio-economic facilities, day lighting, building total lifecycle costs and annual operating costs, as the most essential sustainability indicators scoring a mean value of 5.00 on average. The same sustainability indicators were ranked the most essential in round two showing great consistence. Day lighting and viewing comfort indicator improved in ranking and average mean from rank 5 with an average mean of 4.80 to rank 1 with an average mean of 5.00. The least ranked included energy saving-natural gas efficiency and building operation and disposal impacts with a mean of 2.00 each. These two indicators are consistently ranked least in both rounds 2 and 3. Notably, Geo-technical aspects of the construction site that was the lowest ranked in round two with a mean score value of 1.80, improved to a mean score of 2.20 as consensus among the respondents improved after round three. The difference in the mean score was 3.00, indicating a wide variation in the ranks of the indicators.

**Table 4.25: Level of agreement among mechanical engineers round three of Delphi**

| Criterion | Mean | Std. Deviation | RK |
|---|---|---|---|
| Land use | 5.00 | 0.000 | 1 |
| Access to social, domestic, and socio-economic facilities | 5.00 | 0.000 | 1 |
| Day lighting and viewing comfort | 5.00 | 0.000 | 1 |
| Building total lifecycle costs | 5.00 | 0.000 | 1 |
| Annual operating costs | 5.00 | 0.000 | 1 |
| Building form and orientation | 4.80 | 0.447 | 6 |
| Access to public transport | 4.60 | 0.548 | 7 |
| Useful floor space | 4.60 | 0.548 | 7 |
| Parking capacity | 4.60 | 0.548 | 7 |
| Natural ventilation | 4.60 | 0.548 | 7 |
| Energy-efficient equipment | 4.60 | 0.548 | 7 |
| Affordability | 4.60 | 0.548 | 7 |
| Safety and security | 4.60 | 0.548 | 7 |
| Education and awareness | 4.60 | 0.548 | 7 |
| Visual comfort | 4.40 | 0.548 | 15 |
| User health | 4.40 | 0.548 | 15 |
| Building water conservation | 4.40 | 0.548 | 15 |
| Leak detection | 4.40 | 0.548 | 15 |
| Energy-efficient heating and cooling | 4.40 | 0.548 | 15 |
| Energy saving Reduction of electricity | 4.40 | 0.548 | 15 |
| Local/regional building materials | 4.40 | 0.548 | 15 |
| Construction and demolition waste management | 4.40 | 0.548 | 15 |
| Building architectural appearance | 4.20 | 0.447 | 23 |
| Safety and inclusiveness of opportunities | 4.20 | 0.837 | 23 |
| Application of innovative water | 4.20 | 0.447 | 23 |
| Water-efficient landscaping and irrigation | 4.20 | 0.447 | 23 |
| Air pollution monitoring | 4.00 | 0.707 | 27 |
| Building Regulation and bye laws | 3.80 | 0.447 | 28 |
| Landscape irrigation | 3.80 | 0.447 | 28 |
| Universal design thinking | 3.80 | 1.095 | 28 |
| Renewable energy sources use | 3.80 | 0.837 | 28 |
| Acoustic comfort | 3.20 | 1.095 | 32 |
| Secondary use of recycled materials | 2.80 | 1.095 | 33 |
| Rewarding sustainability points and incentivizing compliant buildings | 2.40 | 0.894 | 34 |
| Building heights | 2.40 | 0.894 | 34 |
| Geo-technical aspects of the construction site | 2.20 | 1.095 | 36 |
| Thermal comfort | 2.20 | 0.447 | 36 |
| Energy saving-natural gas efficiency | 2.00 | 0.000 | 38 |
| Building operation and disposal impacts | 2.00 | 1.225 | 38 |
| **N** | | **5** | |
| **Kendall's W** | | **0.655** | |
| **Chi-Square** | | **124.421** | |
| **df** | | **38** | |

| | | | |
|---|---|---|---|
| **Significance** | | **0** | |
| **H0: No agreement** | | **Reject H0** | |

### Quantity surveyors

The level of agreement among the quantity surveyors (10 participants) to sustainability indicators was moderately high (W=0.558). The level of agreement improved from 0.558 in round two to 0.572 in round three as participants' understanding of the indicators improved as more discussions of the indicators were carried out with the respondents. The agreement between the opinions of the raters (quantity surveyors) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.000) at 0.05 and 0.01 level of significance with a degree of freedom 38. The quantity surveyors in Delphi round three ranked; building form and orientation as the most essential sustainability indicators scoring a mean value of 5.00 on average, Day lighting and viewing comfort with a mean score of 4.90, land use, access to social, domestic, and socio-economic facilities, and building total lifecycle costs, with a mean score of 4.80, as the most essential top five indicators after round three of the Delphi survey. These were the most essential as well, in round two, hence giving a great level of consistency required for the Delphi studies. The least ranked indicator after round three was geo-technical aspects of the construction site with a mean score value of 1.80 similar to round two although the mean score was slightly less 1.56 in round two. on average. The difference in the mean score was 3.20, indicating a wide variation in the ranks of the indicators.

**Table 4.26: Level of agreement among quantity surveyors for round three of Delphi**

| Criterion | Mean | Std. Deviation | RK |
|---|---|---|---|
| Building form and orientation | 5.00 | 0.000 | 1 |
| Day lighting and viewing comfort | 4.90 | 0.316 | 2 |
| Land use | 4.80 | 0.422 | 3 |
| Access to social, domestic, and socio-economic facilities | 4.80 | 0.422 | 4 |
| Building total lifecycle costs | 4.80 | 0.422 | 5 |
| Access to public transport | 4.70 | 0.483 | 6 |
| Renewable energy sources use | 4.70 | 0.483 | 6 |
| Energy-efficient equipment | 4.60 | 0.516 | 8 |
| Parking capacity | 4.60 | 0.516 | 9 |
| Energy-efficient heating and cooling | 4.60 | 0.516 | 9 |
| Construction and demolition waste management | 4.60 | 0.516 | 9 |
| Natural ventilation | 4.50 | 0.527 | 12 |
| Application of innovative water | 4.50 | 0.527 | 12 |
| Annual operating costs | 4.50 | 0.527 | 12 |
| Safety and security | 4.50 | 0.527 | 12 |
| Building architectural appearance | 4.40 | 0.516 | 16 |
| Building water conservation | 4.40 | 0.516 | 16 |
| Affordability | 4.40 | 0.516 | 16 |
| Education and awareness | 4.40 | 0.516 | 16 |
| Water-efficient landscaping and irrigation | 4.40 | 0.516 | 20 |
| User health | 4.30 | 0.483 | 21 |
| Leak detection | 4.30 | 0.483 | 21 |
| Energy saving Reduction of electricity | 4.30 | 0.483 | 21 |
| Local/regional building materials | 4.30 | 0.483 | 21 |
| Visual comfort | 4.30 | 0.483 | 25 |
| Useful floor space | 4.20 | 0.422 | 26 |

| | | | |
|---|---|---|---|
| Safety and inclusiveness of opportunities | 4.20 | 0.789 | 27 |
| Building Regulation and bye laws | 3.80 | 0.422 | 28 |
| Landscape irrigation | 3.30 | 1.160 | 29 |
| Air pollution monitoring | 3.30 | 1.059 | 29 |
| Universal design thinking | 3.20 | 1.317 | 31 |
| Acoustic comfort | 2.80 | 1.033 | 32 |
| Secondary use of recycled materials | 2.80 | 1.033 | 32 |
| Building heights | 2.70 | 1.418 | 34 |
| Rewarding sustainability points and incentivizing compliant buildings | 2.40 | 0.843 | 35 |
| Building operation and disposal impacts | 2.40 | 1.174 | 35 |
| saving Natural gas efficiency | 2.40 | 0.843 | 37 |
| Thermal comfort | 2.30 | 0.483 | 38 |
| Geo-technical aspects of the construction site | 1.80 | 0.919 | 39 |
| **N** | | **10** | |
| **Kendall's W** | | **0.572** | |
| **Chi-Square** | | **217.526** | |
| **df** | | **38** | |
| **Significance** | | **0** | |
| **H0: No agreement** | | **Reject H0** | |

**Structural engineers**

The level of agreement among the structural engineers (3 participants) to sustainability indicators was moderately high (W=0.683). The level of agreement improved from 0.690 in round two to 0.683 in round three, indicating a great level of consistency in the experts' opinions. The agreement between the opinions of the raters (structural engineers) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.000) at 0.05 and 0.01 level of significance with a degree of freedom 38. The structural engineers in Delphi round three ranked; land use, access to social, domestic, and socio-economic facilities, natural ventilation, affordability and safety and security, as the most essential sustainability indicators scoring a mean value of 5.00 on average. Land use and impacts on ecology joined the most essential sustainability indicators in round three after its average mean improved from 4.33 in round two to 5.00 in round three with the improvement in its ranking by the experts. The least ranked included geo-technical aspects of the construction site and thermal comfort, with a mean score value of 1.67 on average. These indicators were also the lowest ranked in Delphi round two indicating consistency in the experts' opinions/rankings. The difference in the mean score was 3.33, indicating wider variation in the ranks of the indicators.

**Table 4.27: Level of agreement among structural engineers round three of Delphi**

| Criterion | Mean | Std. Deviation | RK |
|---|---|---|---|
| Land use | 5.00 | 0.000 | 1 |
| Access to social, domestic, and socio-economic facilities | 5.00 | 0.000 | 1 |
| Natural ventilation | 5.00 | 0.000 | 1 |
| Affordability | 5.00 | 0.000 | 1 |
| Safety and security | 5.00 | 0.000 | 1 |
| Access to public transport | 4.67 | 0.577 | 6 |
| Building architectural appearance | 4.67 | 0.577 | 6 |
| Building form and orientation | 4.67 | 0.577 | 6 |
| Useful floor space | 4.67 | 0.577 | 6 |
| Parking capacity | 4.67 | 0.577 | 6 |
| Day lighting and viewing comfort | 4.67 | 0.577 | 6 |
| Renewable energy sources use | 4.67 | 0.577 | 6 |
| Construction and demolition waste management | 4.67 | 0.577 | 6 |
| Annual operating costs | 4.67 | 0.577 | 6 |
| Education and awareness | 4.67 | 0.577 | 6 |
| Visual comfort | 4.33 | 0.577 | 16 |
| Safety and inclusiveness of opportunity | 4.33 | 0.577 | 16 |
| Air pollution monitoring | 4.33 | 0.577 | 16 |
| User health | 4.33 | 0.577 | 16 |
| Building water conservation | 4.33 | 0.577 | 16 |
| Application of innovative water | 4.33 | 0.577 | 16 |
| Water-efficient landscaping and irrigation | 4.33 | 0.577 | 16 |
| Energy-efficient heating and cooling | 4.33 | 0.577 | 16 |
| Energy-efficient equipment | 4.33 | 0.577 | 16 |
| Local/regional building materials | 4.33 | 0.577 | 16 |
| Building total lifecycle costs | 4.33 | 0.577 | 16 |
| Leak detection | 4.00 | 0.000 | 27 |
| Energy saving Reduction of electricity | 4.00 | 0.000 | 27 |
| Building Regulation and bye laws | 3.67 | 0.577 | 29 |
| Acoustic comfort | 3.33 | 1.155 | 30 |
| Building operation and disposal | 3.33 | 1.155 | 30 |
| Universal design thinking | 3.00 | 1.732 | 32 |
| Landscape irrigation | 2.67 | 1.155 | 33 |
| Energy saving-natural gas efficiency | 2.67 | 1.155 | 33 |
| Building heights | 2.33 | 1.528 | 35 |
| Rewarding sustainability points and incentivizing compliant buildings | 2.00 | 0.000 | 36 |
| Secondary use of recycled material | 2.00 | 0.000 | 36 |
| Geo-technical aspects of the construction site | 1.67 | 0.577 | 38 |
| Thermal comfort | 1.67 | 0.577 | 38 |
| **N** | | **3** | |
| **Kendall's W** | | **0.683** | |
| **Chi-Square** | | **77.904** | |
| **df** | | **38** | |
| **Significance** | | **0** | |
| **H0: No agreement** | | **Reject H0** | |

### Urban planners

The level of agreement among the structural engineers (3 participants) to sustainability indicators was very high (W=0.730). The level of agreement improved from 0.712 in round two to 0.730 in round three with more clarity on the indicators given to the respondents', this showed consistency in the experts' opinions. The agreement between the opinions of the raters (urban planners) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.000) at 0.05 and 0.01 level of significance with a degree of freedom 38. The urban planners in Delphi round three ranked; land use, access to social, domestic, and socio-economic facilities, building form and orientation, parking capacity, day lighting, natural ventilation, user health, leak detection, renewable energy sources use, annual operating costs and affordability as the most essential sustainability indicators scoring a mean value of 5.00 on average. Land use, parking capacity and Day lighting and viewing comfort indicators with a mean score of 4.67 in round two, improved the mean score to 5.00 in round three and joined the top 11 sustainability indicators in Delphi round three. The increase in the number of more indicators upwards exhibits an increased consistency in the opinions of the experts. The least ranked included rewarding sustainability points and incentivising compliant buildings with a mean score value of 2.00 on average. The difference in the mean score was 3.00, indicating a wide variation in the ranks of the indicators.

**Table 4.28: Level of agreement among urban planners round three of Delphi**

| Criterion | Mean | Std. Deviation | RK |
|---|---|---|---|
| Land use | 5.00 | 0.000 | 1 |
| Access to social, domestic, and socio-economic facilities | 5.00 | 0.000 | 1 |
| Building form and orientation | 5.00 | 0.000 | 1 |
| Parking capacity | 5.00 | 0.000 | 1 |
| Day lighting and viewing comfort | 5.00 | 0.000 | 1 |
| Natural ventilation | 5.00 | 0.000 | 1 |
| User health | 5.00 | 0.000 | 1 |
| Leak detection | 5.00 | 0.000 | 1 |
| Renewable energy sources use | 5.00 | 0.000 | 1 |
| Annual operating costs | 5.00 | 0.000 | 1 |
| Affordability | 5.00 | 0.000 | 1 |
| Access to public transport | 4.67 | 0.577 | 12 |
| Application of innovative water | 4.67 | 0.577 | 12 |
| Energy-efficient equipment | 4.67 | 0.577 | 12 |
| Safety and security | 4.67 | 0.577 | 12 |
| Education and awareness | 4.67 | 0.577 | 12 |
| Visual comfort | 4.33 | 0.577 | 17 |
| Building architectural appearance | 4.33 | 0.577 | 17 |
| Safety and inclusiveness of opportunity | 4.33 | 0.577 | 17 |
| Building water conservation | 4.33 | 0.577 | 17 |
| Energy-efficient heating and cooling | 4.33 | 0.577 | 17 |
| Energy saving Reduction of electricity | 4.33 | 0.577 | 17 |
| Local/regional building materials | 4.33 | 0.577 | 17 |
| Construction and demolition waste management | 4.33 | 0.577 | 17 |
| Building total lifecycle costs | 4.33 | 0.577 | 17 |
| Building Regulation and bye laws | 4.00 | 0.000 | 26 |
| Useful floor space | 4.00 | 0.000 | 26 |
| Air pollution monitoring | 4.00 | 1.000 | 26 |
| Water-efficient landscaping and irrigation | 4.00 | 0.000 | 26 |
| Landscape irrigation | 3.33 | 1.155 | 30 |
| Building operation and disposal impacts | 3.33 | 1.155 | 30 |
| Universal design thinking | 3.00 | 1.732 | 32 |
| Geo-technical aspects of the construction site | 2.67 | 1.155 | 33 |
| Thermal comfort | 2.67 | 0.577 | 33 |
| Acoustic comfort | 2.67 | 1.155 | 33 |
| saving Natural gas efficiency | 2.67 | 1.155 | 33 |
| Secondary use of recycled material | 2.67 | 1.155 | 33 |
| Building heights | 2.33 | 1.528 | 38 |
| Rewarding sustainability points and incentivizing compliant buildings | 2.00 | 0.000 | 39 |
| **N** | | **3** | |
| **Kendall's W** | | **0.73** | |
| **Chi-Square** | | **83.26** | |
| **df** | | **38** | |

| | | | | |
|---|---|---|---|---|
| **Significance** | | | **0** | |
| **H0: No agreement** | | | **Reject H0** | |

**All experts**

The level of agreement among the experts (30 participants) to sustainability indicators was moderate (W=0.566). The agreement between the opinions of the raters (all experts) was statistically significant as the chi-square value computed is greater than tabulated statistical value (p=0.000) at 0.05 and 0.01 level of significance with a degree of freedom 38. All experts in Delphi round two ranked; land use, access to social, domestic, and socio-economic facilities, building form and orientation, day lighting, building total lifecycle costs, access to public transport, parking capacity, annual operating costs, natural ventilation, affordability, safety and security, as the most essential (top ten) sustainability indicators scoring a mean value of 4.93, 4.93, 4.90, 4.80, 4.73, 4.70, 4.70, 4.67, 4.67, 4.63 and 4.63, on average, respectively. In the same vein, the top-10 building sustainability assessment indicators after rounds 2 and 3 are the same. This clearly illustrates that consistency in experts' opinions have been achieved. The least ranked included; thermal comfort, geo-technical aspects of the construction site, rewarding sustainability points and incentivizing compliant buildings, with a mean score value of 2.30, 2.30, and 2.25 on average respectively. These are similar to the ones in round two. The difference in the mean score was 2.68, indicating a wide variation in the ranks of the indicators.

