University of Salford MANCHESTER

School of Built Environment

A COMPOSITE INDEX FOR ENHANCING SUSTAINABILITY WITHIN PUBLIC HOUSING PROJECTS IN LIBYA

A Thesis Submitted in Partial Fulfilment of the Requirements of Salford University for the Degree of Doctor of Philosophy

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Acknowledgments

Though this thesis is assigned solely to my name, many people and organisations have contributed to its production. Therefore, this is a great opportunity to express my sincere gratitude to all those who helped this research to see the light.

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Abubekr Mohamed Ali
2019

Declaration

I declare that the research contained in this thesis was carried out by me. This work has not been previously submitted either in part or full for any other award than the degree of Doctor of Philosophy in Built Environment at University of Salford.

Dedication

Dedicated

To the loving memory of my late Father

Mohamed

To my Mother

Omassaed

To my Wife

Ibtisam

To my Children

Mohamed, Maha, Salma, Rahma & Habiba

And

To my Loved Ones

Abstract

The attention on sustainable homes is driven by the desire to use more environmentally friendly products, that are aligned with sustainable technologies and which improve the health and wellbeing of the occupants, whilst attributing to the reduction of house building costs over a life cycle. It is widely acknowledged that sustainable homes should satisfy the overarching principles of sustainability, fitting in with the local influences of the regional specialities they are built in. The ambition of the Libyan government for imbedding sustainability within the construction industry could benefit greatly from such a rigorous set of sustainability assessment-based criteria that aid to design, evaluate and monitor the desired development. The aim of this study is to develop a sustainability-based index of multi-criterion to assist Libyan public home projects in addressing sustainability issues in their activities and strategies. It is argued that well-known sustainable assessment methods are not designed to be used in various countries including Libya. Therefore, this study seeks to investigate the appropriateness of using these methods to integrate their commonalities and establish a new scheme of building sustainability-based criteria for the Libyan context. To achieve the aim of this study a variety of research methods and techniques within a triangulated approach have been adopted. These included (1) a focus group interview; (2) a wide questionnaire survey; and the (3) Analytical Hierarchy Process Method (AHP). The components of the developed model were derived from a thorough analysis of data collection obtained from a variety of sources including practitioners and professionals from contractors, the Libyan government, industry, and academia. A triangulation approach has been utilised within and across the methods and techniques adopted. It has facilitated access to different levels of reality, through the combination of qualitative and quantitative methods. The sustainability-based index that has been developed through this research is composed of 43 criteria, grouped into 7 main categories. Water efficiency ranked at the top with 32 credits, reflecting Libyan crisis due to water scarcity. Whilst Libya has alternative and abundant natural energy resources (i.e. so-lar energy, wend, etc.). This has made energy efficiency issues at the second highest priority (24 credits), which can encourage the adoption of more sustainable, renewable energy resources.

Fundamentally, it provides a clear vision of what needs to be addressed and what would enable the achievement of sustainable homes in Libya. Validation has been conducted through a review of the results obtained on the journey of this research. Utilising a group of local and international experts, who have been selected based on their knowledge in sustainable housing and the construction profession, thus providing the basis for a more successful formula and a final model of sustainable housing for the Libyan context. The contribution of this study to the existing body of knowledge is threefold: (i) academic, through addressing significant research questions that have not been addressed before and providing an evidential base of the findings; (ii) procedural, through the development of a comprehensive model to assist Libyan home projects in better addressing sustainability aspects in their activities and strategies; and (iii) methodological, through the use of triangulation, which construction management research have been reluctant to use in the past, and through the provision of a comprehensive review, successful application and a clear demonstration of the use of focus group interviews and questionnaire methods.

1 Overview of Research

1.1 Chapter Overview

This is an initial part of this thesis, putting the study into context by exploring the background and emphasizing the need for the research. An articulation of the research problem is followed by the identification of the aim and objectives of the study. The significance of this research in light of its originality and potential contributions is rationally raised. Finally, this section highlights an overview of the methodological design that has been adopted for its implementation.

1.2 Research Context

The world is rapidly changing, with emerging critical calls concerned with inertia in our ecological systems and the unreadiness to deal with complex and uncertain-based challenges. Specifically, core environmental problems include resource degradation, climate change and global warming, air pollution, the scarcity and pollution of fresh water, flooding and pollution of the world's seas and oceans. According to a 2014 report published by the United Nations Department of Economic and Social Affairs (UNDESA), 3.9 billion people, or 54% of the global population, live in cities, and by 2050, two-thirds of the global population will be living in cities. Most of this growth is happening in developing countries, which have limited capacity to deal with this rapid change (UN, 2015; 2012). Where increasing mainstream steps towards achieving high levels of living standards and economic growth that have characterised the industrial era, have negatively affected the surrounding environment through resource depletion and energy consumption (IPCC, 2018). Notably, climate change is one of the most pressing global challenges that countries face today, threatening human life on the planet. As IPCC's (2018) report estimated, anthropogenic global warming has recently risen at approximately 0.2°c per decade due to industrial emissions. Furthermore, there is evidence that the construction industry consumes a massive portion of natural resources and energy. Global material use is estimated to increase almost tenfold since 1900, accelerating from an annual growth of 1.3% in 1900–1949, to 2.6% in 1950–1999, and 3.6% annually in 2000–2009 (Krausmann *et al*. 2009). Currently, according to Worldwatch Institute (2003), construction activities, globally absorb approximately 3 billion tons/year of raw materials, constituting 40% of the total annual use. It also consumes nearly 25% of the harvested wood and more than 15% of the fresh water. This tremendous consumption of available resources will undoubtedly exacerbate global environmental problems if radical changes do not urgently take place. These sustainability-related problems can be identified as interdependent and release serious challenges that are shaping our future (RIBA, 2014). Therefore, radical shift is inevitably required to reorient our thinking and shape a new paradigm of change that ensures sustainability of the available resources and protects our environment from the threatening hazards. It is of utmost importance to take prerequisite actions to avoid severe consequences that are likely to happen to the current and future generation.

In this respect, the developing countries' situations are even worse according to the International Energy Agency (IEA, 2017), and to a large extent, this can be traced back to a lack of a sustainability-led paradigm shift, that is able to monitor and guide the industry to ideal performance (Tupenaite *et al*., 2017; Cole & Jose Valdebenito, 2013; Sev, 2011). Subsequently, the importance of a Sustainability Assessment Method (SAM) is fundamental in order to incorporate sustainability interventions into the built environment (Ding, 2008; Fenner & Ryce, 2008; Cole, 2006; 2005).

As several of SAM's efforts have achieved obvious success and have been widely adopted over the world. These initiatives include: BREEAM (The Building Research Establishment Assessment Method); LEED (Leadership in Energy and Environmental Design); DGNB (German Sustainable Building Certificate); and GBCA (Green Building Council Australia). These developments have been aligned with an evolution of sustainability standardisation aspects related to building projects, which were raised through several institutions such as the ISO (International Organization for Standardization) (ISO, 2008; 2006; 2005 2000) and the CEN (European Committee for Standardization) (CEN, 2017) by which various sets of defined standards required for SAM are provided. In spite of almost all SAMs being developed to fit a certain territory, they are not fully appropriate to all regions (Mao *et al*., 2009; Reed, 2009; Fenner & Ryce, 2008; Ding, 2008; Cole, 1998). Thus, the adjustment of a set of sustainability-based criteria that ensures buildings sufficiently fit the relevant international principles of sustainable development is a critical step needed to achieve the desired goals. This study, therefore, is an attempt to develop a Sustainability-based Composite Index for assessing housing investments in the context of Libya.