**Table 4.29: Level of agreement among all experts round three of Delphi**

| Criterions | Mean | Std. Deviation | RK |
|---|---|---|---|
| Land use | 4.93 | 0.254 | 1 |
| Access to social, domestic, and socio-economic facilities | 4.93 | 0.254 | 1 |
| Building form and orientation | 4.9 | 0.305 | 3 |
| Day lighting and viewing comfort | 4.8 | 0.407 | 4 |
| Building total lifecycle costs | 4.73 | 0.45 | 5 |
| Access to public transport | 4.7 | 0.466 | 6 |
| Parking capacity | 4.7 | 0.466 | 6 |
| Annual operating costs | 4.67 | 0.479 | 8 |
| Natural ventilation | 4.67 | 0.479 | 8 |
| Affordability | 4.63 | 0.49 | 10 |
| Safety and security | 4.63 | 0.49 | 10 |
| Education and awareness | 4.6 | 0.498 | 12 |
| Energy-efficient equipment | 4.57 | 0.504 | 13 |
| Construction and demolition waste management | 4.57 | 0.504 | 13 |
| Renewable energy sources use | 4.47 | 0.73 | 15 |
| User health | 4.43 | 0.504 | 16 |
| Building water conservation | 4.43 | 0.504 | 16 |
| Application of innovative water | 4.4 | 0.498 | 18 |
| Energy-efficient heating and cooling | 4.4 | 0.498 | 18 |
| Building architectural appearance | 4.33 | 0.479 | 20 |
| Useful floor space | 4.33 | 0.479 | 20 |
| Leak detection | 4.33 | 0.479 | 20 |
| Local/regional building materials | 4.33 | 0.479 | 20 |
| Energy saving Reduction of electricity | 4.3 | 0.466 | 24 |
| Water-efficient landscaping and irrigation | 4.27 | 0.45 | 25 |
| Safety and inclusiveness of opportunity | 4.23 | 0.774 | 26 |
| Visual comfort | 4.17 | 0.592 | 27 |
| Building Regulation and bye laws | 3.8 | 0.407 | 28 |

| | | | |
|---|---|---|---|
| Air pollution monitoring | 3.77 | 0.971 | 29 |
| Universal design thinking | 3.3 | 1.208 | 30 |
| Landscape irrigation | 3.17 | 1.085 | 31 |
| Acoustic comfort | 3 | 1.017 | 32 |
| Building heights | 2.77 | 1.223 | 33 |
| Secondary use of recycled material | 2.67 | 0.959 | 34 |
| Building operation and disposal impacts | 2.5 | 1.137 | 35 |
| Energy saving-natural gas efficiency | 2.47 | 0.86 | 36 |
| Thermal comfort | 2.3 | 0.535 | 37 |
| Geo-technical aspects of the construction site | 2.3 | 1.208 | 37 |
| Rewarding sustainability points and incentivizing compliant buildings | 2.27 | 0.691 | 39 |
| **N** | | **30** | |
| **Kendall's W** | | **0.566** | |
| **Chi-Square** | | **645.071** | |
| **df** | | **38** | |
| **Significance** | | **0** | |
| **H0: No agreement** | | **Reject H0** | |

#### 4.4.8 Validation of expert`s agreement with IRA and ANOVA for round three of Delphi

One-way ANOVA was performed to compare the mean differences among the expert groups with construction sustainability indicators. The ANOVA results revealed that there was not a significant difference in mean ranks for the expert`s groups with most of the indicators. The absence of difference in the mean scores for the groups shows that expert`s opinions were in the same interval. Moreover, the Inter-Rater Agreement results deduced that the level of agreement among experts with particular indicator ranged between 0.190 (lack of agreement) to 0.904 (very strong agreement); it was found that the level of consensus among the experts was very strong for one (01) indicators, strong for thirteen (13) indicators in Delphi round three. This represented a consistent consensus among experts after round three. Moderate agreement for seventeen (17) indicators, one more than in round two which had fourteen (16) indicators with moderate agreement, weak agreement for five (5) indicators in round two, one more than the four (4) indicators in round two, and three (3) indicators where participants did not have agreement like the 3 indicators in round two where there was no agreement among the experts.

Experts had a moderate consensus on Land use and impacts on ecology being sustainability indicator in Ugandan construction industry (IRA=0.522), with no differences in the mean ranks of expert`s groups (F=0.639, p-value=0.698), moderate consensus on access to social, domestic and socio-economic facilities (IRA=0.522) with no differences in the mean ranks (F=0.639, p-value=0.698), moderate agreement on access to public transport (IRA=0.619), with no differences in the mean ranks (F=0.158, p-value=0.985), lack of agreement on Geo-technical aspects of the Construction site (IRA=0.190), with no differences in the mean ranks (F=1.713, p-value=0.163), very strong agreement on Building Regulation and bye laws (IRA=0.904), with no differences in the mean ranks

(F=0.271, p-value=0.945), strong agreement on Rewarding sustainability points and incentivizing compliant buildings (IRA=0.731), with no differences in the mean ranks (F=0.385, p-value=0.881), weak agreement on Landscape irrigation (IRA=0.422), with no differences in the mean ranks (F=1.273, p-value=0.308), strong agreement on visual comfort (IRA=0.741), with no differences in the mean ranks (F=2.042, p-value=0.101), strong agreement on building architectural appearance (IRA=0.798), with no differences in the mean ranks (F=0.785, p-value=0.59), lack of agreement on building heights (IRA=0.261), with no differences in the mean ranks (F=1.109, p-value=0.387).

**Table 4.30: Validation of expert`s level of agreement round three of Delphi**

| | | | ANOVA | |
|---|---|---|---|---|
| **Criterion** | **IRA** | **Level of agreement** | **F** | **Sig.** |
| Land use | 0.522 | Moderate agreement | 0.639 | 0.698 |
| Access to social, domestic, and socio-economic facilities | 0.522 | Moderate agreement | 0.639 | 0.698 |
| Access to public transport | 0.619 | Moderate agreement | 0.158 | 0.985 |
| Geo-technical aspects of the construction site | 0.19 | Lack of agreement | 1.713 | 0.163 |
| Building Regulation and bye laws | 0.904 | Very strong agreement | 0.271 | 0.945 |
| Rewarding sustainability points and incentivizing compliant buildings | 0.731 | Strong agreement | 0.385 | 0.881 |
| Landscape irrigation | 0.422 | Weak agreement | 1.273 | 0.308 |
| Visual comfort | 0.741 | Strong agreement | 2.042 | 0.101 |
| Building architectural appearance | 0.798 | Strong agreement | 0.785 | 0.59 |
| Building heights | 0.261 | Lack of agreement | 1.109 | 0.387 |
| Building form and orientation | 0.535 | Moderate agreement | 0.836 | 0.555 |
| Useful floor space | 0.798 | Strong agreement | 1.145 | 0.369 |
| Universal design thinking | 0.273 | Lack of agreement | 0.389 | 0.878 |
| Parking capacity | 0.619 | Moderate agreement | 0.544 | 0.769 |
| Safety and inclusiveness of opportunities | 0.529 | Moderate agreement | 1.197 | 0.343 |
| Thermal comfort | 0.841 | Strong agreement | 1.138 | 0.372 |
| Day lighting and viewing comfort | 0.576 | Moderate agreement | 1.449 | 0.239 |
| Acoustic comfort | 0.496 | Weak agreement | 0.694 | 0.657 |
| Air pollution monitoring | 0.461 | Weak agreement | 1.301 | 0.296 |
| Natural ventilation | 0.633 | Moderate agreement | 0.717 | 0.64 |
| User health | 0.746 | Strong agreement | 0.771 | 0.601 |
| Building water conservation | 0.746 | Strong agreement | 0.144 | 0.988 |
| Application of innovative water | 0.763 | Strong agreement | 0.548 | 0.767 |
| Leak detection | 0.798 | Strong agreement | 1.585 | 0.197 |
| Water-efficient landscaping and irrigation | 0.835 | Strong agreement | 0.788 | 0.589 |
| Renewable energy sources use | 0.438 | Weak agreement | 1.914 | 0.122 |
| Energy-efficient heating and cooling | 0.763 | Strong agreement | 0.818 | 0.567 |
| Energy-efficient equipment | 0.68 | Moderate agreement | 0.144 | 0.988 |
| Energy saving-reduction of electricity | 0.817 | Strong agreement | 0.271 | 0.945 |
| Energy saving-natural gas efficiency | 0.612 | Moderate agreement | 0.896 | 0.514 |
| Local/regional building materials | 0.798 | Strong agreement | 0.223 | 0.965 |
| Secondary use of recycled materials | 0.539 | Moderate agreement | 1.261 | 0.313 |
| Construction and demolition waste management | 0.68 | Moderate agreement | 0.556 | 0.76 |
| Building operation and disposal impacts | 0.328 | Weak agreement | 1.258 | 0.315 |

| | | | | |
|---|---|---|---|---|
| Building total lifecycle costs | 0.604 | Moderate agreement | 1.884 | 0.127 |
| Annual operating costs | 0.633 | Moderate agreement | 0.958 | 0.474 |
| Affordability | 0.649 | Moderate agreement | 1.49 | 0.226 |
| Safety and security | 0.649 | Moderate agreement | 0.417 | 0.86 |
| Education and awareness | 0.664 | Moderate agreement | 0.691 | 0.659 |

Moderate agreement on building form and orientation (IRA=0.535), with no differences in the mean ranks (F=0.836, p-value=0.555), strong agreement on Useful floor space (IRA=0.798), with no differences in the mean ranks (F=1.145, p-value=0.369), lack of agreement on Universal design thinking (IRA=0.273), with no differences in the mean ranks (F=0.389, p-value=0.878), moderate agreement on parking capacity (IRA=0.619), with no differences in the mean ranks (F=0.544, p-value=0.769), moderate agreement on Safety and inclusiveness of opportunities (IRA=0.529), with no differences in the mean ranks (F=1.197, p-value=0.343), strong agreement on thermal comfort (IRA=0.841), with no differences in the mean ranks (F=1.138, p-value=0.372), moderate agreement on Day lighting and viewing comfort(IRA=0.576), with no differences in the mean ranks (F=1.449, p-value=0.239), weak agreement on acoustic comfort (IRA=0.496), with no differences in the mean ranks (F=0.694, p-value=0.657), weak agreement on air pollution monitoring (IRA=0.461), with no differences in the mean ranks (F=1.301, p-value=0.296), moderate agreement on natural ventilation (IRA=0.533), with no differences in the mean ranks (F=0.717, p-value=0.64).

Strong agreement on user health (IRA=0.746), with no differences in the mean ranks (F=0.771, p-value=0.601), strong agreement on building water conservation (IRA=0.746), with no differences in the mean ranks (F=0.144, p-value=0.988), strong agreement on application of innovative water (IRA=0.763), with no differences in the mean ranks (F=0.548, p-value=0.767), strong agreement on leak detection (IRA=0.798), with no differences in the mean ranks (F=1.585, p-value=0.197), strong agreement on water-efficient landscaping and irrigation (IRA=0.835), with no differences in the mean ranks (F=0.788, p-value=0.589), strong agreement on energy-efficient heating and cooling (IRA=0.763), with no differences in the mean ranks (F=0.818, p-value=0.567), moderate agreement on energy-efficient equipment (IRA=0.680), with no differences in the mean ranks (F=0.144, p-value=0.988), strong agreement on energy saving-reduction of electricity (IRA=0.817), with no differences in the mean ranks (F=0.271, p-value=0.945)

Moderate agreement on energy saving-natural gas efficiency (IRA=0.612), with no differences in the mean ranks (F=0.896, p-value=0.514), strong agreement on local/regional building materials (IRA=0.798), with no differences in the mean ranks (F=0.223, p-value=0.965), moderate agreement on secondary use of recycled materials (IRA=0.539), with no differences in the mean ranks (F=1.261, p-value=0.313), moderate agreement on construction and demolition waste management (IRA=0.680), with no differences in the mean ranks (F=0.556, p-value=0.760), weak agreement on building operation and disposal impacts (IRA=0.328), with no differences in the mean ranks (F=1.258, p-value=0.315), moderate agreement on Building total lifecycle costs (IRA=0.604), with no differences in the mean ranks (F=1.884, p-value=0.127), moderate agreement on annual operating costs (IRA=0.633), with no differences in the mean ranks (F=0.958, p-value=0.474), Moderate agreement on affordability (IRA=0.649), with no differences in the mean ranks (F=1.490, p-value=0.226), moderate agreement on safety and security (IRA=0.649), with no differences in the mean ranks (F=0.417, p-value=0.86), moderate agreement on education and awareness (IRA=0.664), with no differences in the mean ranks (F=0.691, p-value=0.659).

#### 4.4.9 Ranking based on significance grading and IRA analysis for round three of Delphi

The indicators were ranked on the basis of significance level; from the extremely important to somewhat important. The first fourteen (14) indicators were extremely important with a moderate consensus among all the indicators, weak agreement among the experts for the 15$^{th}$ indicator irrespective of it being very important, strong consensus for the 16$^{th}$-25$^{th}$, 27$^{th}$ indicators. For the 26$^{th}$ indicator, the experts had moderate agreement with the indicator being very important. The 28$^{th}$ indicator had a very strong agreement with an important significance grading. Indicator number 39 was very important with a weak level of agreement. The 30$^{th}$ and the 38$^{th}$ indicators had one level of agreement although they were important. Indicators 31, 32 and 35 were all important but with a weak level of agreement among the experts. The 33$^{rd}$ indicator had no level of agreement among the experts but was extremely important. While indicators 34 and 36 were important, they had a moderate agreement level among the experts.

**Table 4.31: Ranking of Criteria for round three of Delphi**

| Criterion | RK | Level of agreement | Significance grading |
|---|---|---|---|
| Land use | 1 | Moderate agreement | Extremely important |
| Access to social, domestic, and socio-economic facilities | 1 | Moderate agreement | Extremely important |
| Building form and orientation | 3 | Moderate agreement | Extremely important |
| Day lighting and viewing comfort | 4 | Moderate agreement | Extremely important |
| Building total lifecycle costs | 5 | Moderate agreement | Extremely important |
| Access to public transport | 6 | Moderate agreement | Extremely important |
| Parking capacity | 6 | Moderate agreement | Extremely important |
| Annual operating costs | 8 | Moderate agreement | Extremely important |
| Natural ventilation | 9 | Moderate agreement | Extremely important |
| Affordability | 10 | Moderate agreement | Extremely important |
| Safety and security | 11 | Moderate agreement | Extremely important |
| Education and awareness | 12 | Moderate agreement | Extremely important |
| Energy-efficient equipment | 13 | Moderate agreement | Extremely important |
| Construction and demolition waste management | 13 | Moderate agreement | Extremely important |
| Renewable energy sources use | 15 | Weak agreement | Very important |
| User health | 16 | Strong agreement | Very important |
| Building water conservation | 17 | Strong agreement | Very important |
| Application of innovative water | 18 | Strong agreement | Very important |
| Energy-efficient heating and cooling | 18 | Strong agreement | Very important |
| Building architectural appearance | 20 | Strong agreement | Very important |
| Useful floor space | 21 | Strong agreement | Very important |
| Leak detection | 21 | Strong agreement | Very important |
| Local/regional building materials | 21 | Strong agreement | Very important |
| Energy saving Reduction of electricity | 24 | Strong agreement | Very important |
| Water-efficient landscaping and irrigation | 25 | Strong agreement | Very important |
| Safety and inclusiveness of opportunities | 26 | Moderate agreement | Very important |
| Visual comfort | 27 | Strong agreement | Very important |
| Building Regulation and bye laws | 28 | Very strong agreement | Important |
| Air pollution monitoring | 29 | Weak agreement | Very important |
| Universal design thinking | 30 | Lack of agreement | Important |
| Landscape irrigation | 31 | Weak agreement | Important |
| Acoustic comfort | 32 | Weak agreement | Important |
| Building heights | 33 | Lack of agreement | Extremely important |
| Secondary use of recycled materials | 34 | Moderate agreement | Important |
| Building operation and disposal impacts | 35 | Weak agreement | Important |
| Energy saving-natural gas efficiency | 36 | Moderate agreement | Important |
| Thermal comfort | 37 | Strong agreement | Important |
| Geo-technical aspects of the construction site | 38 | Lack of agreement | Important |
| Rewarding sustainability points and incentivising compliant buildings | 39 | Strong agreement | Important |

From the analysis, land use, access to social, domestic, and socio-economic facilities, building form and orientation, day lighting, building total lifecycle costs, access to public transport, parking capacity, annual operating costs, natural ventilation, affordability, safety and security, education and awareness, energy-efficient equipment, construction and demolition waste management, were extremely important with moderate consensus among the experts.