1.3 Rationale of the Study

The research field of SAM (Sustainability Assessment Method) has recently emerged as an area of interest to address such issues across the developed countries (*Tupenaite et al*., 2017; Cole & Jose Valdebenito, 2013; Rees. 2009; Ding, 2008; Fenner & Ryce, 2008; Cole, 2006; 2005; 1998). Although the well-known methods (e.g. BREEAM; LEED) are widely utilised around the world, an extensive body of literature available (Lee, 2013; Reed *et al.,* 2009; Rees, 2009; Chew & Das, 2008; Ding, 2008; Fenner & Ryce, 2008; Lee & Burnett, 2008; Lee *et al*., 2002), has criticised existing SAM use from various perspective such as; 1) using methods to evaluate areas that it was not developed for; 2) inappropriateness of applied credit weighting schemes; and 3) transparency-based issues related to the significance of constituent elements used in SAM's structure. As Alyami *et al*. (2013), Ali and Al Nsairat (2009) and Chang *et al*. (2007) assert that these systems have been proven to be inapplicable to the context of developing countries, giving the fact that these tools were originally designed for a different context. With the environmental and socio-cultural focus, using a total aggregate score to allocate an overall rating as part of prevailing models such as BREEAM, raising concerns about their robustness and leading to criticism that their practical use may mask certain unsustainable aspects of development and could lead to unsustainable solutions being erroneously deemed sustainable (Rees, 2009; Ding, 2008). Moreover, a range of factors affect the direct use of well-known SAMs in a country other than its own origin. They include 1) geographical features; 2) climate context; 3) resource consumption; 4) government regulation and policy; 5) understanding of construction stocks; and 6) understanding of the culture value and public awareness (Mao *et al*., 2009; Ding, 2008; Cole, 2005: 1998). Possible development routes for future generations of sustainability assessment tools for built environment as argued by Ding (2008) and Fenner and Ryce (2008), include the importance of expanding the assessment to include both social and economic indicators, thereby developing a complete sustainability assessment system.

Nevertheless, it is evident that there is a lack of research on the selection of criteria related to sustainability in Libya's construction investments. Despite calls from academia (Elgadi *et al.,* 2016; Shawesh, 2016; Shibani & Gherbal, 2016; Ahmed *et al.,* 2015; Gherbal, 2015) for a paradigm shift away from the scheme limited to the assessment of economically driven approaches, overarching sustainability-led assessment systems are still rarely used. As Ahmed *et al*. (2015) point out, it is essential for the industry to have regular evaluations and assessments, thereby allowing the collation of evidence related to changes and impacts which might affect the environment. Ultimately, moderating these impacts in order to develop the quality of building practices. Although, extensive studies (Elgadi *et al*., 2016; Mohamed, 2013; Shebob 2012; Omran *et al.,* 2012; Almansuri *et al.,* 2009; Ismail *et al*., 2009) focus on a wide range of developmental issues associated with the built environment in Libya, only a few have addressed specific aspects relevant to building sustainability-related features. For example, Quality Management and Environmental Management systems were addressed through a study by Ismail *et al*. (2009) with the aim of applying an integrated management system for assessing and monitoring the construction processes and activity status in the Libyan building sectors. A study conducted by Omran *et al.* (2012) developed a range of critical success factors that are most important to the success of construction projects in Libya. In this study, feedback ability was ranked first, followed by project monitoring, coordination effectiveness, design of education organisation structures and decision-making effectiveness. Whilst Shebob's (2012) study focused on issues that are more likely to influence the success of building projects through the investigation of delay factors affecting the Libyan construction projects. Furthermore, an extensive study by Mohamed (2013), which focuses on the phenomenon of urban fragmentation at neighbourhood level, which investigated different urban typologies in the city of Benghazi. This study considered the main characteristics of the sustainable city namely: urban liveability which includes designs for thermal comfort and privacy intervention; accessibility represented by the level of spatial connectivity and urban diversity; environmental sustainability measured by embedded green solutions and a sense of ecological footprint. This study faced limitations at different levels including its lack of focus on urban areas, instead investigation of the physical form and the process of city building being aligned with both landscaping and socio-economic and cultural aspects were essential to the idea of sustainable development. A further study entitled 'Do courtyard houses provide the ideal climatic solution in hot climate regions?' was published by Almansuri *et al.* (2009). The focus of this study was on sustainability-based solutions for architecture to reduce energy consumption of houses, but there was also a tentative reference to some factors related to sustainable homes. Including the need for achieving harmony with nature, proper insulation and the shading of houses, harnessing natural ventilation and natural light and green roofing as well as a few energy and water conservation measures. Nevertheless, it is unfortunate that the recommendations of this broad study have not been translated into action and the study lacked details and goals. More recently, a study by Elgadi *et al*. (2016) identified a set of indicators for sustainable neighbourhoods in Tripoli, Libya, reflecting economic, environmental, social, and institutional dimensions. Indicators in this study were developed to measure progress of the urban and community features, opposing the current study which is determined to identify a sustainability-based tool for precisely assessing building projects in Libya.

The urgent need for research to investigate a set of standards for sustainable buildings in the Libyan context has been emphasized by a number of authors including, Elgadi *et al*. (2016), Shawesh (2016), Shibani and Gherbal (2016) Shebob (2012), and Almansuri *et al*. (2009) who have corroborated previous studies from Ngab (2007), UPA (2006) and El-Hasia (2005). Collectively this body of work strongly argues that sustainability-based criteria of Libya's buildings should be identified to assess their compliance when benchmarked against the fundamental principles of sustainable development, emphasising that there are a lack of specific policies and assessment tools that evaluate and monitor the building. The absence of comprehensive frameworks and a lack of assessment methods relevant to sustainability in building projects are what interestingly motivate this study to address the topic of adjusting sustainability-based criteria for dwellings in Libya. Consequently, this study has raised the argument that a customised sustainability-based assessment method should be developed based on the natural Libyan context. In this essence, the desired system should be designed in ways that eliminate the weaknesses of the existing methods. This method needs to be developed through a reliable process that ensures: (i) effective identification of criteria and categories for the Libyan context; (ii) transparent set of a credit weighting system; and (iii) sufficient prioritising of the components of the model.

Against this background, the rationale of this study can conclude that the leading global sustainability assessment models (e.g. BREEAM; LEED) have neither been adapted to the cultural, economic and political specificities nor the context of the Libyan built environment. These constraints appear through a lack of attention to region-related variations, including the availability of resources, the nature of local architecture, certain environmental conditions, and other specific critical economic and socio-cultural factors. By contrast, a review of the Libyan context has demonstrated that a specific criteria and ranking system that assesses the extent to which Libyan buildings satisfy the sustainability principles is quite absent, this study therefore, is an attempt to fill these gaps for the Libyan Sustainable Homes Assessment Model (LSHAM).

1.4 Significance of the Study

Raising criteria is highly useful in planning sustainability when they are linked to sustainability goals that are frequently set by policy makers as a reference to a level of sustainability that must be satisfied in the future. This study aims to adjust a selection of sustainable criteria for residential building in Libya. The findings of this study will help the shift to sustainable homes in which design, operations and implementation are to be modified on the basis of such criteria and standards. The value of the Composite Index of sustainable homes lies in its potential to assist contractors in re-designing their building projects with sustainability-based criteria in mind. This index can provide an effective framework for decision-making processes in order to incorporate sustainability principles into project processes by embedding sustainable design priorities and setting appropriate sustainable design strategies for housing projects. The customised tool can also be used as an assessment tool that helps to meaningfully determine performance measures and reflect how well Libyan dwellings are prepared for the sustainable built environment.