User health, building water conservation, application of innovative water, energy-efficient heating and cooling, building architectural appearance, useful floor space, leak detection, local/regional building materials, energy saving-reduction of electricity, water-efficient landscaping and irrigation, and visual comfort, were all very important with a strong level of agreement among the experts. Renewable energy sources use and air pollution monitoring were very important with a weak level of agreement among the experts. Surprisingly, Building Regulation and bye laws that was suggested by the participants after Delphi round one was important with a very strong level of agreement among the experts. Despite air pollution monitoring indicator having a weak level of agreement, it was very important according to the experts. Although universal design thinking and geo-technical aspects of the construction site indicators lacked agreement from the experts, they were important. Landscape irrigation, acoustic comfort and building operation and disposal impacts were important much as they had a weak level of agreement among the experts.

The Building heights indicator was extremely important despite its lack of agreement among the experts. Secondary use of recycled materials and energy saving-natural gas efficiency indicators had a moderate level of agreement and important according to the experts. Lastly, thermal comfort and rewarding sustainability points and incentivising compliant buildings, indicators were important with a strong level of agreement from the experts.

Conclusively, as seen from the analysis, the level of agreement improved alongside the significance grading. The significance grade of somewhat important vanished as the experts understood that all the building sustainability assessment indicators are all important.

## 4.5 Determination of building sustainability assessment indices for benchmarking the performance of buildings in Uganda

In this section, the CRITIC technique of MCDA to assign relative weights to different criteria was used, which were then used to calculate the sustainability index of the construction industry in Uganda.

### 4.5.1 Determination of relative weights for indicators

From the analysis, the environmental, social and economic categories of sustainability were considered. The economic sustainability category had the lowest weighting (0.057) compared to the social category (0.218) and environmental category (0.75) has the highest weighting value. This clearly implied that the environmental category of sustainability was the highest ranked of the three, and social category was ranked second and the last being economic category with a weighting of 0.057.

This was in agreement with the findings of Dixon *et al.* (2007) that there is negligence of the economic and social aspects of sustainability which could lead to an imbalance among the sustainability dimensions that would lead to missing of real goals of sustainable development (Goh and Rawlinson, 2013)

**4.5.1.1 Economic sustainability indicators weightings**

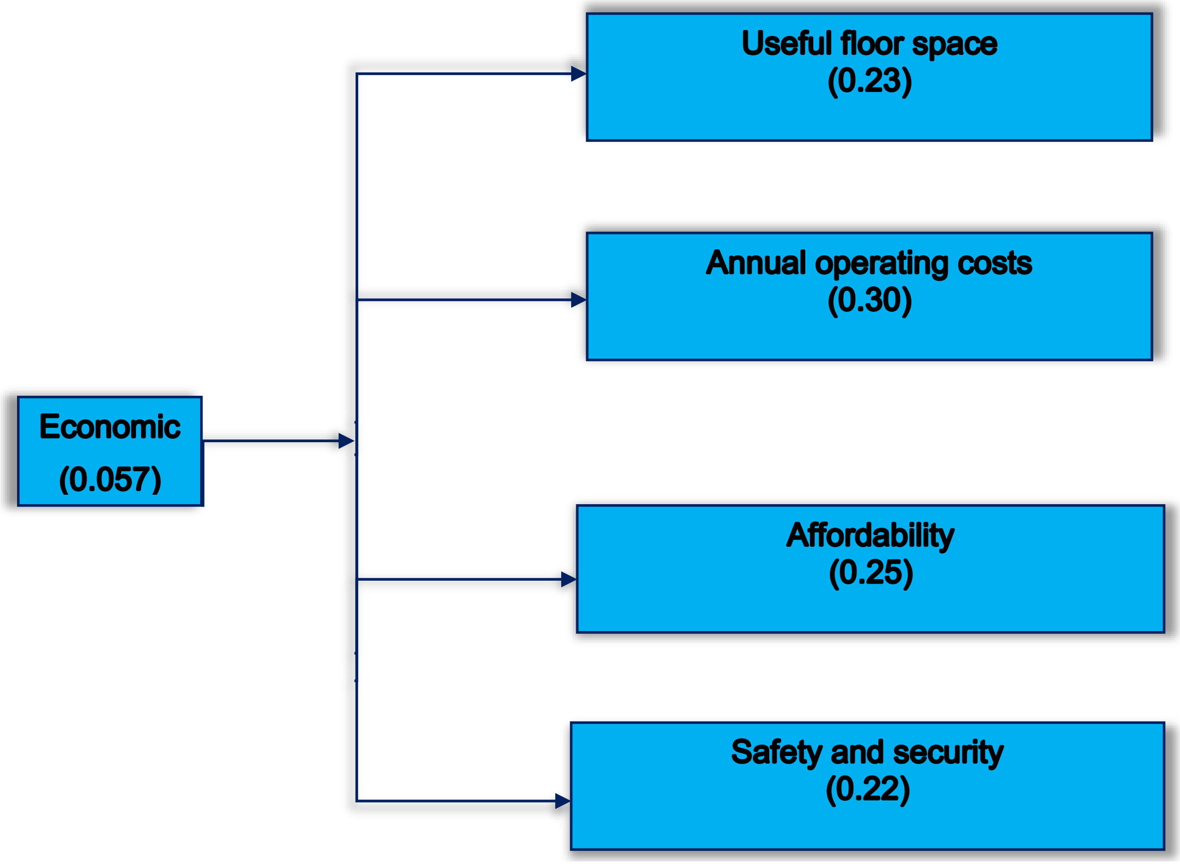



**Figure 4.6: Relative weights for economic indicators**

However, analysis of the economic aspects or indicators revealed that annual operating costs had the highest weighting of 0.30 followed by affordability (0.25), useful floor space (0.23) and safety and security with a weighting of 0.22 respectively. The order of importance is according to the indices in descending order.

#### 4.5.1.2 Social sustainability indicators weightings

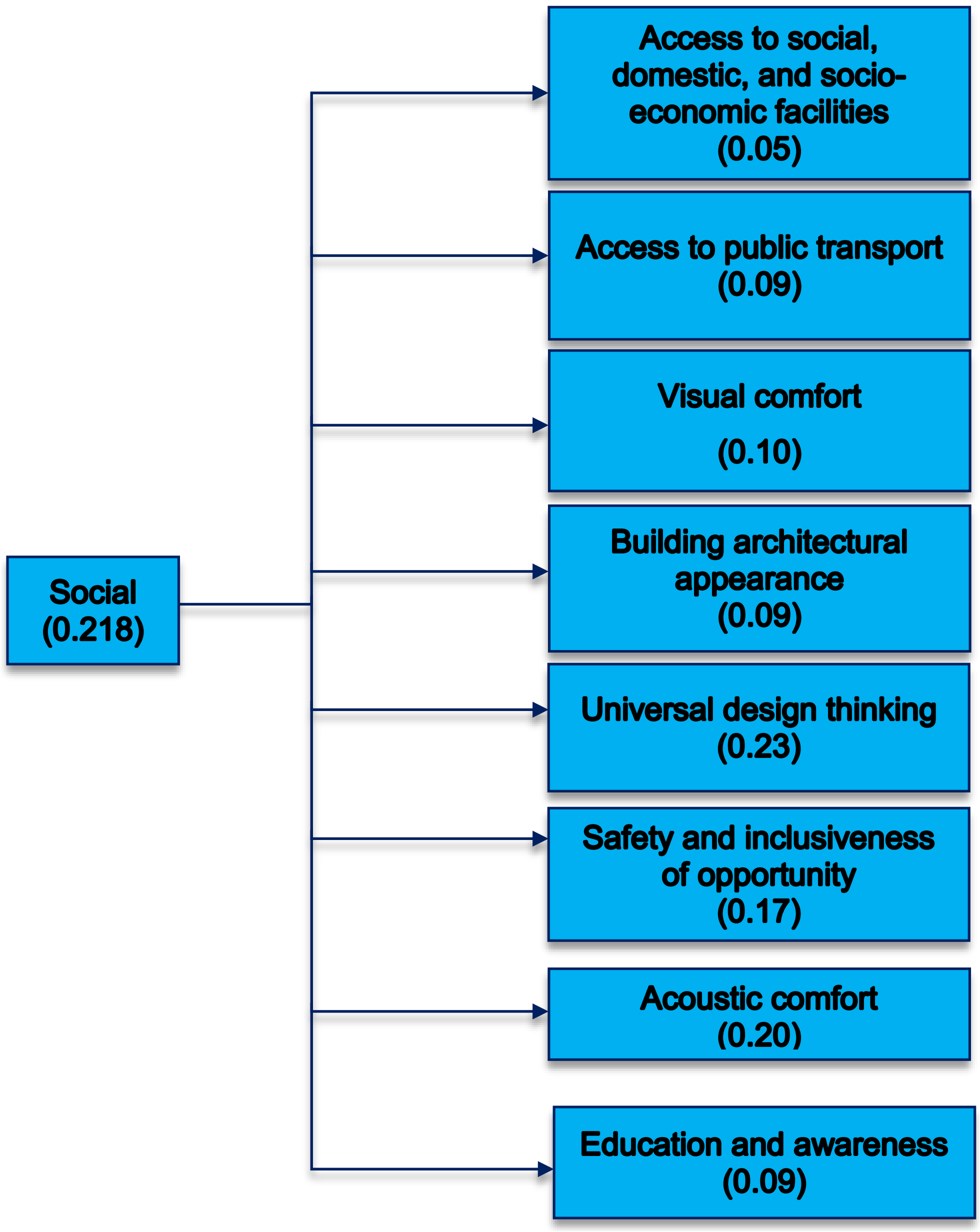



**Figure 4.7: Relative weights for social indicators**

Analysis shows that universal design thinking (0.23) has the highest weighting among the social category followed by acoustic comfort (0.20), safety and inclusiveness of opportunity (0.17), visual comfort (0.10), education and awareness, building architectural appearance, and access to public transport, each has a weighting of 0.09, and access to social, domestic, and socio-economic facilities (0.05), respectively. This implies that the indicators order of importance corresponds with the value of the weighting obtained.

#### 4.5.1.3 Environmental sustainability indicators weightings

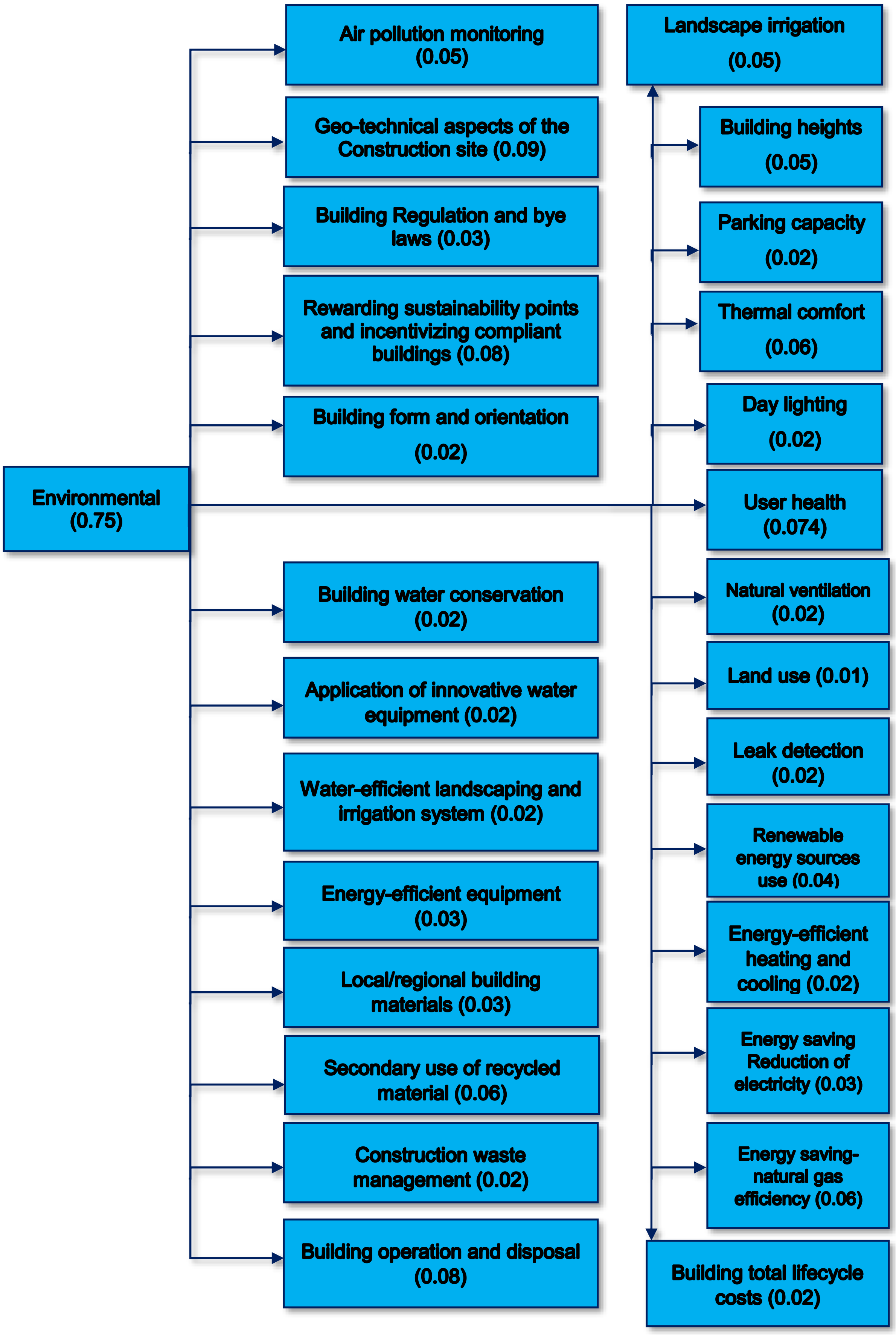



**Figure 4.8: Relative weights for environmental indicators**

Determination of the indices under the environmental category with 27 sustainability indicators revealed that; Rewarding sustainability points and incentivizing compliant buildings with weighting of 0.09, is the indicator with the highest weighting. Implying that, if implemented, it would highly encourage the practice of sustainability in the construction industry. Rewarding sustainability points and incentivizing compliant buildings, and building operation and disposal, each with a weighting of 0.08 came second. Furthermore, Secondary use of recycled materials, energy saving-natural gas efficiency, thermal comfort, follow each with a weighting of 0.06. Landscape irrigation, building heights, air pollution monitoring, each has a weighting of 0.05. Renewable energy sources use has a weighting of 0.04, while, building regulations and bye laws, energy-efficient equipment, energy-saving-reduction of electricity, and local/regional building materials each had a weighting of 0.03. In the same vein, building form and orientation, parking capacity, day lighting, natural ventilation, user health, building water conservation, application of innovative water equipment, leak detection, water-efficient landscaping and irrigation, energy-efficient heating and cooling, construction waste management, and building total lifecycle costs, each has a weighting of 0.02, while land use, has a weighting of 0.01, as illustrated in the figure above.

## 4.6 Discussion

### 4.6.1 Introduction

The construction industry has played significant role in the economic and social development of Uganda. However, the construction process was found to have adverse effects on the environment, social wellbeing of the population and the economy. To address this problem, this study developed a framework for assessing the sustainability of construction practices in Uganda. In this discussion, the key findings of the study and the implications of the framework for the construction industry are explored.

### 4.6.2 Sustainability framework

The first objective of the study was to identify sustainability assessment indicators for assessment of buildings. There are several sustainability indicators that were identified in the literature as relevant for assessing the sustainability of buildings. These were broadly categorized into environmental, social, and economic aspects. Environmental indicators included energy efficiency, water conservation, waste reduction, and the use of environmentally friendly materials. These indicators are commonly used to evaluate the resource consumption and environmental impact of buildings. Social indicators include factors such as indoor air quality, occupant health and comfort, and accessibility. These indicators are used to assess the impact of buildings on the well-being and productivity of their occupants. Economic indicators included economic feasibility. These indicators are used to evaluate the financial viability of sustainable building practices. The literature review provided a comprehensive understanding of the key concepts, theories, and practices related to sustainability in the construction industry.

The second objective of the study was to identify relevant criteria for assessing sustainability in the construction industry of Uganda. A comprehensive list of criteria was developed through a systematic review of the literature and consultation with experts in the field. The identified criteria provided a basis for the development of the sustainability framework in the subsequent objective. The results of the study indicated that environmental criteria had the highest weight (0.75), followed by social (0.218) and economic criteria (0.057). From the results, it can be observed that land use and impacts on ecology (ENV2), building form and orientation (ENV4), building total lifecycle costs (ENV23), local/regional building materials (ENV7), day lighting and viewing comfort (ENV1), parking capacity (ENV10), have extreme importance from the environmental aspect; and annual operating costs (ECO2) and safety and security (ECO4), have extreme importance from the economic aspect; and access to social, domestic, and socio-economic facilities (SOC1), access to public transport (SOC2), safety and inclusiveness of opportunities (SOC5), have extreme importance from the social aspects.

This suggests that the sustainability of buildings in Uganda is heavily influenced by their impact on the environment. For the economic sustainability criteria, the extant literature (Liu, Ding and Samali 2013; Ali and Al Nsairat 2009) have also discussed extensively the need for an increase in the consideration of economic criteria in the development of building projects which are currently lacking in the existing green building rating systems. Based on the weight score by sub-criteria, a construction sustainability index for Uganda construction industry was found to be 68.7, indicating a moderate level of sustainability in the industry. These findings will help policymakers and stakeholders to re-evaluate their priorities and improve the sustainability of buildings in Uganda by considering a more balanced approach that considers all three criteria equally.

The development of a construction sustainability assessment framework for Uganda's construction industry was a crucial step towards sustainable development in the country. Uganda's construction industry is rapidly growing, and with it comes an increased demand for resources, energy and land. This growth has put significant pressure on the environment, and there are concerns that the current practices are not sustainable in the long term. The sustainability assessment framework was based on a robust methodology that can be applied consistently across different construction projects. The sustainability framework provided a systematic approach for assessing and improving sustainability in the construction industry. The UBSAF incorporated local context, regional variation, climatic conditions and topographical aspects by crucially observing a number of criteria to reflect and diagnose regional sustainability. Uganda is a developing country, which is promoting sustainability in the construction industry, hence there is an imperative need for encouraging and adopting sustainability principles to avoid adverse impacts on conventional principles and practices in Uganda.

#### 4.6.3 Relevance of the sustainability framework

A sustainability index of 68.7 for the construction industry of Uganda based on social, economic, and environmental indicators is a reasonably good score, indicating that the industry is performing well in these areas. The construction sustainability index based on social, economic, and environmental indicators is a crucial tool for measuring sustainability in the construction industry. The index provides an objective and comprehensive assessment of the industry's performance in key areas, including social responsibility, economic growth, and environmental impact. Experts in the field of sustainability have emphasized the importance of using such indices to guide decision-making in the construction industry. According to them, sustainable construction practices are critical for achieving global goals such as reducing greenhouse gas emissions, minimizing waste, and ensuring social equity.

This was in agreement with the findings of Dixon et al., (2007) that there is negligence of the economic and social aspects of sustainability which could lead to an imbalance among the sustainability dimensions that would lead to missing of real goals of sustainable development (Goh and Rawlinson, 2013). Nonetheless, the relevance of these results lies in the insights that can be gained from analyzing the scores achieved by the three buildings. For instance, the building that achieved the lowest score of 41.94 had areas where sustainability performance can be improved, while the two buildings that achieved the highest score of 60.55 can serve as benchmarks for sustainable construction practices that can be replicated in other buildings.

#### 4.6.4 Synthesis of literature

Despite the statistics which show the use of international certifications in some regions, developing countries have began to establish their own national certification based on their own priorities. For instance, Ghana GBC has released a national rating system named Building Rating System to include regional characteristics of the country based on the national standard building codes of Ghana (Fowler and Rauch 2006: 107); Nguyen *et al*. (2017: 12). Although South

Africa utilizes well-known certifications, namely EDGE, and Green star (Alaloul et al. 2022: 315), debates exist that such international rating systems may neglect some certain sustainability aspects. This condition could be more problematic in situations where their rating systems are adopted from developed countries with no adaptation in accordance with regional requirements (Assefa, Lee and Shiue 2022: 2).

India’s implementation of LEED for their assessment, a researcher (Gupta, 2009) demonstrated that this country has different context in terms of architecture and climate compared to USA. GRIHA, which is a green rating established by TERI (The Energy and Resources Institute) for integrated habitat assessment, considers sustainability requirements in the Indian context. This certification, which has more than 800 certified buildings, has addressed contextual issues specific for India, which may not be well included by international rating systems.

Indonesia also has implemented international assessment tools namely, LOTUS, LEED, and EDGE, however, barriers exist within such certifications during the assessment of sustainability impacts of Indonesian buildings (Nguyen *et al.* 2017). A study by Soebarto and Ness (2011) compared international assessment systems with Kampung Improvement Programme (KIP) implemented by Indonesia. They recommended that for a consideration of socio- economic as well as contextual issues, KIP should be integrated with an international rating tool to be applicable in developing countries’ contexts. In the same vein, the UBSAF developed for Ugandan context has been linked with LEED and its certification levels adopted for assessing the sustainability of buildings in Uganda. The adopted certification levels are Certified (40-49 points), Silver (50-59-38 points), and Gold (60-79 points), (Ruparathna, Hewage and Sadiq 2016; Shan and Hwang 2018). The last certification level Platinum (80-110 points) wasn’t considered because from the opinions of the experts, the developed model or framework had a total of 68.7 points as compared to 110 points of LEED version 2.0. However, it should be noted that UBSAF considers social, environmental and economic aspects of sustainability, unlike the main sustainability assessment tools that consider mainly the environmental aspects.

### 4.6.5 Contribution to knowledge

This research contributes to knowledge in the following ways;

**a) New framework in Uganda**

It has developed a framework for assessing the sustainability of buildings in Uganda. This is so because there has not been any framework like mine before.

This being new, it’s a great contribution to knowledge especially in the aspects of environmental protection, social well-being and economic sustainability.

**b) Application of a framework in a new context**

Sustainability assessment is done in many countries with varying local contexts and geography. The fact that a framework has been developed for the Ugandan local conditions different from those of other countries where sustainability assessment of building has been done before is a contribution to knowledge.

**c) Publication**

A publication about a sustainability assessment framework for sustainability assessment of buildings in Uganda is a contribution to knowledge as this publication is to be used by scholars to enhance and improve the concept of sustainability assessment in the construction industry of Uganda (see appendix E).

**d) Significant contribution to policy or practice in Uganda’s construction industry**

The developed framework will help improve the policies and practices relating to buildings in Uganda which will improve the aspects of environmental protection, economic, and social well-being with regards to the buildings in Uganda.

# CHAPTER FIVE: SUSTAINABILITY ASSESSMENT FRAMEWORK FOR BUILDINGS IN UGANDA

## 5.1 Sustainability index

From the analysis shown in Table 5.1, the sustainability index of the Ugandan construction industry is 68.7 constructed on relevant criteria suggested by the study participants. From LEED rating system which was adapted for this framework, the achieved index is good for construction sustainability in Uganda, as its rated as gold by the experts. Three essential components for sustainability development were considered in the framework; environmental protection, social equity, and economic growth.

The results in Table 5.1 show that economic sustainability index was 26.81, with the affordability indicator having the highest score of 6.77 and the social sustainability index was 21.65, with safety and inclusiveness of opportunities having the highest score of 4.063. The environmental sustainability index was 20.27, which was less compared to the social and economic sustainability index. This was because some indicators were considered somewhat relevant to the construction industry but with lower weight. Among the environmental sustainability indicators, building operations and cost had the highest score of 1.221, and geotechnical aspects of the construction site scored 1.176. The overall results are presented in Table 5.1.

**Table 5.1: Sustainability indices for the indicators**

| ENVIRONMENTAL INDICATORS | TOTAL INDICES 20.27 |
|---|---|
| Land use | 0.407 |
| Geo-technical aspects of the construction site | 1.176 |
| Building Regulation and bye laws | 0.736 |
| Rewarding sustainability points and incentivising compliant buildings | 1.034 |
| Landscape irrigation | 0.772 |
| Building heights | 0.941 |
| Building form and orientation | 0.520 |
| Parking capacity | 0.621 |
| Thermal comfort | 1.099 |
| Day lighting | 0.580 |
| Air pollution monitoring | 0.993 |
| Natural ventilation | 0.646 |
| User health | 0.597 |
| Building water conservation | 0.574 |
| Application of innovative water equipment | 0.567 |
| Leak detection | 0.570 |
| Water-efficient landscaping and irrigation | 0.540 |
| Renewable energy sources use | 0.929 |
| Energy-efficient heating and cooling | 0.556 |
| Energy-efficient equipment | 0.714 |
| Energy saving-reduction of electricity | 0.614 |
| Energy saving-natural gas efficiency | 0.899 |
| Local/regional building materials | 0.621 |
| Secondary use of recycled materials | 1.028 |
| Construction waste management | 0.653 |
| Building operation and disposal | 1.221 |
| Building total lifecycle costs | 0.662 |
| **ECONOMIC INDICATORS** | **TOTAL INDICES 26.81** |
| Useful floor space | 5.81 |
| Annual operating costs | 8.28 |
| Affordability | 6.77 |
| Safety and security | 5.95 |
| **SOCIAL INDICATORS** | **TOTAL INDICES 21.65** |
| Access to social, domestic, and socio-economic facilities | 1.329 |
| Access to public transport | 2.389 |
| Visual comfort | 2.470 |
| Building architectural appearance | 2.157 |
| Universal design thinking | 3.882 |
| Safety and inclusiveness of opportunities | 4.063 |
| Acoustic comfort | 2.948 |
| Education and awareness | 2.414 |
| **OVERALL INDEX** | **68.70** |

## 5.2 Development and validation of the building sustainability assessment framework

### 5.2.1 Sustainability assessment framework

A sustainability index of 68.7, as rated by LEED, indicates a good level of sustainability performance for the construction industry. The framework developed contain three criteria considered to be relevant for sustainability of construction industry in Uganda. Each sub-criterion was assigned a score, summing up to 68.7. The framework shows that, by following the same road map in the Ugandan construction industry, resources used will not be depleted and the environment will not be harmed in the process of construction, enhancing the sustainability of the environment, economic and social friendly building in the country. The sustainability index of 68.7 in the developed framework is a positive indicator for Uganda`s construction industry. This suggests that the industry is taking steps towards sustainable practices and making progress towards improving the overall quality and safety standards of its operations. However, it is important to note that there is room for improvement, and the industry should continue to strive towards higher sustainability ratings. The framework developed for the Ugandan construction industry is shown in Figure 5.1.


**Figure 5.1:Building Sustainability Framework for the construction industry in Uganda**

| 2023 UBSAF Uganda Building Sustainability Assessment Framework | | | PROJECT NAME: | | |
|---|---|---|---|---|---|
| | | | DATE: | | |
| | | | PROJECT CHECK LIST | | |
| Y | ? | N | ENVIRONMENTAL INDICATORS | POSSIBLE POINTS 20.27 | POINTS ARCHIVED |
| ☐ Check | ☐ Check | ☐ Check | Land use | 0.407 | |
| ☐ Check | ☐ Check | ☐ Check | Geo-technical aspects of the Construction site | 1.176 | |
| ☐ Check | ☐ Check | ☐ Check | Building Regulation and bye laws | 0.736 | |
| ☐ Check | ☐ Check | ☐ Check | Rewarding sustainability points and incenticising compliant buildings | 1.034 | |
| ☐ Check | ☐ Check | ☐ Check | Landscape irrigation | 0.772 | |
| ☐ Check | ☐ Check | ☐ Check | Building heights | 0.941 | |
| ☐ Check | ☐ Check | ☐ Check | Building form and orientation | 0.520 | |
| ☐ Check | ☐ Check | ☐ Check | Parking capacity | 0.621 | |
| ☐ Check | ☐ Check | ☐ Check | Thermal comfort | 1.099 | |
| ☐ Check | ☐ Check | ☐ Check | Day lighting | 0.580 | |
| ☐ Check | ☐ Check | ☐ Check | Air pollution monitoring | 0.993 | |
| ☐ Check | ☐ Check | ☐ Check | Natural ventilation | 0.646 | |
| ☐ Check | ☐ Check | ☐ Check | User health | 0.597 | |
| ☐ Check | ☐ Check | ☐ Check | Building water conservation | 0.574 | |
| ☐ Check | ☐ Check | ☐ Check | Application of innovative water | 0.567 | |
| ☐ Check | ☐ Check | ☐ Check | Leak detection | 0.570 | |
| ☐ Check | ☐ Check | ☐ Check | Water-efficient landscaping and irrigation | 0.540 | |
| ☐ Check | ☐ Check | ☐ Check | Renewable energy sources use | 0.929 | |
| ☐ Check | ☐ Check | ☐ Check | Energy-efficient heating and cooling | 0.556 | |
| ☐ Check | ☐ Check | ☐ Check | Energy-efficient equipment | 0.714 | |
| ☐ Check | ☐ Check | ☐ Check | Energy saving-reduction of electricity | 0.614 | |
| ☐ Check | ☐ Check | ☐ Check | Energy saving-natural gas efficiency | 0.899 | |
| ☐ Check | ☐ Check | ☐ Check | Local/regional building materials | 0.621 | |
| ☐ Check | ☐ Check | ☐ Check | Secondary use of recycled materia | 1.028 | |
| ☐ Check | ☐ Check | ☐ Check | Construction waste management | 0.653 | |
| ☐ Check | ☐ Check | ☐ Check | Building operation and disposal | 1.221 | |
| ☐ Check | ☐ Check | ☐ Check | Building total lifecycle costs | 0.662 | |
| | | | | | |
| | | | ECONOMIC INDICATORS | POSSIBLE POINTS 26.81 | POINTS ARCHIVED |
| ☐ Check | ☐ Check | ☐ Check | Useful floor space | 5.81 | |
| ☐ Check | ☐ Check | ☐ Check | Annual operating costs | 8.28 | |
| ☐ Check | ☐ Check | ☐ Check | Affordability | 6.77 | |
| ☐ Check | ☐ Check | ☐ Check | Safety and security | 5.95 | |
| | | | | | |
| | | | SOCIAL INDICATORS | POSSIBLE POINTS 21.65 | POINTS ARCHIVED |
| ☐ Check | ☐ Check | ☐ Check | Access to social, domestic, and socio-economic facilities | 1.329 | |
| ☐ Check | ☐ Check | ☐ Check | Access to public transport | 2.389 | |
| ☐ Check | ☐ Check | ☐ Check | Visual comfort | 2.470 | |
| ☐ Check | ☐ Check | ☐ Check | Building architectural appearance | 2.157 | |
| ☐ Check | ☐ Check | ☐ Check | Universal design thinking | 3.882 | |
| ☐ Check | ☐ Check | ☐ Check | Safety and inclusiveness of opportunities | 4.063 | |
| ☐ Check | ☐ Check | ☐ Check | Acoustic comfort | 2.948 | |
| ☐ Check | ☐ Check | ☐ Check | Education and awareness | 2.414 | |
| Y-Yes | ?-Not sure | N-No | Certified 40-49 points  Silver 50-59 points  Gold 60-79 points | | |

**Figure 5.2: Sustainability Assessment Tool**

### 5.3 Validation of the Sustainability Framework

The test results from evaluating the construction sustainability index of 68.7 on three buildings were as follows: 51.41, 41.94, and 60.55 (refer to the appendices: K1, K2, and K3 respectively). These results imply that the evaluated building were all certified. It was noted that some indicators were practiced from the selected sites; for example, the finished building of St. Francis Hospital in Nsambya, the contractor being Excel Construction Company Limited, the site manager needed to be more knowledgeable about rewarding sustainability points and incentivising compliant buildings. Yet, it was one of the most critical indicators for environmental sustainability in Uganda. Contractors needed to be more knowledgeable about other indicators like landscape irrigation, thermal comfort, water-efficient landscape and irrigation, energy-saving reduction of electricity, and secondary use of recycled materials.

Besides, some of the environmental indicators were not practiced: land use, building heights, air pollution monitoring, building water conservation, application of innovative water, energy-efficient heating and cooling, energy-efficient equipment, energy-saving natural gas efficiency, and building operation and disposal, which explains why the environmental sustainability index was lower compared to social and economic indicators. In the case of social sustainability indicators, apart from accessibility to social, domestic, and socio-economic facilities, other indicators were practiced at the site. This was the same for the economic indicators, where annual operating cost was the only indicator to be practiced. Therefore, this scored 41.94, indicating that many of the sustainability indicators must be considered during the three phases of the site construction.

The second site used for validating the framework was the proposed new chamber building for the Parliament of Uganda, with ROKO Construction Limited as the contractor. The results revealed that, regarding practicing sustainability, this company performed better than Excel Construction Limited, as it scored 60.55. The project manager was unaware of only three indicators: rewarding sustainability points and incentivizing compliant buildings, secondary use of recycled materials for environmental indicators, and safety and inclusiveness of opportunities for social indicators. Notwithstanding, environmental sustainability scored less for this site than other sustainability criteria. The third site was the Makerere University Icon Tower, under reconstruction within Makerere University, with Excel Construction Limited as the project contractor, which scored 51.41. The project manager was more knowledgeable regarding the sustainability indicators than the managers of the other two projects. However, it was noticed that eleven (11) environmental indicators should have been practiced. All four (4) economic indicators were practiced, and only one (1) social sustainability indicator was not practiced. The overall results reveal that the project managers were not knowledgeable about some of the sustainability indicators which were proposed in the framework for sustainability of the Uganda Construction industry. Besides, many of the environmental indicators were not practiced during the three phases of the project: pre-construction, during construction, and post-construction. This was different for social indicators and economic indicators as they were practiced during the three phases of construction.

## 5.4 Acceptability of the framework in the construction industry

To verify the plausibility of the proposed framework, experts in different fields were requested to answer questions about how easy and intuitive the proposed construction sustainability framework was. Among the experts selected, two (2) were female (quantity surveyor and architect) and the others were male (structural engineer, mechanical engineer, and architect). All the participants were from the construction industry with working experience of over five (5) years.