1.5 Purpose of the Study

The principle purpose of this study is to provide a decision support system that allows the promotion of sustainable development in housing investments through the development of a sustainability-based assessment method, thus enabling identification of the most effective interventions and optimising performance in favour of maximising the users' satisfaction, environmental protection, and economic benefits.

1.5.1 The Aim

The centric aim of this study has been identified in light of the main purpose motivating the researcher to conduct this study and is stated as follows: "*To customise an applicable*

Composite Index for assessing Libya's sustainable homes". A specific range of objectives was generated in order to rationally achieve the desired aim.

1.5.2 Objectives

Based on the centric aim, this study is determined to fulfil a fivefold objective which is outlined below:

Obj.1 To critically review the perceived importance of sustainability together with the current sustainability assessment methods for housing investments.

Obj.2 To analyse the categories and criteria of well-established sustainability-based assessment methods to set the foundation for a new insight of a Composite Index.

Obj.3 To customise applicable categories and criteria that constitute the main characteristics of sustainability in Libya's housing investments.

Obj.4 To determine the weighting coefficient that ensures prioritisation of its main categories and criteria based on the specifications of Libyan context.

Obj.5 To refine the Composite Index of sustainable homes and provide recommendations for further development.

1.6 Research Design and Methodology

The study focuses on the adaptation of a reliable sustainability-based Composite Index for housing investments for the Libyan context, which is based on the groundwork of well-established methods (i.e. BREEAM; LEED; GBCA; DGNB). In order to design this model, care has been given to deliver applicable assessment categories and criteria and an appropriate weighting system. To achieve the centric aim of this study, two major stages are organised; the theoretical and empirical stages. Figure 1.1 below illustrates the methodological structure of the study.

The theoretical stage consists mainly of: (i) a critical review of sustainability-based assessment rating methods; (ii) a selection of well-established assessment models (i.e. BREEAM; LEED; GBCA; DGNB); and (iii) an integrated analysis to determine the commonalties and synthesize the criteria and categories for the theoretical framework. This stage has the potential to provide an in-depth theoretical background for developing a new model for sustainable homes in the Libyan built environment. The identified components are assessed within the next stage.

The empirical stage was launched with a focus group interview, which recruited five experts in the relevant sustainability field of sustainable homes in Libya. In order to examine the current sustainability assessment applications in housing investments, as well as investigating the most important sustainability interventions for sustainable homes. A large-scale questionnaire survey is a principle method of the study, which allowed engagement with a wide spectrum of practitioners, professors and administrators, who are well-experienced in both the scientific community and the practice field relevant to the context of Libya's built environment. The questionnaire technique structures the most applicable categories and criteria for assessment of sustainability in housing investments. While an Analytical Hierarchy Process (AHP) has been employed to provide a reliable weighting system, prioritising these categories and criteria while taking into consideration the distinguishing specifications of the Libyan built environment. Finally, this study employed a supplementary technique to validate the proposed model. A small-scale interview with local and international academics and professionals, was conducted with the aim of evaluating the Composite Index developed. The research was then determined to develop a discussion and connect the literature review and the findings from the focus group interview, questionnaire survey and the AHP technique along with the results obtained from the validating interview. In order to structure a robust Sustainability-based Composite Index for assessment of Libya's homes, and formulate meaningful findings and recommendations.

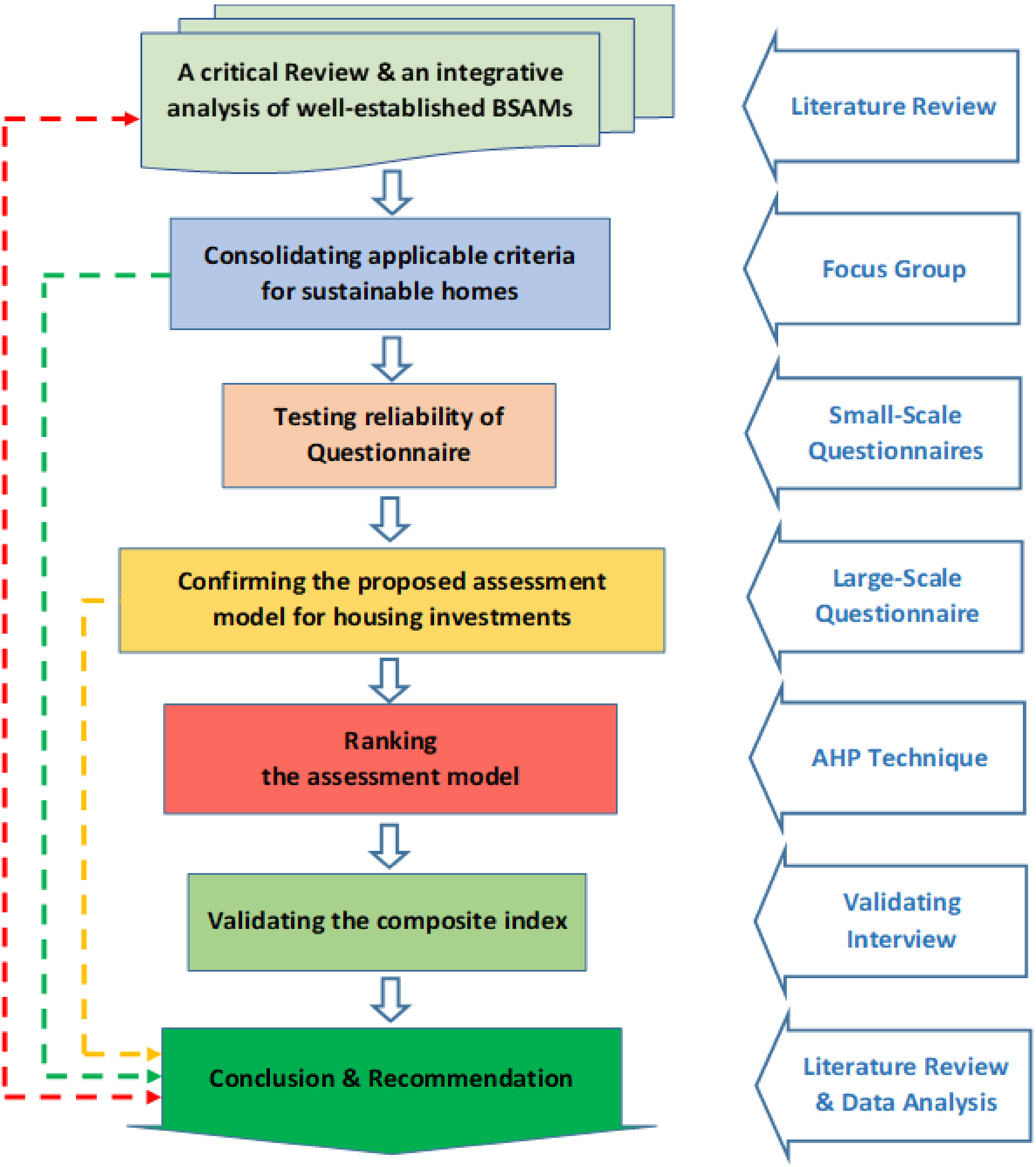


Figure 1.1: The Research Methodology Flow Chart.