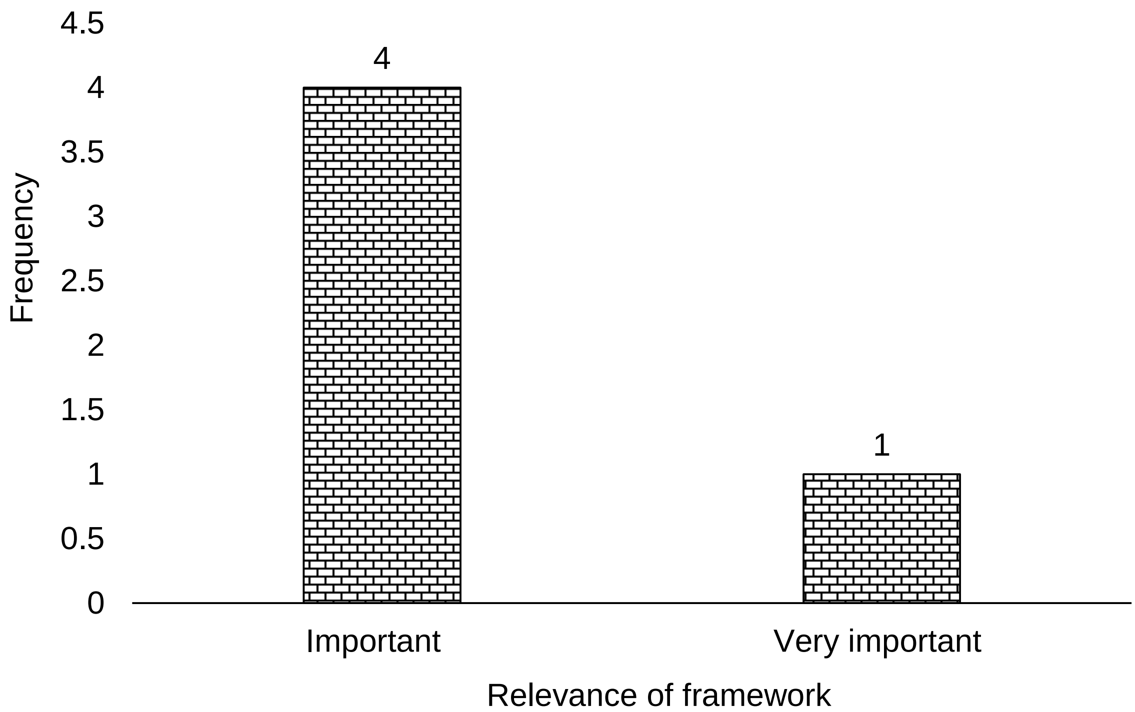



**Figure 5.3: Relevance of framework to practitioners**

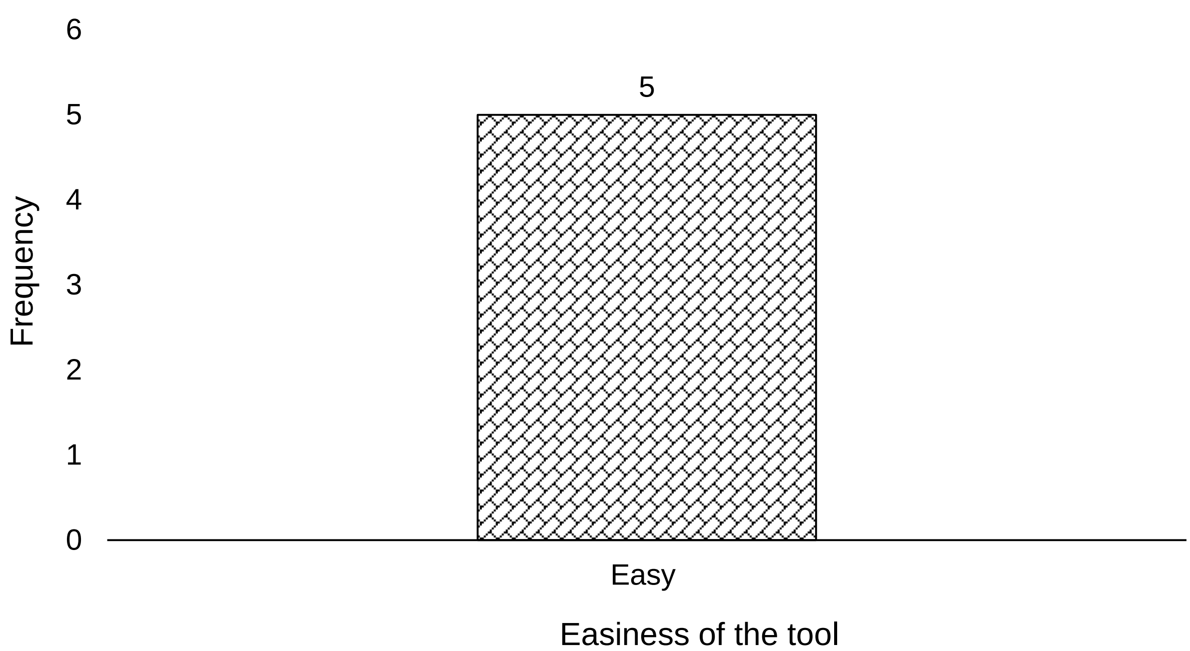



**Figure 5.4: Easiness of the tool**

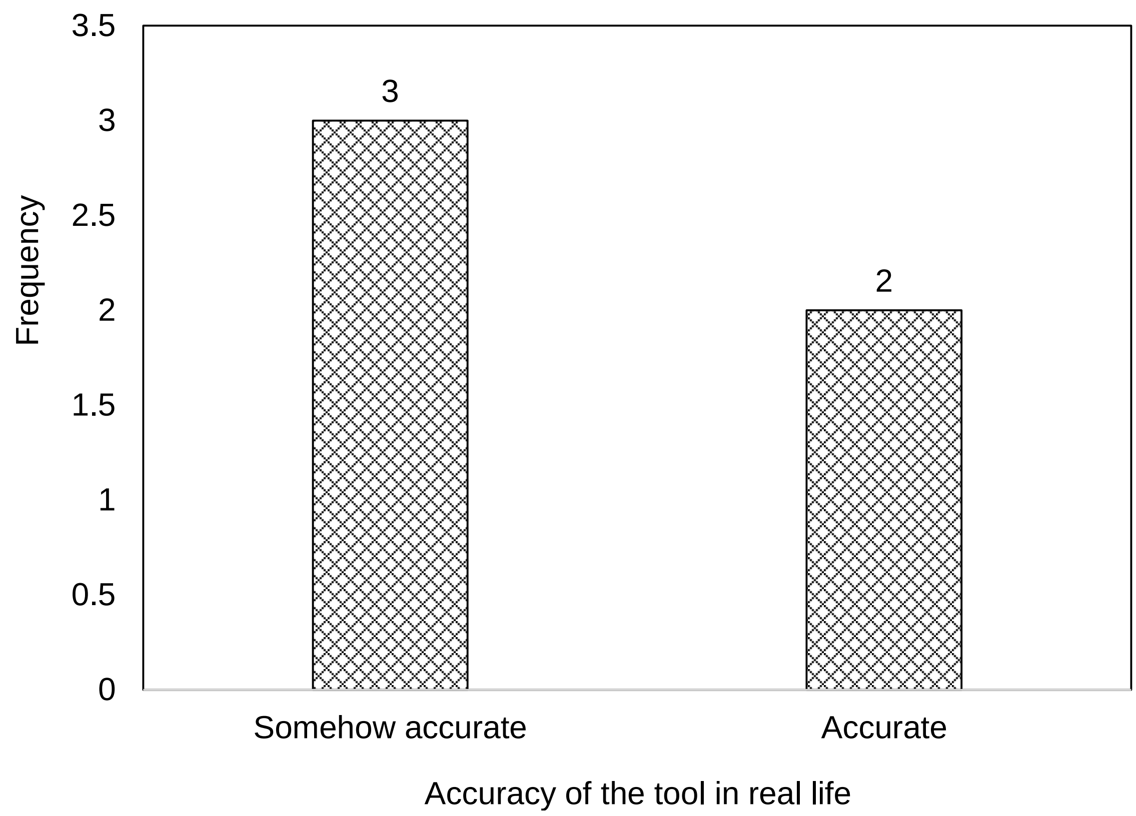



**Figure 5.5: Accuracy of the tool in real life**

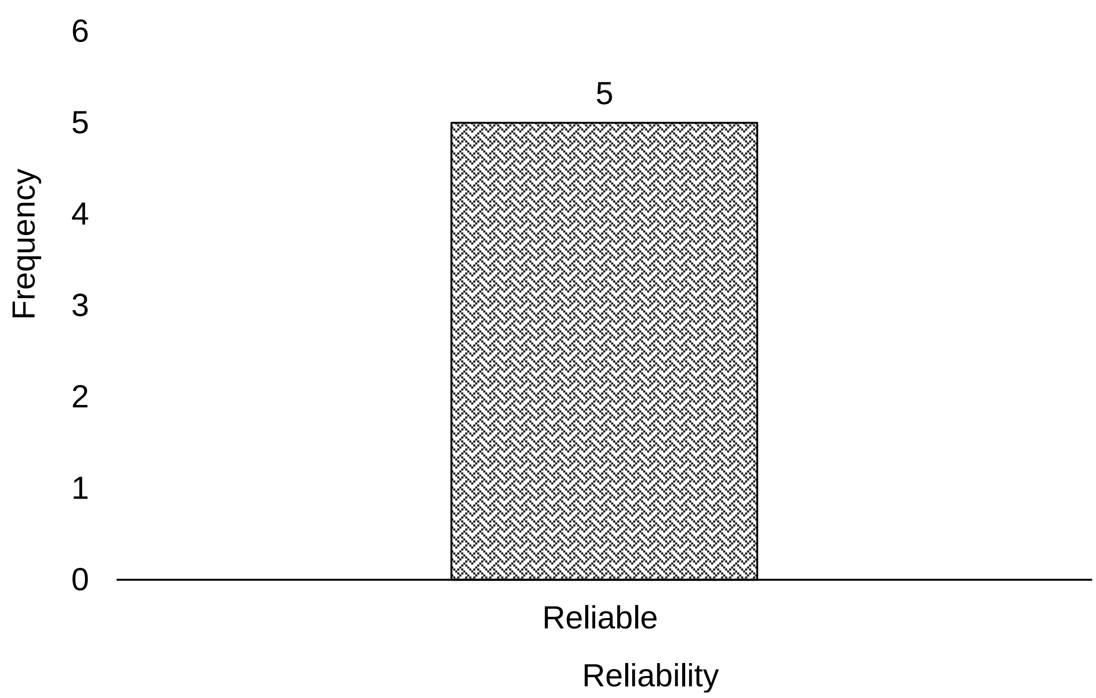



**Figure 5.6: Reliability of the tool results**

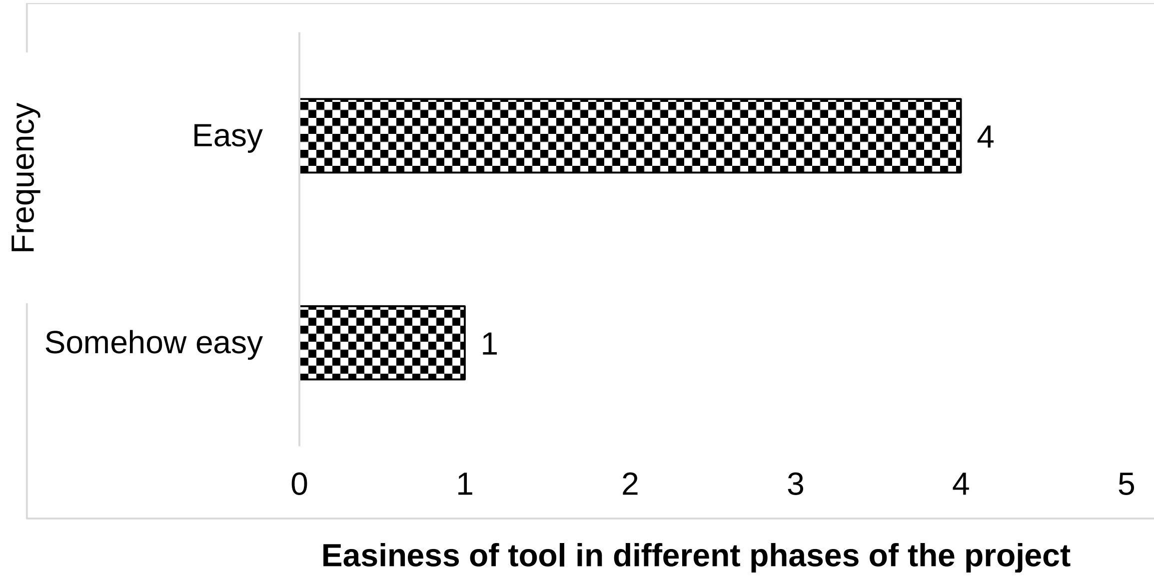



**Figure 5.7: Easiness of tool in different phases of the project**

Four (4) of the participants suggested that the framework was relevant to the practitioners in the Ugandan construction industry. All the experts suggested that the framework was easy to use, three (3) of the experts suggested that the tool was somehow accurate and the two (2) suggested that the tool was accurate, all the experts suggested that the tool results were reliable, and four (4) of the experts suggested that the tool is easy to be used in the different phase of construction.

# CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

## 6.1 Conclusions

The recent innovations and development in the built environment have led to calls for academics and practitioners alike to use innovative technologies such as sustainability practices to drive the implementation of the sustainable smart city. The study established the various building sustainability assessment indicators through the systematic content analysis of extant literature under three (3) categories namely, social, economic and environment. A Delphi survey technique was adopted which involved thirty experts from academia and other industry practitioners, who formed the expert panel and provided the data for this study across three rounds of Delphi survey. A series of statistical methods such mean score ranking, Kendall’s coefficient of concordance, inter-rater agreement (IRA) statistics, analyses were used in analyzing the responses solicited from the expert panel.

The expert panel achieved reasonable levels of consensus after the third round of Delphi survey and likewise among the respondents’ groups such as the academicians, practitioners, etc. Moreover, the expert panel, as well as the experts’ groups, were significantly improved in their levels of the agreement after the second and third rounds with both Kendall's coefficient values and the chi-square values higher than the values obtained in the first round of Delphi survey. More so, some factors have increased ranking after the second and third-round while some retained the same rank and a few reduced in the ranking.

Meanwhile, the IRA statistic was used to validate the consensus reached by the expert panel on each factor, and the factors’ significance levels were incorporated to rank each indicator in descending order. Utilizing the significance level and level of agreement, the study identified ten extremely important indicators of building sustainability assessment in construction projects. These include “land use,” “access to social, domestic, and socio-economic facilities,” “building form and orientation,” “day lighting and viewing comfort,” “building total lifecycle costs,” “access to public transport,” “parking capacity,” “annual operating costs,” “natural ventilation,” “affordability,” “safety and security,” “education and awareness,” “energy-efficient equipment,” and “construction and demolition waste management.”

UBSAF assesses the sustainability of all types of buildings and considers all phases of the project, not the specific phases of the project. It also assesses ongoing and complete projects and its basically for the Ugandan local conditions, climate and geographical aspects.

## 6.2 Recommendations

It is anticipated that in the future, the performance standards of buildings in Uganda would rise (more buildings become ‘greener’ or the baseline improves); therefore, over time, regulations would be updated, sustainable technologies, local capabilities and understanding of issues would evolve, and sustainable building performance may be improved. In fact, it should be noted that the proposed benchmarks in this thesis are by no means definitive or conclusive. As many of the benchmarks are context dependent, they should also be adjusted if adopted in different areas or regions. Adjustments should also be made to weightings and scoring in response to changing priorities.

Assessment criteria included in the Validated Comprehensive UBSA framework must be extended at any point in time when the severity of certain issues become more acute or of greater political and public concern. This process will not only facilitate the necessary integration of issues, perspectives and views in building assessment but also facilitate participation and transfer of knowledge among stakeholders.

## 6.3 Recommendations for Further Research

It is recommended for the following areas to be investigated for further study:

(i) Developing the sustainability assessment framework for the different phases of the project. This is due to the fact that UBSAF is for both an ongoing project and a complete project.

(ii) Testing the appropriateness of UBSAF criteria and benchmarks – applicable to the different phases of the project development – on case study of buildings in Uganda;

(iii) Studies related to life cycle assessments (LCA) to profile the environmental performance of projects, materials, and components produced in Uganda;

(iv) Development of a Uganda-specific building sustainability assessment framework for the various building types, using the UBSA framework as the basis; and

(v) Development of a country-specific building sustainability assessment framework in other emerging/developing countries, using the UBSA framework as the basis.

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# APPENDICES

## Appendix A: The Delphi questionnaire

**Dear Participant,**

Makerere University in collaboration with Durban University of Technology is undertaking a project titled "***Developing a sustainability assessment framework for buildings in Uganda***" that is aimed at developing sustainable construction industry. The thematic area is the built environment (focus on habitable and conducive housing for residential, commercial and institutions).

The research topic is triggered by the lack of sustainability assessment standards that have led to lack of laws regulating the built environment hence leading to environmental, social-cultural, and economic violations and low quality of life. The purpose of the research is therefore to explore the various sustainability indicators in the various building sustainability assessment tools, and practices globally and come up with a framework that will suite the Ugandan local conditions thereby coming up with the sustainability assessment framework for buildings in Uganda.

As a project deliverable for the Built Environment, we are currently conducting a study on the development of a sustainability assessment tool/framework for buildings in Uganda. To achieve this objective, we have designed a questionnaire targeting building professionals including Architects, Quantity Surveyors, Engineers, Environmentalists, and academicians in the built environment.

You have been identified as a key participant for the study and we thereby request that you spare approximately 10 minutes of your time to respond to this questionnaire. Completion of the questionnaire is completely voluntary and returning the completed questionnaire will be considered as your consent to participate in the study. The data collected from this study is purely for research purposes and will be strictly confidential.

In the event of questions or queries, please do not hesitate to contact us. Thank you for your time.

Yours sincerely,

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**QUESTIONNAIRE**

**Topic: Developing a Sustainability Assessment Framework for Buildings in Uganda**

**INSTRUCTION: simply fill or tick in the space to give an answer**

| **PART 1: DEMOGRAPHIC INFORMATION** | |
|---|---|
| **1. Indicate your gender** | |
| Male | |
| Female | |
| **2. Indicate your highest qualification** | **tick** |
| Diploma | |
| Bachelor's degree | |
| Master's degree | |
| Doctorate degree | |
| Other (specify) | |
| **3. Please indicate your profession** | |
| Architect | |
| Structural Engineer | |
| Mechanical Engineer | |
| Quantity surveyor | |
| Electrical Engineer | |
| Environmentalist | |
| Academician | |
| **4. What is your age category?** | |
| 18 – 25 | |
| 26 – 35 | |
| 36 – 45 | |
| 46 – 55 | |
| Above 55 | |
| **5. How many years of experience do you have in the building industry?** | |
| 0 – 5 | |
| 6 – 10 | |
| 11 – 15 | |
| 16 – 20 | |
| Above 20 | |

**Questionnaire continues.**
**Round one**

| **PART 2: RELEVANCE / IMPORTANCE OF THE CATEGORIES AND INDICATORS** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sustainability assessment can be done by using several categories and indicators. The categories and their indicators listed in the table below were obtained from an extensive literature review and as an expert, you are required to rate the importance of the following indicator/s for the sustainability assessment framework for buildings in Uganda to be developed. The main goal is to ensure the importance of each assessment item and its applicability to Uganda's local context. Please rate the appropriateness of inclusion of the indicators in the sustainability assessment framework for buildings to be developed for Uganda on a five-point Likert scale based on: 1 = Not important, 2 = Slightly important, 3 = Moderately important, 4 = important, 5 = Very important | | | | | | | |
| **Sustainability Assessment categories and indicators** | | | | | | | |
| **Category** | **Indicator** | **Environmental, Social, Economic** | **1** | **2** | **3** | **4** | **5** |
| Category 1: Construction site selection and Infrastructure; | Land use and impacts on ecology(using land for construction in accordance with the functional purpose of the land and having existing public utilities), | Environmental | | | | | |
| | Low-impact site construction (minimizing effects of construction activities through selection of land previously occupied by buildings and infrastructure, it also includes actions to protect and restore the environment during the construction process). | Environmental | | | | | |
| | Access to social, domestic, and socio-economic facilities (availability of basic services like banks, pharmacy, medical facility, school, place of worship, supermarket, grocery, fire station, laundry; within 800 m of the building entrance), | Social | | | | | |
| | Landscape irrigation (Using equipment for land irrigation like automated system with drain batteries, water tap sprinkler and garden tap) | Environmental | | | | | |
| | Access to public transport | Social | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Visual comfort (Aimed to provide favorable emotional conditions for users and is measured by lack of monotonous landscapes, facades, roofs, windows, and interior) | Social | | | | | |
| Category 2: Building architectural and planning solutions quality; | Building architectural appearance quality (ensuring that the building architectural and planning solutions quality: building architectural appearance fits the surrounding environment and its functional purpose and aesthetic requirements with architectural uniqueness, originality and architectural novelty) | Social | | | | | |
| | Building form and orientation (this has an impact on energy efficiency of the building facility) | Environmental | | | | | |
| | Useful floor space (This aims at providing the sufficient zone for users to work in the building) | Economic | | | | | |
| | Parking capacity (As addressed in LEED and BREEAM is intended to reduce pollution and land development impacts from automobiles use) | Environmental | | | | | |
| | Safety and inclusiveness of opportunities (space should be designed in a way to enhance connectivity to all building occupants including disabled, healthy and elderly persons as well as accessibility for minor mobile group of population) | Social | | | | | |
| Category 3: Indoor Environmental Quality; Indicator: | Thermal comfort (aims to create a desirable state of occupants in the building. It's measured by heating, ventilation and air conditioning system in the building) | Environmental | | | | | |
| | Day lighting and viewing comfort(Aims at providing sufficient natural lighting in the building) | Environmental | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Acoustic comfort (this considers the indoor ambient noise levels during daytime and nighttime) | Social | | | | | |
| | Air pollution monitoring (helps to monitor indoor environment from contamination from penetrated air form the outdoor environment) | Environmental | | | | | |
| | Natural ventilation (Is evaluated by the passive cooling system used in the building during the nighttime) | Environmental | | | | | |
| | User health | Environmental | | | | | |
| Category 4: Water efficiency; Indicator: | Application of innovative water efficient equipment | Environmental | | | | | |
| | Leak detection | Environmental | | | | | |
| | Water-efficient landscaping and irrigation systems (helps to save the water use in the building (e.g. rainwater and storm water can be used for irrigation and landscaping) | Environmental | | | | | |
| Category 5: Energy efficiency; | Renewable energy sources use (use of sources like hydro, solar, biomass, wind) | Environmental | | | | | |
| | Energy-efficient heating and cooling (plays a role in reaching energy-efficient building. Adequate insulation and sealing of the building envelope as well as using energy-saving windows are important in preventing heat loss) | Environmental | | | | | |
| | Energy-efficient equipment (using equipment like electric and water heaters, electric stoves, and ovens, that are energy efficient) | Environmental | | | | | |
| | Energy savings Reduction of electricity consumption (use of energy-efficient lighting fixtures and energy-efficient elevators to reduce electricity consumption) | Environmental | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Energy saving Natural gas efficiency (use of natural gas for electricity production can have a tremendous effect on the cost benefits, social comfort and environmental protection) | Environmental | | | | | |
| Category 6: Green Building Materials; | Local/regional building materials (use of local building materials can enhance the production of green certified building materials domestically leading to job creation | Environmental | | | | | |
| | Secondary use of recycled materials (use of recycled materials to help raise the interest of building materials manufacturers to develop the recycling process) | Environmental | | | | | |
| | Construction and demolition waste management | Environmental | | | | | |
| Category 7: Waste; | Building operation and disposal impact | Environmental | | | | | |
| | Building total lifecycle costs (including construction, operation, and maintenance costs) | Economic | | | | | |
| Category 8: Economy; | Annual operating costs (annual maintenance costs and building exploitation costs including heating and electricity costs are crucial factors as well as considering an affordability of the buildings) | Economic | | | | | |
| | Affordability (this is associated with rental affordability of building spaces in green facilities) | Economic | | | | | |
| | Safety and security | Economic | | | | | |
| Category 9: Management; | Education and awareness | Social | | | | | |

| Please, provide any additional assessment item that you would consider appropriate and important or that you felt is missing | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

Any other comments (Optional)

…………………………………………………………………………………………......

**Thank you**

**Delphi, rounds two and three questionnaire**

**PART 2: RELEVANCE / IMPORTANCE OF THE CATEGORIES AND INDICATORS**

Sustainability assessment can be done by using several categories and indicators. The categories and their indicators listed in the table below were obtained from an extensive literature review and as an expert, you are required to rate the importance of the following indicator/s for the sustainability assessment framework for buildings in Uganda to be developed. The main goal is to ensure the importance of each assessment item and its applicability to Uganda's local context. Please rate the appropriateness of inclusion of the indicators in the sustainability assessment framework for buildings to be developed for Uganda on a five-point Likert scale based on: 1 = Not important, 2 = Slightly important, 3 = Moderately important, 4 = important, 5 = Very important

| **Sustainability Assessment categories and indicators** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Category** | **Indicator** | **Environmental, Social, Economic** | **1** | **2** | **3** | **4** | **5** |
| Category 1: Construction site selection and Infrastructure; | Land use and impacts on ecology(using land for construction in accordance with the functional purpose of the land and having existing public utilities), | Environmental | | | | | |
| | Low-impact site construction (minimizing effects of construction activities through selection of land previously occupied by buildings and infrastructure, it also includes actions to protect and restore the environment during the construction process). | Environmental | | | | | |
| | Access to social, domestic, and socio-economic facilities (availability of basic services like banks, pharmacy, medical facility, school, place of worship, supermarket, grocery, fire station, laundry; within 800 m of the building entrance), | Social | | | | | |
| | Landscape irrigation (Using equipment for land irrigation like automated system with drain batteries, water tap sprinkler and garden tap) | Environmental | | | | | |
| | Access to public transport | Social | | | | | |
| | *Geo-technical aspects of the construction site* | Environmental | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | *Building Regulation and bye laws (Building Bye laws are the rules and regulations set forth by the concerned government authorities and updated time to time. These regulations guide us about what to construct, how and where. Building by laws help in making a planned Development).* | Environmental | | | | | |
| | *Rewarding sustainability points and incentivizing compliant buildings (Governments through its agencies may provide incentives to promote sustainability building practices in the construction sector as a way of promoting the sustainability practice).* | Environmental | | | | | |
| | Visual comfort (Aimed to provide favorable emotional conditions for users and is measured by lack of monotonous landscapes, facades, roofs, windows, and interior) | Social | | | | | |
| Category 2: Building architectural and planning solutions quality; | Building architectural appearance quality (ensuring that the building architectural and planning solutions quality: building architectural appearance fits the surrounding environment and its functional purpose and aesthetic requirements with architectural uniqueness, originality and architectural novelty) | Social | | | | | |
| | Building form and orientation (this has an impact on energy efficiency of the building facility) | Environmental | | | | | |
| | Useful floor space (This aims at providing the sufficient zone for users to work in the building) | Economic | | | | | |
| | Universal Design-thinking beyond the mere provision of ramps when designing for PWD | Social | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Parking capacity (As addressed in LEED and BREEAM is intended to reduce pollution and land development impacts from automobiles use) | Environmental | | | | | |
| | *Building Height (skyline), orientation in relation to sun and wind movement* | Social | | | | | |
| | Safety and inclusiveness of opportunities (space should be designed in a way to enhance connectivity to all building occupants including disabled, healthy and elderly persons as well as accessibility for minor mobile group of population) | Social | | | | | |
| Category 3: Indoor Environmental Quality; Indicator: | Thermal comfort (aims to create a desirable state of occupants in the building. It's measured by heating, ventilation and air conditioning system in the building) | Environmental | | | | | |
| | Day lighting and viewing comfort(Aims at providing sufficient natural lighting in the building) | Environmental | | | | | |
| | Acoustic comfort (this considers the indoor ambient noise levels during daytime and nighttime) | Social | | | | | |
| | Air pollution monitoring (helps to monitor indoor environment from contamination from penetrated air form the outdoor environment) | Environmental | | | | | |
| | Natural ventilation (Is evaluated by the passive cooling system used in the building during the nighttime) | Environmental | | | | | |
| | User health | Environmental | | | | | |
| Category 4: Water efficiency; Indicator: | Application of innovative water efficient equipment | Environmental | | | | | |
| | Leak detection | Environmental | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Water-efficient landscaping and irrigation systems (helps to save the water use in the building (e.g. rainwater and storm water can be used for irrigation and landscaping) | Environmental | | | | | |
| Category 5: Energy efficiency; | Renewable energy sources use (use of sources like hydro, solar, biomass, wind) | Environmental | | | | | |
| | Energy-efficient heating and cooling (plays a role in reaching energy-efficient building. Adequate insulation and sealing of the building envelope as well as using energy-saving windows are important in preventing heat loss) | Environmental | | | | | |
| | Energy-efficient equipment (using equipment like electric and water heaters, electric stoves, and ovens, that are energy efficient) | Environmental | | | | | |
| | Energy savings Reduction of electricity consumption (use of energy-efficient lighting fixtures and energy-efficient elevators to reduce electricity consumption) | Environmental | | | | | |
| | Energy saving Natural gas efficiency (use of natural gas for electricity production can have a tremendous effect on the cost benefits, social comfort and environmental protection) | Environmental | | | | | |
| Category 6: Green Building Materials; | Local/regional building materials (use of local building materials can enhance the production of green certified building materials domestically leading to job creation | Environmental | | | | | |
| | Secondary use of recycled materials (use of recycled materials to help raise the interest of building materials manufacturers to develop the recycling process) | Environmental | | | | | |
| | Construction and demolition waste management | Environmental | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Category 7: Waste; | Building operation and disposal impact | Environmental | | | | | |
| | Building total lifecycle costs (including construction, operation, and maintenance costs) | Economic | | | | | |
| Category 8: Economy; | Annual operating costs (annual maintenance costs and building exploitation costs including heating and electricity costs are crucial factors as well as considering an affordability of the buildings) | Economic | | | | | |
| | Affordability (this is associated with rental affordability of building spaces in green facilities) | Economic | | | | | |
| | Safety and security | Economic | | | | | |
| Category 9: Management; | Education and awareness | Social | | | | | |

**Appendix B: Sustainability Indicators codes**

| Indicator | Code |
|---|---|
| Land use and impacts on ecology | ENV-1 |
| Access to social, domestic, and socio-economic facilities | SOC-1 |
| Access to public transport | SOC-2 |
| Landscape irrigation | ENV-2 |
| Visual comfort | SOC-3 |
| Building architectural appearance | SOC-4 |
| Building form and orientation | ENV-3 |
| Useful floor space | SOC-5 |
| Parking capacity | ENV-4 |
| Safety and inclusiveness of opportunity | SOC-6 |
| Thermal comfort | ENV-5 |
| Day lighting and viewing comfort | ENV-6 |
| Acoustic comfort | SOC-7 |
| Air pollution monitoring | ENV-7 |
| Natural ventilation | ENV-8 |
| User health | ENV-9 |
| Building water conservation | ENV-10 |
| Application of innovative water | ENV-11 |
| Leak detection | ENV-12 |
| Water-efficient landscaping and irrigation | ENV-12 |
| Renewable energy sources use | ENV-13 |
| Energy-efficient heating and cooling | ENV-14 |
| Energy-efficient equipment | ENV-15 |
| Energy saving-reduction of electricity | ENV-16 |
| Energy saving-natural gas efficiency | ENV-17 |
| Local/regional building materials | ENV-18 |
| Secondary use of recycled materials | ENV-19 |
| Construction and demolition waste management | ENV-20 |
| Building operation and disposal impacts | ENV-21 |
| Building total lifecycle costs | ENV-22 |
| Annual operating costs | ECO-1 |
| Affordability | ECO-2 |
| Safety and security | ECO-3 |
| Education and awareness | ECO-4 |
| Geo-technical aspects of the Construction site | ENV-23 |
| Building Regulation and bye laws | ENV-24 |
| Rewarding sustainability points and incentivising compliant buildings | ENV-25 |
| Building heights | SOC-8 |
| Universal design thinking | SOC-9 |

## Appendix C: Ethics clearance approval

DUT
INSTITUTIONAL RESEARCH ETHICS COMMITTEE

Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

8 May 2023

Mr J Semanda
Department of Construction Economics and Management
Makerere University
P.O. Box 7062
Kampala
Uganda

Dear Mr Semanda

**Developing a Sustainability Assessment Framework for Buildings in Uganda**
**Ethical Clearance number IREC 197/22**

The Institutional Research Ethics Committee acknowledges receipt of your final data collection tool for review.

We are pleased to inform you that the data collection tool has been approved. Kindly ensure that participants used for the pilot study are not part of the main study.

In addition, the DUT-IREC acknowledges receipt of your gatekeeper permission letter.

Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the DUT-IREC according to the DUT-IREC Standard Operating Procedures (SOP's).

Please note that any deviations from the approved proposal require the approval of the DUT-IREC as outlined in the DUT-IREC SOP's.