1.7 Research Scope

As mentioned previously, the general purpose of this study is to develop and support a decision system for assessment of sustainability in the Libyan housing industry. This includes the customisation and quantification of a range of criteria and categories that present the most applicable sustainability interventions in sustainable homes. Therefore, the study has been narrowed to the following scopes:

1. The study is focused on the identification of criteria that influences the Libyan housing building industries, taking into consideration environmental, economic and socio-cultural constraints.
2. Influencing criteria were found through integrated analyses of well-known assessment methods, which were only used to identify and compare the possible assessment criteria for Libyan housing projects.
3. The consultants were selected from the academia, industry and government sectors, who were shown an adequate knowledge in the relevant subject and from different regions across the state of Libya.
4. The HAP technique was used to analyse and quantify the proposed categories and criteria, to establish a Composite Index for assessment of sustainability in housing sectors.

1.8 The Added Value of the Study

The present study aims to contribute to the body of existing knowledge significantly, with the aspect of sustainability-based assessment methods for housing investments in the context of Libya (LSHAM). The most applicable categories and criteria of well-known building assessment methods are considered as the basis of this study and proposed to develop the structure of LSHAM. The study adopts a ranking system which reflects the most applicable interventions relevant to sustainability in the Libyan built environment context, involving a calculation procedure via a weighting coefficient, as well as rating formulas that present a single result for the level of sustainability embodied in the project.

Notably, the contribution of this thesis to the existing body of knowledge can be determined threefold as: (i) Theoretical, through addressing significant research questions that have not been addressed before and providing the evidence based on these findings; (ii) Methodological, through the use of triangulation via the provision of a comprehensive review, successful application and clear demonstration of the use of a focus group interview and large-scale questionnaire; and (iii) Practical, through development of a Composite Index to assist decision makers in better addressing sustainable homes through consideration of the major features related to sustainability in Libyan context.

Research on sustainability-based assessment methods for Libyan dwellings is both timely and responsive to frequent calls from researchers for improved progression of the built environment in Libya, towards more environmentally, economically and socially sustainable development. As a result, this work can be considered as a unique attempt, undertaking a scope that has not been dealt with previously.

1.9 Thesis Layout

This study comprises of nine chapters (see Figure 1.2), a brief overview of the content of each chapter is described as follows:

Chapter 1: Overview of Research

This chapter sets the rationale for the study, providing a general introduction to the research. It includes a brief discussion of the subject matter, exploring the background context and need for the study. The rationale of the research is then followed by presentation of the core aim and objectives. It also highlights the added value and scope of the study. Finally, it briefly visualises the research methodology and outlines a thesis structure.

Chapter 2: Sustainable Development and Reflections on Construction

This chapter broadly considers the global threats facing humankind and the planet before discussing the main agenda of sustainable development with a special focus on sustainability in construction. Consideration is also given to the themes associated with the home concept, including the definitions and influential factors of sustainability in housing investments. Finally, potential research gaps have been identified after reviewing the relevant efforts in the literature available.

Chapter 3: The Housing Industry in Libya

Chapter 3 seeks to highlight the Libyan context through an extensive literature review by presenting a brief background about the state of Libya including topographic and geographical features, the construction and housing industry and socio-cultural aspects, aligned with the relevant challenges and constraints. It also highlights the main housing types and provisions in Libya, following by exploration of a range of challenges facing sustainable homes with some sustainability initiatives in the Libyan context.

Chapter 4: The Development of a Theoretical Framework for Sustainable Homes

This chapter highlights the main features of SAM including its principles, typology, systems criteria and rating systems, followed by an overview of the prevailing SAMs worldwide. It also presents an integrative data analysis of the well-established sustainability assessment methods, in order to establish a theoretical model of study that is intended to be developed further through the next stages.

Chapter 5: Research Design and Methodology

This chapter presents the methodological approach employed in this research. For this purpose, the philosophical assumptions of research methodology and a justification of the methodology adopted were explained. Then greater attention is given to the adopted methods of the focus group interview and questionnaire survey. The selection of the research sample and analysis techniques are addressed before highlighting the triangulation and ethical considerations that took place.

Chapter 6: Data Analysis and Discussion

This major chapter provides analysis of the assessment categories and criteria derived from the focus group and questionnaire survey results that were proven to be applicable for Libyan sustainable homes. It discusses the main findings obtained through triangulation of the results derived from the literature review, integrated analyses of well-known SAMs, focus group interview results and the large-scale survey, in confirmation with the main objectives, contribution, features and possible orientations that can be recognised for each criterion. These categories and criteria are then utilised to design the study's model (LSHAM).

Chapter 7: Establishing a Weighting System for a Sustainability Composite Index

This chapter presents analysis and discussion of the findings in relation to the weighting system, along with the credit allocation, rating formulas, and benchmark classification that are employed in the developed model. This presentation concludes with a discussion of the approved weighting system for the Libyan context, along with the distinctive aspects of the LSHAM when compared to well-established methods and its added value of practice.

Chapter 8: Validating the Developed Model

This chapter presents a final assessment of the developed index in order to obtain an evaluation of the views of recognised experts to extend the discussion and provide a critical understanding of the validation of the index. While also identifying other possible refinements or possible directions for the research to enable its implementation in practice.

Chapter 9: Conclusion

This chapter presents conclusions about the contribution, limitations and implications of the study, and suggests recommendations for further research.

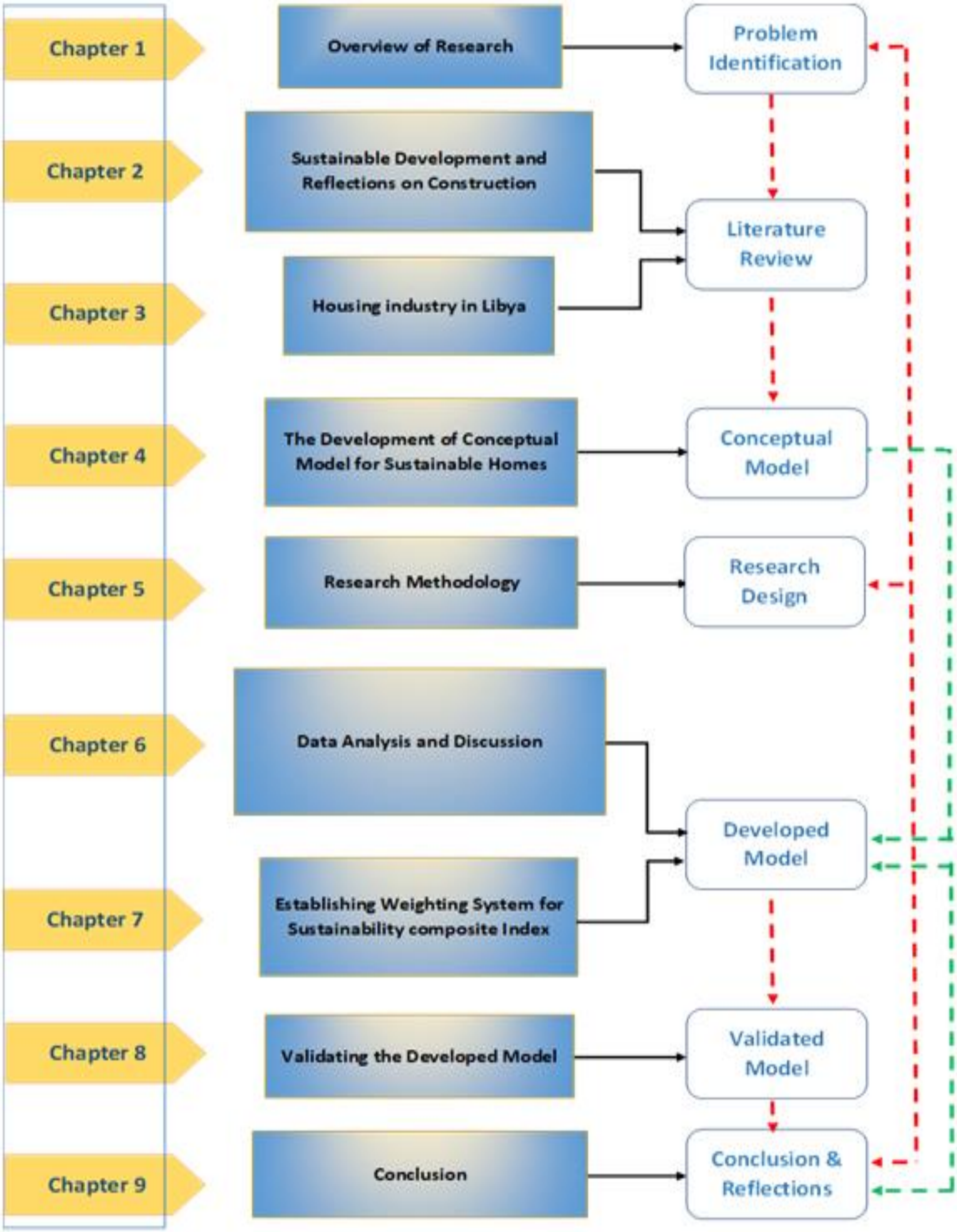


Figure 1.2: The Structure of the Thesis.

1.10 Chapter Summary

This chapter has presented the background, rationale, research aim, objectives and methodology followed by outlines of the thesis structure. It has sought to provide an overarching scene of the study along with a route map describing the research tasks and developmental processes, whilst contextualising the study in order to highlight its added value. In the next chapter, the main agenda of sustainable development will be addressed before discussing sustainability in construction with a special focus on home concept and its sustainability considerations are drawn.

2 Sustainable Development and Reflections on Construction

2.1 Chapter Overview

Since the centric aim of the study is to understand and define a sustainable development-based assessment tool for housing projects, it is of the utmost importance to pay higher attention to the concept of Sustainable Development (SD) in light of the sustainability agenda and the objectives beyond the appraisal process for Sustainable Construction (SC). This has been addressed by aligning the discussion with the need for shaping Sustainable Homes and the potential challenges associated with SD in the housing sectors. With this in mind, the literature review is devoted to responding to five principal questions that have been proposed to synthesize the theoretical framework of the study. They are: (i) Why does SD exist? (ii) What does SD mean and how is it perceived? (iii) Why is SC important and what are its key features? (iv) How can the concept of Home be defined and what are its sustainability considerations? And finally, (v) How can an effective assessment model be helpful to deliver sustainability in the housing sector?

To answer these queries, this chapter has been presented through four wide lenses. The first scope broadly considers the global threats facing humankind and the planet. This leads to the discussion of the main agenda of sustainable development in the second perspective. While, a special focus on sustainability in construction is addressed through layer three. Finally, in the fourth lens, consideration is extensively given to themes that are associated with the home concept, as deemed the central focus in this study. This covers the definitions and influential factors of sustainability in housing projects. The final axis is devoted to drawing out potential research gaps that are planned to bridge this study throughout. It reviews the relevant efforts that offer the most insight into sustainability appraisal techniques.

2.2 Changes Threatening the Global Environment

With the development of people's living standards and the industrial revolution, humans have drastically altered the ecological system. Although this development has had a positive impact on human life in terms of an increased life expectancy rate and well-being, population growth and natural resource depletion have ultimately led to negative effects on the natural environment such as global warming and climate change.

2.2.1 World Population Growth

One of the most obvious characteristics of human evolution and history has been the exponential growth of the global population. As this growth continues, it will have a significant impact upon every aspect of human existence from increasing demand on natural resources to the proliferation of mega-cities and the infrastructural needs of an increasingly urbanized world population. Figure 2.1 shows world population growth between 1750 and 2100 (Ourworldindata, 2017).

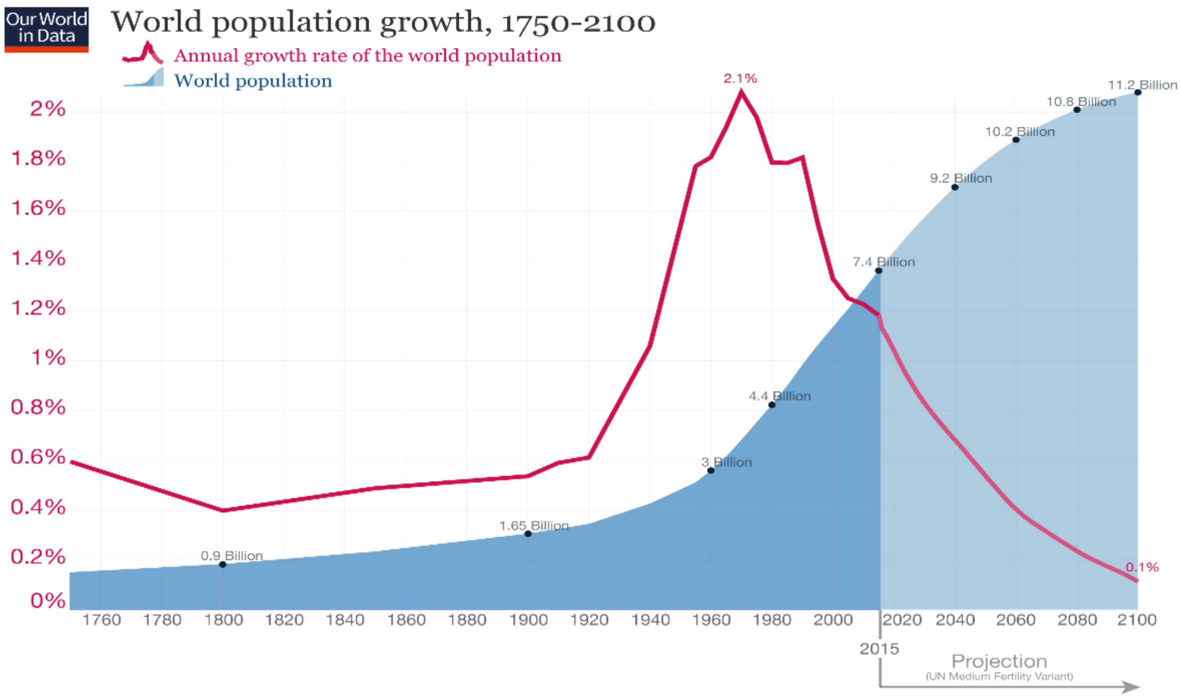


Figure 1.1: World Population Growth, 1750-2100 (Source: Ourworldindata, 2017).

Historically, the number of global populations according to Ourworldindata (2017), was approximately one billion in 1800, with an annual growth rate of 0.4%, and it took one century to reach the second billion. The growth trend after that, increasingly expanded, reaching three billion after 30 years in 1960. Only 15 years later, it arrived at four billion, with the greatest annual growth rate of 2.1%. This number dramatically increased to hit six billion by the end of the 20th century. In 2015, the world population became 7.4 billion even though the annual growth rate decreased at 1.1%. Moreover, the world population is expected to be nine billion in 2050 and eleven billion by the end of the ongoing century with an annual growth rate of only 0.1%.

One of the biggest challenges, according to a 2014 report by the United Nations Department of Economic and Social Affairs (UNDESA), is that 3.9 billion people, or 54% of the global population now live in cities, and by 2050, two-thirds of the global population will be living in cities, whilst most of this growth is happening in developing countries which have limited capacity to deal with this rapid change (UN, 2015). This extraordinary increase in population has the potential to lead to further pressure on resource consumption. This leads to added concern of another serious issue, which is threatening the world today, that of resource depletion.