**It is compulsory for a student or researcher to apply for recertification on an annual basis. The failure to do so will result in withdrawal of ethics clearance. It is the responsibility of the researcher and the supervisor to apply for recertification.**

**Please note that you are required to submit a Notification of Completion of Study form together with an abstract to the DUT-IREC office on completion of your study.**

Yours Sincerely

Prof J K Adam
Chairperson: DUT-IREC

ENVISION2030 transparency · honesty · integrity · respect · accountability
fairness · professionalism · commitment · compassion · excellence

**Appendix D: FRC Proposal Approval**

**5th March 2020**

**Student number: 22064549**

**Dear Mr J Semanda**

## <u>DOCTOR OF PHILOSOPHY IN MANAGEMENT STUDIES: BUSINESS ADMINISTRATION</u>

**This serves to confirm the approval of your research proposal by the Faculty Research Committee, at its meeting on** 3rd March 2020**, as follows:**

1. Research proposal and provisional dissertation title:

**Developing a Sustainability Assessment Framework for Building in Uganda.**

Supervisor: **Professor S Moyo**

Co-supervisor 1: **Dr SHP Chikafalimani**

Co-supervisor 2**: Dr Nathan Kibwami**

**Please note that any proposed changes in the thesis/dissertation title require the approval of your supervisor/s, the Faculty Research Committee, as well as ratification thereof by the Higher Degrees Committee.**

2. Research budget to the amount of **R15 000.00**
**Please note that this funding is not a scholarship or bursary and is therefore not paid directly to you but is controlled by the Faculty. Any proposed changes to the use of this funding allocation requires the approval of your supervisor and the Dean. Please note that funding will be reimbursed to you after the provision of receipts.**

**The Institutional Research Committee has stipulated that:**

(a) This University retains the ownership of any Intellectual Property (patent, design, etc.) registered in respect of the results of your Masters/Doctors Degree in Technology studies as a result of the award and the provisions of the above

Act.

(b) Should you find any of the terms above not acceptable then you are given the option to decline the Research budget award to your project in writing.

**May we remind you that in terms of Rule G25(2)(b), if you fail to obtain the Masters/Doctors degree within the maximum time period allowed after first registering for the qualification, Senate may refuse to renew your registration or may impose any conditions it deems fit. You may apply to the Faculty Research Committee for an extension.**

**Please note that you are required to convert your registration from the informal to the formal course and re-register each year.**

**Please note that the following must be adhered to:**

## Registration:

1. Ensure formal registration has taken place ***(the onus is on the student and the supervisor to ensure registration takes places at the beginning of each year whilst the student is currently engaged with his/her Masters or PhD qualification)***
2. Ensure that application for Conferment of Status has been made in the event of your undergraduate qualification being different to this application. ***Your attention is drawn to the fact that Conferment of Status is required for registration.***
3. Ensure that your supervisor has submitted your proposal to the Faculty Research Officer (FRO) for IREC clearance (institutional research ethics committee). This is in the case of Ethics level 2 IREC and level 3 IREC (in the case of a study dealing with vulnerable populations). See guideline attached. ***It is the researcher's responsibility to check the Ethics requirements and submit to the relevant bodies irrespective of the reviewer's recommendation.***

## Dissertation submission for examination:

1. Ensure that you submit the intention to submit form **(PG 5)**, signed by the HOD and Supervisor
2. Ensure that the signed checklist is submitted with the **PG 5**
3. Once your dissertation is submitted to the supervisor for examination purposes, communication from here on will only be with your supervisor and not with the faculty.
4. Your supervisor MUST nominate the examiners three months prior to submission of the dissertation/thesis for examination.
5. On submission for examination, please note that three ring bound signed copies must be submitted to your supervisor along with the completed and signed **PG 7** form, **FMS Checklist** and **Turn it in report**.
6. Feedback will be provided to your supervisor regarding the examination result after the result is ratified by the Higher Degrees Committee (HDC).
7. In the event of a resubmission the reports will be submitted to the supervisor who will communicate with you for revision. Once revision has taken place your supervisor will submit to the FRO for resubmission to the examiners.
8. In the case where there is a discrepancy in examiners results, an Arbiter will be nominated via the HOD and supervisor and tabled at FRC and ratified at HDC. On completion of this process, the Arbiters report will be tabled at FRC and ratified at HDC.

9. Results of the Arbitration process will be communicated to your supervisor

## Graduation requirements:

1. Ensure that you submit a completed signed PG10 form
2. one hard bound dissertation/thesis with a pdf version on CD
3. response to post graduate examination form
4. completion of study form (IREC form)

**Should you experience any problems relating to your research, your supervisor must be informed of the matter as soon as possible. If the difficulties persist, you should then approach your Head of Department and thereafter the Faculty Research Coordinator.**

**Please refer to the 2020 General Rule Book and the Postgraduate Students' Guide 2020 concerning the rules relating to postgraduate studies, which include *inter alia* acceptable minimum and maximum timeframes, submission of thesis/dissertations, etc. Please do not hesitate to contact this office for any assistance. We wish you success in your studies.**

**Kind regards,**

.................................

**Prof FG Netswera**

**Faculty of Management Sciences**

## Appendix E: Turnitin report

turnitin

# Digital Receipt

This receipt acknowledges that Turnitin received your paper. Below you will find the receipt information regarding your submission.

The first page of your submissions is displayed below.

| | |
|---|---|
| Submission author: | Julius Semanda |
| Assignment title: | Chapter 1 to 5 |
| Submission title: | THESIS FINAL |
| File name: | Thesis_Final-Julius_Semanda.docx |
| File size: | 16.5M |
| Page count: | 189 |
| Word count: | 51,335 |
| Character count: | 307,235 |
| Submission date: | 19-Apr-2024 08:13AM (UTC+0200) |
| Submission ID: | 2295362990 |


DEVELOPING A SUSTAINABILITY ASSESSMENT FRAMEWORK FOR BUILDINGS IN UGANDA


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FACULTY OF MANAGEMENT SCIENCES
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Submitted in fulfilment of the requirements of the degree of Doctor of Philosophy of Management Sciences specializing in Business Administration in the Faculty of Management Sciences at Durban
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**Appendix F1: Gate Keepers' Letters-Engineers Registration Board**

Telephone: 256 - 39 - 3194942
Email: admin@erb.go.ug
Website : www.erb.go.ug

Engineers Registration Board,
P.O. Box 29267,
Kampala, UGANDA.

In any correspondence on this subject
please quote No: ...*ERB/2*

14th April, 2023

Chair of Research Ethics Review Committee,
Faculty of Management Sciences,
Department of Entrepreneurial Studies and Management,
Durban University of Technology,
Durban, South Africa.

Dear Sir

**LETTER OF SUPPORT FOR MR. SEMANDA JULIUS TO USE OUR DATABASE OF REGISTERED ENGINEERS TO CARRY OUT HIS RESEARCH STUDY.**

The Engineers Registration Board (ERB) is a statutory body under Ministry of Works and Transport (MoWT) mandated by the Engineers Registration Act, (1969), to regulate and control the practice of engineering in Uganda and to advise Government on engineering matters.

Reference is made to your letter dated 4th April 2023 on the above subject matter introducing **Mr. Julius Semanda** requesting for support in using our registered engineer's database in carrying out his research study titled ***"Developing a sustainability assessment framework for buildings in Uganda".*** as a requirement in fulfillment of his PhD studies in Doctor of Philosophy in Management Studies: Business Administration.

We wish to inform you that the Board has accepted your request and our Secretariat Staff will support the student with utmost cooperation towards achieving his research goals. In doing so, the student is to develop and share the online questionnaire to be forwarded to our registered engineers for feedback.

For the purposes of sharing knowledge, we look forward to receiving a copy of the final research report for our Resource Centre.

Yours Sincerely

**ENG. NAMUGERA RONALD**
**REGISTRAR, ENGINEERS REGISTRATION BOARD**

c.c. Chairman, Engineers Registration Board

## Appendix F2: Gate Keepers' Letters-Uganda Society of Architects

**UGANDA SOCIETY OF ARCHITECTS**

Kalamu House 1st Floor Wing A Plot 1B, Kira Road. P.O. Box 9514, Kampala Uganda.
Tel: 256 393 264 359. email: archi.uganda@gmail.com Website: www.architectuganda.com

**Our Ref: USA/21/PS/23/280**
**Date: 12th April, 2023**

The Chair of Research Ethics Review Committee,
Faculty of Management Sciences,
Department of Business Administration
Durban, University of Technology,
Durban, South Africa.

Dear Sir,

**RE: LETTER OF SUPPORT FOR MR. JULIUS SEMANDA TO USE OUR DATABASE TO CARRY OUT HIS RESEARCH STUDY**

Warm greetings from the 21st Council of Uganda Society of Architects (USA)!

The USA was founded in 1966 to advance the practice of the architectural profession in Uganda. Our key objectives are to organize, lobby, and unite architects in Uganda; to foster and strengthen ties among architects and other organizations; to foster and maintain public confidence in the integrity and ability of architects; and to provide a link with the government, the public, and other organizations.

Reference is made to the letter dated 3rd April 2023, requesting us to grant Mr. Julius Semanda permission to use our database to aid him in his research study titled: **"Developing a sustainability assessment framework for buildings in Uganda"** in fulfillment of his PhD studies.

We have considered the matter carefully and we shall avail him with needed assistance with regards to the society's database as per allowable measures.

We hope that the society shall be availed with a copy of the research report for the benefit of our members.

Yours sincerely,

**ARCH. DR. EMMANUEL SSINABULYA,**
**President,**
**Uganda Society of Architects.**

**Appendix F3: Gate Keepers' Letters-Surveyors Registration Board**

INSTITUTION OF SURVEYORS OF UGANDA

Our Ref: ISU/32/04/03/2023/GA

29th March, 2023



Chair of Research Ethics Review Committee,
Faculty of Management Sciences,
Department of Business Administration,
Durban University of Technology,
Durban, South Africa.

Dear Sir,

**RE: LETTER OF SUPPORT FOR MR. JULIUS SEMANDA TO USE OUR DATABASE TO CARRY OUT HIS RESEARCH STUDY**

The Institution of Surveyors of Uganda (ISU), is a Premier Professional body that brings together Land Surveying, Quantity Surveying, Valuation Surveying, Mining and Hydrological Surveying Professionals in Uganda. Our key objective is to secure the advancement and facilitate the acquisition of professional knowledge and promote the general interest of the profession and the Institution to maintain and extend their usefulness for public advantage.

Reference is made to communication introducing Mr. Julius Semanda requesting for approval to use our database of the institution of surveyors of Uganda. This is only to aid his research study titled: "developing a sustainability assessment framework for buildings in Uganda" in fulfillment for his PhD studies.

We wish to inform you of our acceptance of this request and hereby assure the student of our utmost cooperation towards achieving his research goals, of which the outcome we believe will help in supporting surveyors, improve their skills and capabilities in construction projects and achieve success in terms of time, cost and quality delivery.

The database in category of quantity surveying chapter has been availed to Mr. Julius Semanda as per the request.
We look forward to receiving a copy of the research report for the benefit of our members.

Yours Faithfully

INSTITUTION OF SURVEYORS OF UGANDA
29 MAR 2023
P. O. BOX 2122, KAMPALA

RSU. Robert Wafula
HONORARY SECRETARY


Karobwa Towers, Nkrumah Rd, 5th floor - Room 001 • +256 (0)414 251258
P.O. Box 2122, Kampala, Uganda • isusecretariat@gmail.com • www.surveyorsofuganda.org

**Appendix G: Framework acceptance questionnaire**

**Acceptability of the framework in the construction industry questionnaire**

| The main goal is to assess the acceptability of the developed framework by the practitioners. On the Likert scale of 1 to 5, rate the following: 1 = Not important, 2 = Slightly important, 3 = Moderately important, 4 = important, 5 = Very important | | | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 1. | How relevant is this to practitioners in Uganda construction industry? | | | | | |

| On the Likert scale of 1 to 5, rate the following: 1 = Very inaccurate, 2 = inaccurate, 3 = somehow accurate, 4 = accurate, 5 = Very accurate | | | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 2. | How accurate does this tool represent real life? | | | | | |

| On the Likert scale of 1 to 5, rate the following: 1 = very difficult, 2 = difficult, 3 = somehow easy, 4 = easy, 5 = Very easy | | | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 3. | How easy is it to use the developed tool? | | | | | |

| On the Likert scale of 1 to 5, rate the following: 1 = very difficult, 2 = difficult, 3 = somehow easy, 4 = easy, 5 = Very easy | | | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 4. | How would you rate the easiness of using this tool in different phases of the project? | | | | | |

| On the Likert scale of 1 to 5, rate the following: 1 = very unreliable, 2 = unreliable, 3 = somehow reliable, 4 = reliable, 5 = Very reliable | | | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 5. | How reliable are the tool results? | | | | | |

## Appendix H1: Framework validated on Makerere University Project

CONTRACTOR: EXCEL CONSTRUCTION LT

2023 Uganda Buildings Sustainability Assessment Framework (UBSAF)

PROJECT NAME: CONSTRUCTION AND RESTORATION OF MAKERERE UNIVERSITY MAIN BUILDING.

DATE: 26/10/2023

PROJECT CHECK LIST

| Y | ? | N | ENVIRONMENTAL INDICATORS | POSSIBLE POINTS 20.27 | POINTS ARCHIVED |
|---|---|---|---|---|---|
| ☑ Check | ☐ Check | ☐ Check | Land use | 0.407 | |
| ☑ Check | ☐ Check | ☐ Check | Geo-technical aspects of the Construction site | 1.176 | |
| ☑ Check | ☐ Check | ☐ Check | Building Regulation and bye laws | 0.736 | |
| ☐ Check | ☑ Check | ☐ Check | Rewarding sustainability points and incenticising compliant buildings | 1.034 | |
| ☐ Check | ☐ Check | ☑ Check | Landscape irrigation | 0.772 | |
| ☐ Check | ☐ Check | ☑ Check | Building heights | 0.941 | |
| ☑ Check | ☐ Check | ☐ Check | Building form and orientation | 0.520 | |
| ☑ Check | ☐ Check | ☐ Check | Parking capacity | 0.621 | |
| ☑ Check | ☐ Check | ☐ Check | Thermal comfort | 1.099 | |
| ☑ Check | ☐ Check | ☐ Check | Day lighting | 0.580 | |
| ☐ Check | ☐ Check | ☑ Check | Air pollution monitoring | 0.993 | |
| ☑ Check | ☐ Check | ☐ Check | Natural ventilation | 0.646 | |
| ☐ Check | ☐ Check | ☑ Check | User health | 0.597 | |
| ☐ Check | ☐ Check | ☑ Check | Building water conservation | 0.574 | |
| ☐ Check | ☐ Check | ☑ Check | Application of innovative water | 0.567 | |
| ☑ Check | ☐ Check | ☐ Check | Leak detection | 0.570 | |
| ☐ Check | ☐ Check | ☑ Check | Water-efficient landscaping and irrigation | 0.540 | |
| ☑ Check | ☐ Check | ☐ Check | Renewable energy sources use | 0.929 | |
| ☐ Check | ☐ Check | ☑ Check | Energy-efficient heating and cooling | 0.556 | |
| ☐ Check | ☐ Check | ☑ Check | Energy-efficient equipment | 0.714 | |
| ☑ Check | ☐ Check | ☐ Check | Energy saving-reduction of electricity | 0.614 | |
| ☐ Check | ☐ Check | ☑ Check | Energy saving-natural gas efficiency | 0.899 | |
| ☑ Check | ☐ Check | ☐ Check | Local/regional building materials | 0.621 | |
| ☐ Check | ☑ Check | ☐ Check | Secondary use of recycled materials | 1.028 | |
| ☑ Check | ☐ Check | ☐ Check | Construction waste management | 0.653 | |
| ☐ Check | ☐ Check | ☑ Check | Building operation and disposal | 1.221 | |
| ☑ Check | ☐ Check | ☐ Check | Building total lifecycle costs | 0.662 | |
| | | | **ECONOMIC INDICATORS** | **POSSIBLE POINTS 26.81** | **POINTS ARCHIVED** |
| ☑ Check | ☐ Check | ☐ Check | Useful floor space | 5.81 | |
| ☑ Check | ☐ Check | ☐ Check | Annual operating costs | 8.28 | |
| ☑ Check | ☐ Check | ☐ Check | Affordability | 6.77 | |
| ☑ Check | ☐ Check | ☐ Check | Safety and security | 5.95 | |
| | | | **SOCIAL INDICATORS** | **POSSIBLE POINTS 21.65** | **POINTS ARCHIVED** |
| ☑ Check | ☐ Check | ☐ Check | Access to social, domestic, and socio-economic facilities | 1.329 | |
| ☑ Check | ☐ Check | ☐ Check | Access to public transport | 2.389 | |
| ☑ Check | ☐ Check | ☐ Check | Visual comfort | 2.470 | |
| ☑ Check | ☐ Check | ☐ Check | Building architectural appearance | 2.157 | |
| ☑ Check | ☐ Check | ☐ Check | Universal design thinking | 3.882 | |
| ☐ Check | ☐ Check | ☑ Check | Safety and inclusiveness of opportunities | 4.063 | |
| ☑ Check | ☐ Check | ☐ Check | Acoustic comfort | 2.948 | |
| ☑ Check | ☐ Check | ☐ Check | Education and awareness | 2.414 | |
| | | | TOTAL | Possible points: 68.730 | |

Y-Yes ?-Not sure N-No Certified 40-49 points Silver 50-59 points Gold 60-79 points

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## Appendix H2: Framework validated on Mother Kevin Building