2.2.2 Natural Resource Depletion

Developments in scientific and technological knowledge along with tremendous economic growth, have led to intensive exploitation of natural resources including fossil fuels, materials, water and land, which have increasingly impacted on the built environment. As Krausmann *et al*. (2009) point out, global demand for resources has increased substantially since the start of the 20th century. While global material use is estimated to increase almost tenfold since 1900, accelerating from an annual growth of 1.3% in 1900–1949, to 2.6% in 1950–1999, and 3.6% annually in 2000–2009 (Krausmann *et al*. 2009). Notably, developing regions account for an increasing proportion of global resource use. With Europe responsible for 19% of total resource extraction in 1980 and the US accounting for 18%, both falling to 10% by 2009. However, Asia's share increased from 41% to 57% over the same period. Figure 2.2 shows the development in global use of construction materials, ores and industrial minerals, fossil energy carriers, and biomass (Krausmann *et al*., 2009).

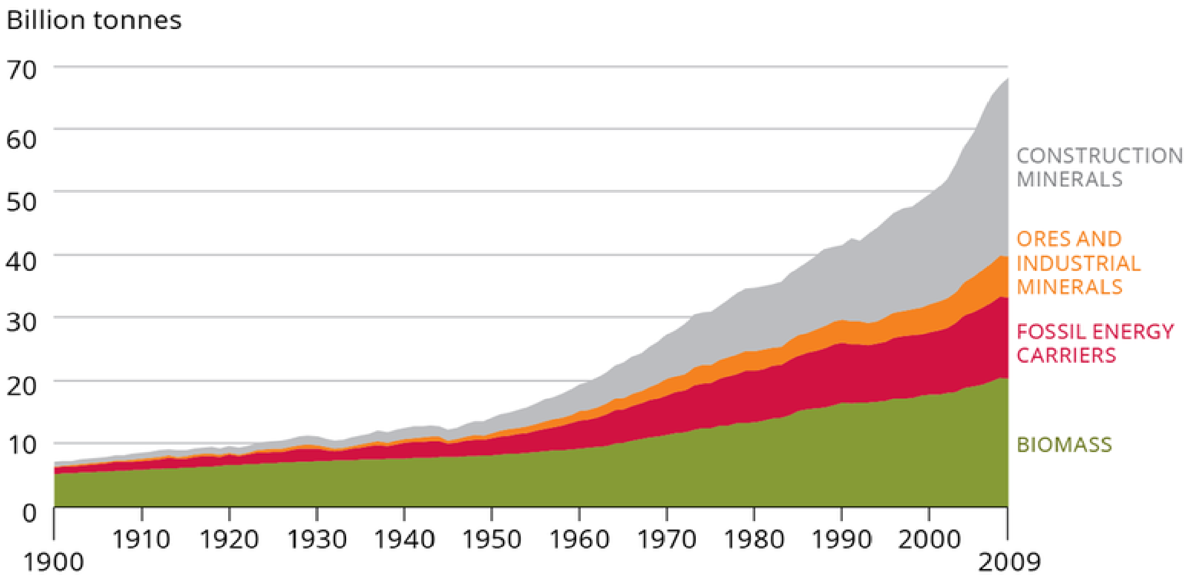


Figure 2.2: Global Total Material Use by Resource Type, 1900–2009 (Source: Krausmann *et al*., 2009).

Whilst global demand for natural resources is expected to grow increasingly in the coming years, the outlook for supplies is more uncertain. Geographic concentration of reserves in a range of nations is a serious concern since it affords suppliers greater influence over global prices and supplies, as shown by the influence of the Organization of Petroleum Exporting Countries (OPEC) over global oil markets. Uncertainty regarding access to products goes up if reserves are concentrated in politically unstable regions (EC, 2014). Certain non-renewable resources deserve particular attention because of their economic relevance, including their role in green-energy technologies. Significantly both Lelieveld *et al.* (2012) and Almasroui *et al*. (2012) have stated that there is an intensive concern with regard to the sustainability of these resources and the continuity of economic growth, since any shortage in one will lead to severe global problems such as economic collapse and rigorous environmental degradation. Accordingly, Paudel *et al*. (2014) have argued that the construction sector can be considered as one of the most significant achievements of modern civilisation in which people are quite likely to be healthier, and life is easier and more comfortable. Nevertheless, exploitation of natural resources through construction activities that consume a large amount of resources have many life-threatening side-effects, including stratospheric ozone depletion, air pollution, water pollution and deforestation (Jain, 2013). This tremendous consumption of natural resources has the potential to lead to further pressure on the global ecosystem. Thus, it has brought concern to a further serious problem threatening the world today, which is global warming and climate change.

2.2.3 Climate Change

Human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, which is expected according to IPCC (2018), to hit 1.5°C between 2030 and 2052 if the current rate continues to accelerate. In many regions worldwide, warming temperatures greater than the global annual average have been recorded, particularly in the Arctic which is likely to reach three times higher. As IPCC's (2018) report states, estimated anthropogenic global warming has recently risen at approximately 0.2°c per decade due to ongoing emissions. The graphs in figure 2.3 show the average daily temperatures in four continents (Worlddata, 2017). It can already be seen quite clearly that there has been a high rise in temperatures worldwide since the 1980s. Especially noticeable are the developments in Europe, North America and Asia, where there are considerable temperature increases.

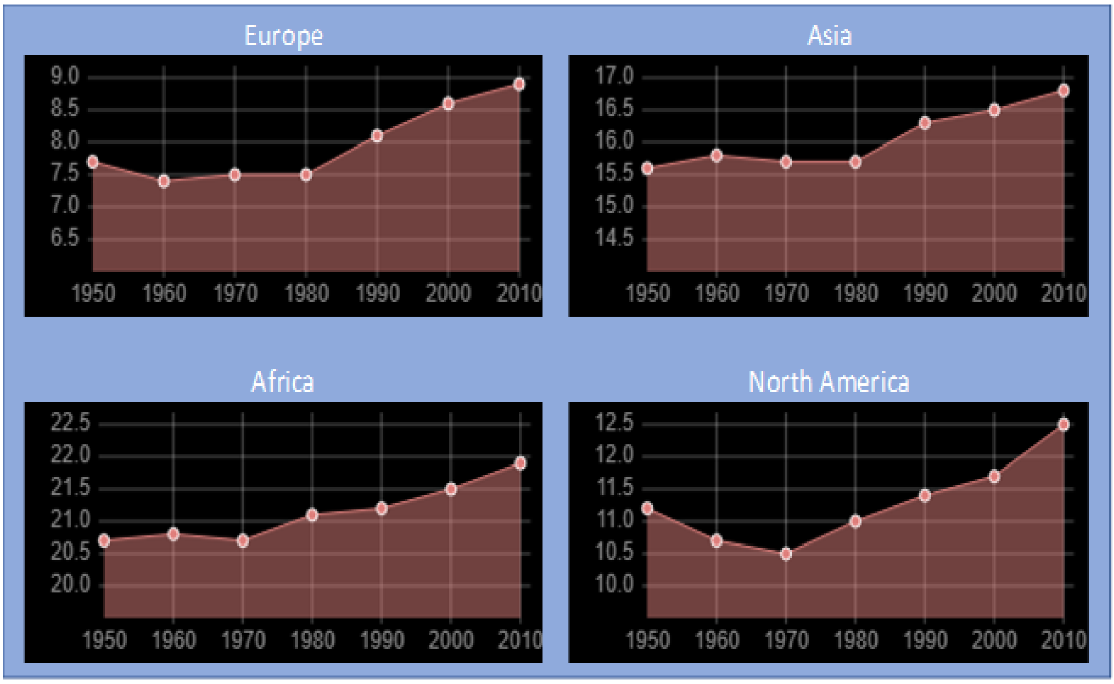


Figure 2.3: The Average Daily Temperatures by Continent (Source: Worlddata, 2017).

Even though the degree of temperature has increased worldwide along with increasing natural disasters such as tsunamis and earthquakes, the underlying causes beyond these conditions are likely to be unpredictable (Lelieveld *et al*., 2012). In this regard, the 2018 Intergovernmental Panel for Climate Change's (IPCC) report confirmed that the greenhouse impact and the increased atmospheric concentration of CO_2 were the main reasons for climatic change (IPCC, 2018). Moreover, the report also claims that human activities such as burning fossil fuels, oil, coal and gas produce high amounts of CO_2 emissions, which can be considered as the major cause of both global warming and climate change. According to Global Carbon Project (GCP), approximately 33% to 50% of the total land surface has been altered by human development, whilst the concentration of CO_2 in the atmosphere has risen to about 40% primarily through the combustion of fossil fuels (GCP, 2018). The GCP's report indicates that Asia has dominated global CO_2 emissions since 2000, whilst its figure (excluding the Middle East) was 16.9 billion tons in 2017, accounting for 54.2% of global CO_2 emissions. Figures 2.4 and 2.5 show annual fossil CO_2 emissions by continent particularly in 2017.

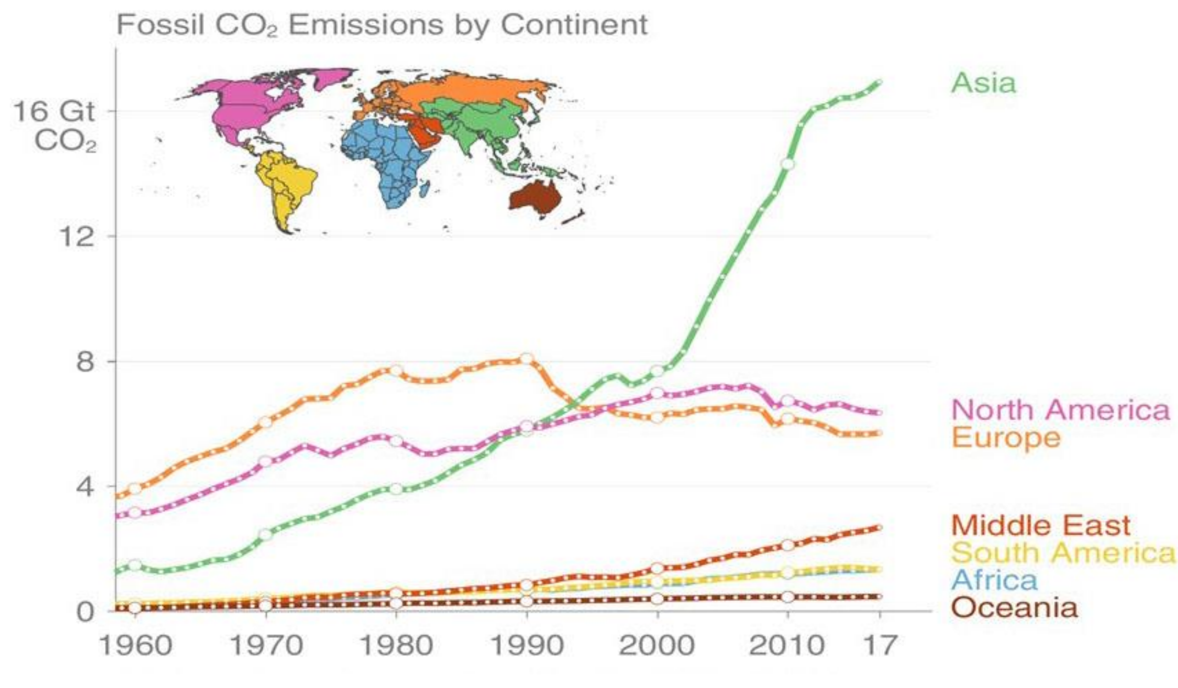


Figure 2.4: Annual Fossil CO_2 Emissions by Continent (Source: GCP, 2018).

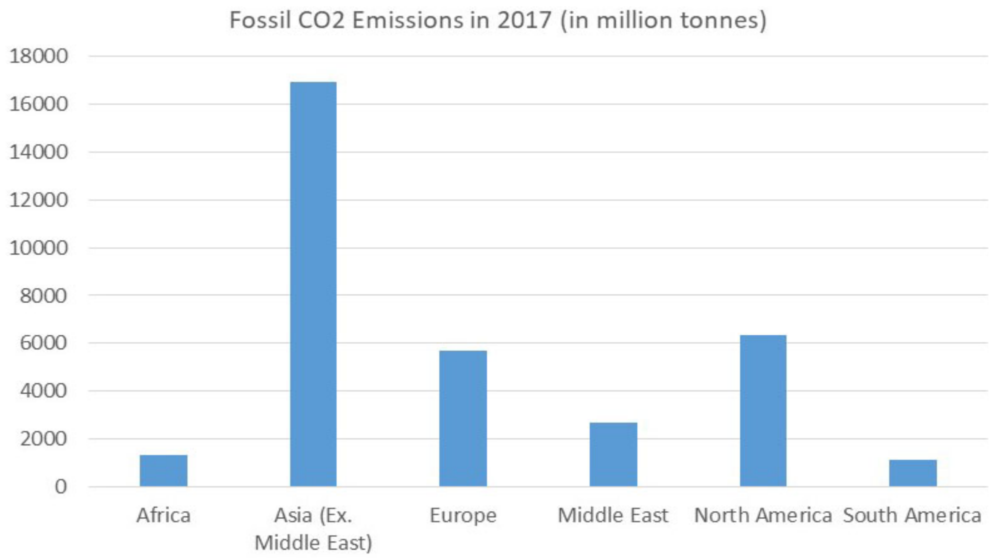


Figure 2.5: Fossil CO_2 Emissions by Continent in 2017 (Source: GCP, 2018).

The expected consequences of global warming are destructive leading to melting ice caps that have the potential to expand the oceans and increase sea levels (Lelieveld *et al*., 2012). Moreover, impacts on the natural and human systems from global warming have already been observed, whilst many land and ocean ecosystems have already changed as a result. Some of these impacts seems to be long-lasting or irreversible, such as the loss of some ecosystems. For example, the sea level rises roughly 6 cm/decade for each temperature rise of 1.5 to 5.5°c, which is expected by 2100 to rise approximately 50 cm. This means that many coastal cities and inhabited islands will be affected (Strauss *et al.* 2015). Notably, according to the 2015 Climate Central's report, China will be most affected by rising sea levels caused by global warming. The report assesses the impact of sea level rises caused by 2 and 4 degrees Celsius global temperature increases. Figure 2.6 shows the 2010 population - in millions - who will be affected by the median locked-in sea level rise from the two different temperature increases (Strauss *et al.,* 2015).