CONTRACTOR: EXCEL CONSTRUCTION LTD

2023 Uganda Buildings Sustainability Assessment Framework (UBSAF)

PROJECT NAME: 70 BED MOTHER KEVIN WING BUILDING AT ST. FRACIS HOSPITAL NSAMBYA

DATE: 27/10/2023

PROJECT CHECK LIST

| Y | ? | N | ENVIRONMENTAL INDICATORS | POSSIBLE POINTS 20.27 | POINTS ARCHIVED |
|---|---|---|---|---|---|
| | | ✓ | Land use | 0.407 | |
| ✓ | | | Geo-technical aspects of the Construction site | 1.176 | |
| ✓ | | | Building Regulation and bye laws | 0.736 | |
| | ✓ | | Rewarding sustainability points and incenticising compliant buildings | 1.034 | |
| | ✓ | | Landscape irrigation | 0.772 | |
| | | ✓ | Building heights | 0.941 | |
| ✓ | | | Building form and orientation | 0.520 | |
| ✓ | | | Parking capacity | 0.621 | |
| | ✓ | | Thermal comfort | 1.099 | |
| ✓ | | | Day lighting | 0.580 | |
| | | ✓ | Air pollution monitoring | 0.993 | |
| ✓ | | | Natural ventilation | 0.646 | |
| ✓ | | | User health | 0.597 | |
| | | ✓ | Building water conservation | 0.574 | |
| | | ✓ | Application of innovative water | 0.567 | |
| | | ✓ | Leak detection | 0.570 | |
| | ✓ | | Water-efficient landscaping and irrigation | 0.540 | |
| ✓ | | | Renewable energy sources use | 0.929 | |
| | | ✓ | Energy-efficient heating and cooling | 0.556 | |
| | | ✓ | Energy-efficient equipment | 0.714 | |
| | ✓ | | Energy saving-reduction of electricity | 0.614 | |
| | | ✓ | Energy saving-natural gas efficiency | 0.899 | |
| ✓ | | | Local/regional building materials | 0.621 | |
| | ✓ | | Secondary use of recycled materials | 1.028 | |
| ✓ | | | Construction waste management | 0.653 | |
| | | ✓ | Building operation and disposal | 1.221 | |
| ✓ | | | Building total lifecycle costs | 0.662 | |

| Y | ? | N | ECONOMIC INDICATORS | POSSIBLE POINTS 26.81 | POINTS ARCHIVED |
|---|---|---|---|---|---|
| ✓ | | | Useful floor space | 5.81 | |
| | | ✓ | Annual operating costs | 8.28 | |
| ✓ | | | Affordability | 6.77 | |
| ✓ | | | Safety and security | 5.95 | |

| Y | ? | N | SOCIAL INDICATORS | POSSIBLE POINTS 21.65 | POINTS ARCHIVED |
|---|---|---|---|---|---|
| | | ✓ | Access to social, domestic, and socio-economic facilities | 1.329 | |
| ✓ | | | Access to public transport | 2.389 | |
| ✓ | | | Visual comfort | 2.470 | |
| ✓ | | | Building architectural appearance | 2.157 | |
| ✓ | | | Universal design thinking | 3.882 | |
| ✓ | | | Safety and inclusiveness of opportunities | 4.063 | |
| ✓ | | | Acoustic comfort | 2.948 | |
| ✓ | | | Education and awareness | 2.414 | |
| | | | TOTAL | Possible points: 68.730 | |

Y-Yes ?-Not sure N-No Certified 40-49 points Silver 50-59 points Gold 60-79 points

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## Appendix H3: Framework validated on Parliament project

2023 Uganda Buildings Sustainability Assessment Framework (UBSAF)

PROJECT NAME: PROPOSED NEW CHAMBER BUILDING FOR THE PARLIAMENT OF UGANDA. – ROKO CONSTRUCTION LTD/ROKO CONSTRUCTION (RWANDA) – (JV)
DATE: 25/10/2023.

PROJECT CHECK LIST

| Y | ? | N | ENVIRONMENTAL INDICATORS | POSSIBLE POINTS 20.27 | POINTS ARCHIVED |
|---|---|---|---|---|---|
| ☑ Check | ☐ Check | ☐ Check | Land use | 0.407 | |
| ☑ Check | ☐ Check | ☐ Check | Geo-technical aspects of the Construction site | 1.176 | |
| ☑ Check | ☐ Check | ☐ Check | Building Regulation and bye laws | 0.736 | |
| ☐ Check | ☐ Check | ☑ Check | Rewarding sustainability points and incenticising compliant buildings | 1.034 | |
| ☐ Check | ☑ Check | ☐ Check | Landscape irrigation | 0.772 | |
| ☑ Check | ☐ Check | ☐ Check | Building heights | 0.941 | |
| ☑ Check | ☐ Check | ☐ Check | Building form and orientation | 0.520 | |
| ☑ Check | ☐ Check | ☐ Check | Parking capacity | 0.621 | |
| ☐ Check | ☐ Check | ☑ Check | Thermal comfort | 1.099 | |
| ☑ Check | ☐ Check | ☐ Check | Day lighting | 0.580 | |
| ☐ Check | ☑ Check | ☐ Check | Air pollution monitoring | 0.993 | |
| ☑ Check | ☐ Check | ☐ Check | Natural ventilation | 0.646 | |
| ☑ Check | ☐ Check | ☐ Check | User health | 0.597 | |
| ☐ Check | ☐ Check | ☑ Check | Building water conservation | 0.574 | |
| ☐ Check | ☑ Check | ☐ Check | Application of innovative water Equipment | 0.567 | |
| ☑ Check | ☐ Check | ☐ Check | Leak detection | 0.570 | |
| ☐ Check | ☐ Check | ☑ Check | Water-efficient landscaping and irrigation | 0.540 | |
| ☑ Check | ☐ Check | ☐ Check | Renewable energy sources use | 0.929 | |
| ☐ Check | ☐ Check | ☑ Check | Energy-efficient heating and cooling | 0.556 | |
| ☑ Check | ☐ Check | ☐ Check | Energy-efficient equipment | 0.714 | |
| ☑ Check | ☐ Check | ☐ Check | Energy saving-reduction of electricity | 0.614 | |
| ☐ Check | ☐ Check | ☐ Check | Energy saving-natural gas efficiency | 0.899 | |
| ☑ Check | ☐ Check | ☐ Check | Local/regional building materials | 0.621 | |
| ☐ Check | ☑ Check | ☐ Check | Secondary use of recycled materials | 1.028 | |
| ☑ Check | ☐ Check | ☐ Check | Construction waste management | 0.653 | |
| ☐ Check | ☐ Check | ☐ Check | Building operation and disposal | 1.221 | |
| ☑ Check | ☐ Check | ☐ Check | Building total lifecycle costs | 0.662 | |

| Y | ? | N | ECONOMIC INDICATORS | POSSIBLE POINTS 26.81 | POINTS ARCHIVED |
|---|---|---|---|---|---|
| ☑ Check | ☐ Check | ☐ Check | Useful floor space | 5.81 | |
| ☑ Check | ☐ Check | ☐ Check | Annual operating costs | 8.28 | |
| ☑ Check | ☐ Check | ☐ Check | Affordability | 6.77 | |
| ☑ Check | ☐ Check | ☐ Check | Safety and security | 5.95 | |

| Y | ? | N | SOCIAL INDICATORS | POSSIBLE POINTS 21.65 | POINTS ARCHIVED |
|---|---|---|---|---|---|
| ☑ Check | ☐ Check | ☐ Check | Access to social, domestic, and socio-economic facilities | 1.329 | |
| ☑ Check | ☐ Check | ☐ Check | Access to public transport | 2.389 | |
| ☑ Check | ☐ Check | ☐ Check | Visual comfort | 2.470 | |
| ☑ Check | ☐ Check | ☐ Check | Building architectural appearance | 2.157 | |
| ☑ Check | ☐ Check | ☐ Check | Universal design thinking | 3.882 | |
| ☐ Check | ☐ Check | ☑ Check | Safety and inclusiveness of opportunities | 4.063 | |
| ☑ Check | ☐ Check | ☐ Check | Acoustic comfort | 2.948 | |
| ☑ Check | ☐ Check | ☐ Check | Education and awareness | 2.414 | |
| | | | TOTAL Possible points: | 68.730 | |

Y-Yes ?-Not sure N-No Certified 40-49 points Silver 50-59 points Gold 60-79 points

NORBERT

ROKO CONSTRUCTION LTD.
KAMPALA

**Appendix I: Editor's Certificate**

Kakiri English professionals,
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Email: Kyarisiimaevaline79@gmail.com


**30th October, 2023**

**FACULTY OF MANAGEMENT SCIENCES**
**DURBAN UNIVERSITY OF TECHNOLOGY**

To whom it may concern,

**DECLARATION BY LANGUAGE EDITOR**

I hereby declare that the research report ***"DEVELOPING A SUSTAINABILITY ASSESSMENT FRAMEWORK FOR BUILDINGS IN UGANDA"*** by an English-speaking professional.

We guarantee 100% language accuracy in the text, as edited and delivered to the student on the date above. We make no claim as to the substantive matter covered by the report and have not altered the intent or research content drafted by the student. The issues corrected were grammar, spelling, punctuation, sentence structure, and phrasing.

Should you have any questions or concerns, my details are as above.

Sincerely

**Kyarisiima Evaline** 30/10/2023

**Appendix J: Statistician Certificate**

## STATISTICIAN CERTIFICATION

I hereby declare that I served as a consultant statistician for the Ph.D. dissertation titled ***"DEVELOPING A SUSTAINABILITY ASSESSMENT FRAMEWORK FOR BUILDINGS IN UGANDA"*** by Julius Semanda.

I provided services including data management and statistical support for the period between 1st August to 28th October 2023.

The certification is issued to confirm that the university received quality research work.

Signed by

28th/oct/2023

**Mugwanya Richard**

Statistician

Email: mugwanyarichard1999@gmail.com

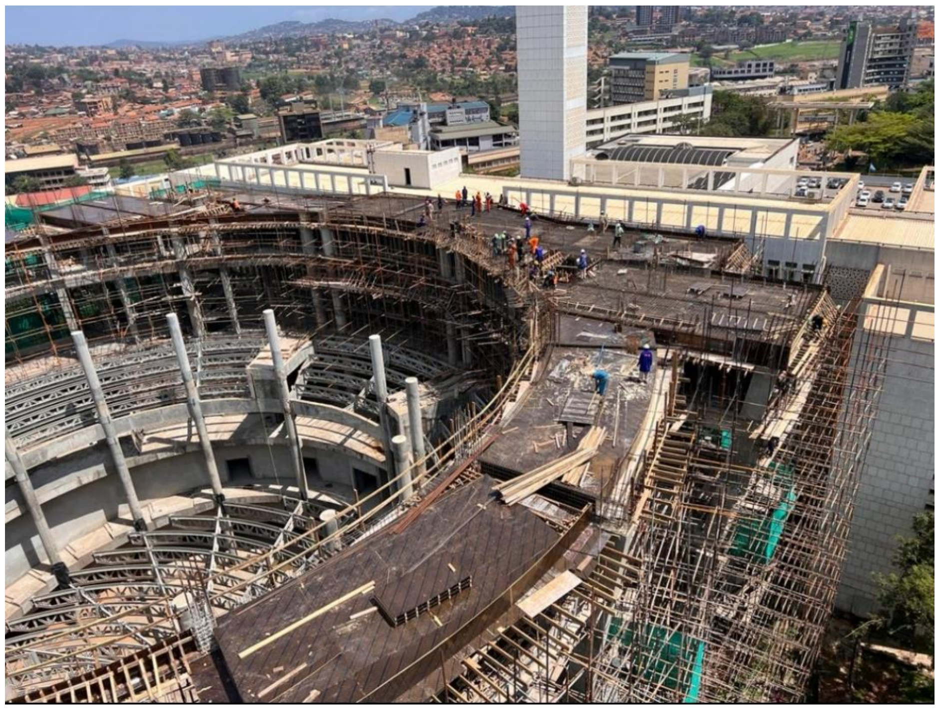
Tel: +256703167011

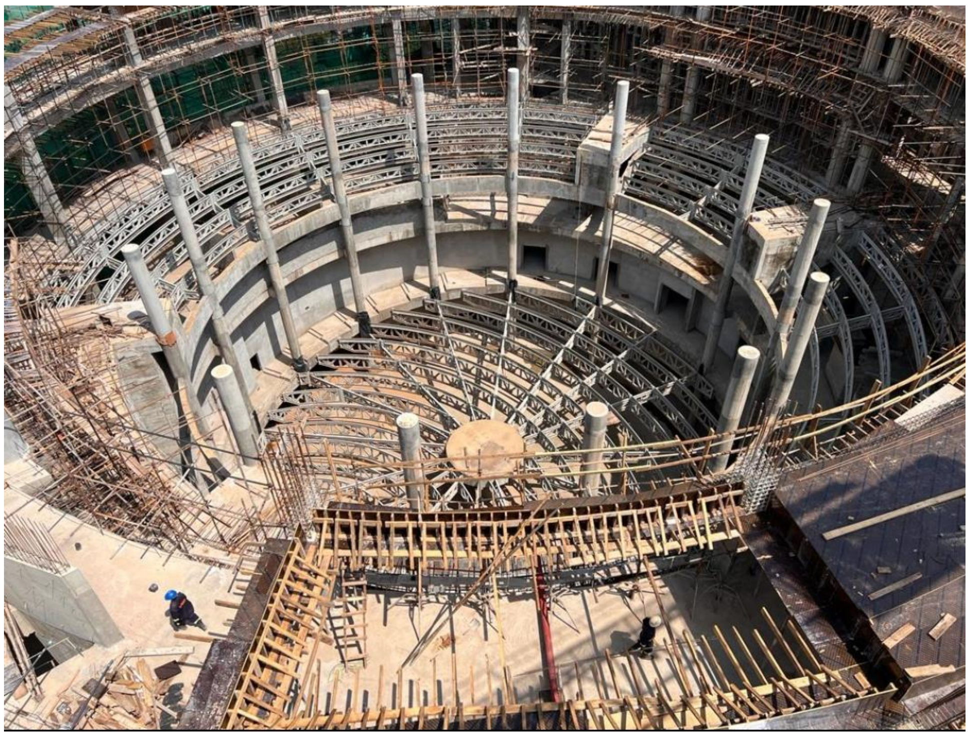
**Appendix K: Projects considered during the framework validation exercise**

**Appendix K1: Proposed new chamber building for the parliament of Uganda**

**Project contractor: ROKO Construction LTD/ROKO Construction Rwanda)-JV**

**Project contract sum: 22 Billion Ugx**



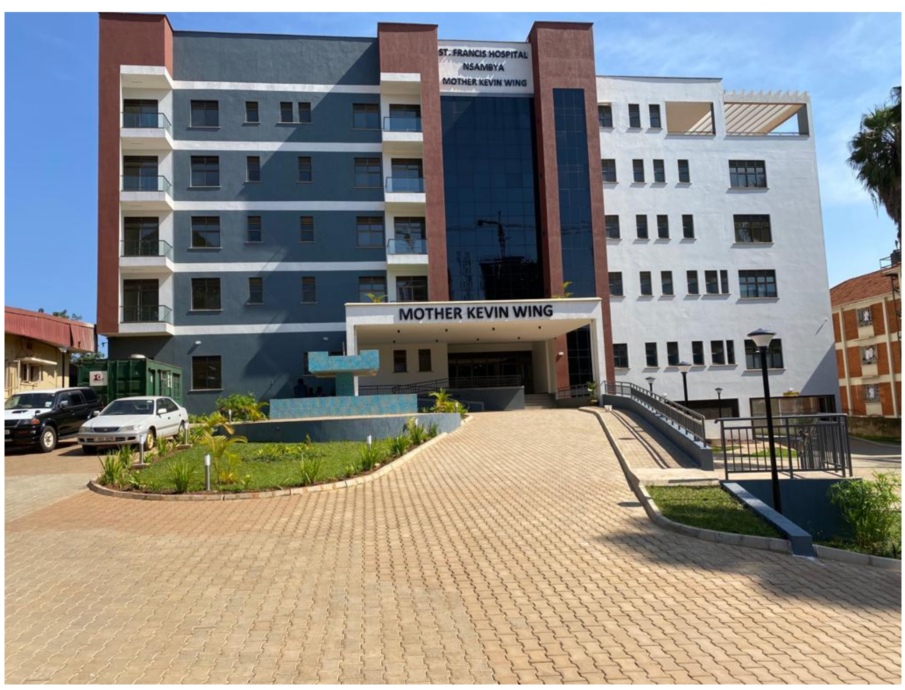


This project achieved a score of 56.49 points and it qualifies for silver (50-59points) classification.

**Appendix K2: 70 bed Mother Kevin wing building at St. Francis Hospital Nsambya**

**Project contractor: Excel Construction LTD**

**Project contract sum: 6,020,474.3 USD**




This project achieved a score of 46.59 points and it qualifies for certified classification of 40-49points.

**Appendix K3: Construction and restoration of Makerere University Main Building**

**Project contractor: Excel Construction LTD**

**Project contract sum: 23,601, 619,110 Ugx**

This project achieved a score of 54.23 points and it qualifies for silver (50-59points) classification.