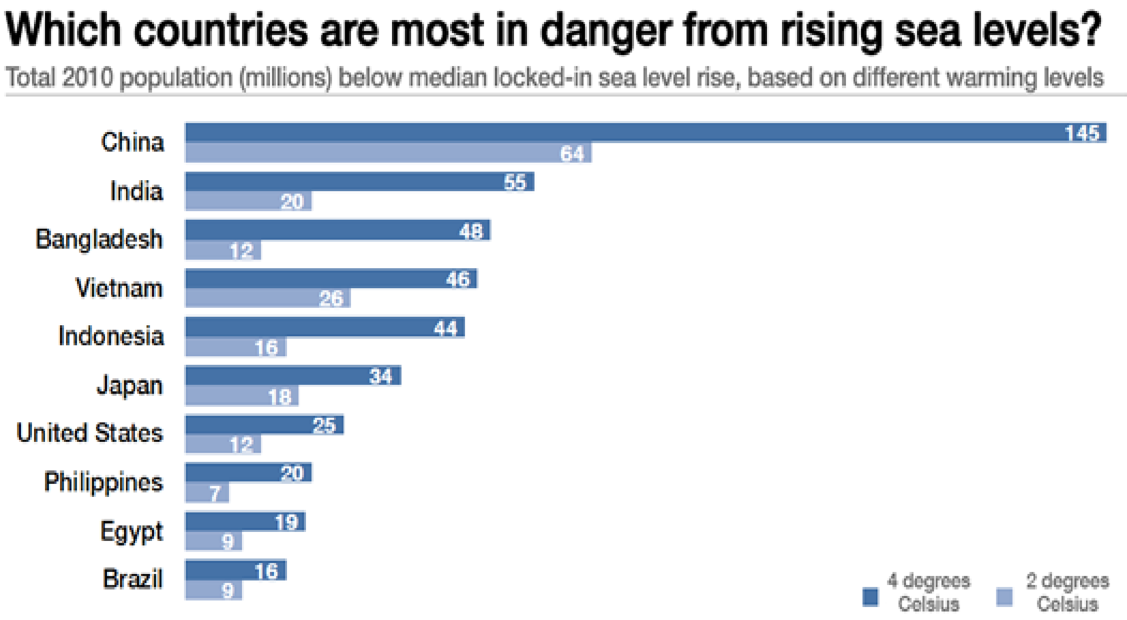


Figure 2.6: Countries Which Will Be Most Affected by Rising Sea Levels (Source: Strauss *et al.*, 2015).

As shown in Figure 2.6 above, the list is strikingly dominated by Asian nations, meaning that 64 million people in China would be affected by rising seas with a 2 degree rise in temperature. However, with a 4 degree rise this figure goes up to 145 million. China is followed in second place by India, with 20 million and 55 million respectively. Whilst India's neighbour, Bangladesh, completes the top three most at risk, followed by Vietnam, Indonesia, Japan and the Philippines, which all appear in the list. The only other nations to feature are the US, Egypt and Brazil at 7th, 9th and 10th respectively.

To this extent, 'sustainable development' in the built environment is essential, as it aims to overcome the aforementioned puzzle, enabling humans to live healthier and engage in a new, wiser era of industry. Therefore, it can be argued that transformation of the world economy and society to a sustainable approach is the most serious challenge of our time. However, this challenge is unprecedented in context, as its scope is the entire planet. Consequently, it needs a radical shift in consciousness as well as action. This indeed, requires new visions and meaningful approaches for shaping ambitious realities.

2.3 Sustainable Development

Even though our earth is exquisitely configured to host life with abundance, humans have systematically compromised almost every vital aspect of its complex systems. If humans are to survive, this trend ought to be reoriented and a lasting balance adopted. Ultimately, Sustainable Development (SD) aims to reflect such insight, gaining increasing recognition in recent years worldwide. However, its widespread use has led to a sense of ambiguous perception, since it is broadly employed with a wide spectrum of understanding.

2.3.1 Definition of Sustainability

Sustainable Development (SD) is a simple word with a complex meaning. One report indicates that SD is "one of the most widely used words in the scientific field" (Leal Filho, 2000, p.9), yet it is deemed to be a complex term, deployed in different ways by individuals, organisations, and governments, and thus, used to support a variety of ambitions, and contested ends. Linguistically, the meaning of the verb 'to sustain' according to the Oxford English Dictionary is to keep something going over time or continuously (Oxford, 1989). Whilst the term 'sustainability' refers to the avoidance of the depletion of natural resources in development fields (Ben-Eli, 2015). It is commonly acknowledged that SD originally derives from the concern that the global consumption of resources and its production of waste could exceed the earth's capacity to produce these resources and absorb waste (Conard, 2013), reflecting the object of a lasting ecosystem over time (Murray, 2011).

Ample definitions for SD have existed, hence it does not have a consensus for its definition (Waas *et al*., 2011). While the classic definition of sustainable development was introduced in the highly influential Brundtland Report from the World Commission on Environment and Development (WCED), which provided the prevalent definition for sustainable development:

> *"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p.8).*

Arguably, the Brundtland definition was a political fudge as Leal Filho (2000) asserted that it is based on an ambiguous meaning in order to gain widespread acceptance. Others have argued that the vagueness of meaning makes the concept almost meaningless and it lacks any clear rigour of analysis or theoretical framework

(Murray, 2011). However, Leal Filho (2000) pointed out that the basic idea of sustainability is quite straightforward: a sustainable system is one which survives or persists. Biologists and ecologists make use of the term to describe the rates at which renewable resources could be extracted or damaged by pollution without threatening the underlying integrity of an ecosystem (Ben-Eli, 2015). Meanwhile, Conard (2013) described sustainability as individuals doing their part to build the kind of world that they want to live in and that they want their children and grandchildren to inherit, so that humans become aware of choices and behaviours that influence the intricate balance of the earth's social, ecological and economic systems. Recently, however, the prevailing definition for sustainability focuses on cross-generational equity (Ben-Eli, 2015), which is undeniably a convincing concept.

> *"Sustainability is a dynamic equilibrium in the process of interaction between a population and the carrying capacity of its environment such that the population develops to express its full potential without producing irreversible, adverse effects on the carrying capacity of the environment upon which it depends"* (*Ben-Eli, 2015, p.3).*

Ben-Eli (2015) has asserted that grounding an alternative perception to the interrelationship between a population and the carrying capacity of its environment represents a revolutionary operational leverage. Furthermore, describing that the current definition contains a range of key ingredients that are likely to be measurable, for example, population size, resource use rate, absorption capacity of sinks, well-being level, and the like. However, the current definition also presents difficulties, as future generations' claims seem undefined or undetermined. At the same time, Murray (2011) concluded that there is agreement about what SD really indicates, since it is fundamentally about the conservation of resources and the way by which the next generations can share the current one with the benefits of development.

Interestingly, although the terms 'Sustainability' and 'Sustainable Development' are often used interchangeably, there seems to be controversially functional differences between the two concepts. According to Waas *et al*. (2011), while Sustainability represents the ability to maintain a 'desired condition' over time, Sustainable Development is considered as the tool required to achieve the desired goal 'Sustainability'. Against this perception, Sustainable Development can be understood as the path to amend unsustainability, whilst the basic premise of Sustainability appears to be how sustaining the well-being of living systems can be achieved over time (e.g. clear ethical values, guidelines for decisions or what priorities are). Therefore, Sustainable Development needs to be based on norms that embed all the issues that societies are concerned with (Waas *et al.*, 2011). Given that this study looks for an assessment model for sustainable homes, its nature revolves around the concept of Sustainable Development, even though they are used interchangeably through this thesis.

The main principles of Sustainability have been emphasised through a number of initiatives, presenting and forming the concept of Sustainability in a broad set of objectives and ambitions in order to facilitate delivering Sustainability in practices, which is to be addressed within the next section.

2.3.2 The Main Principles of Sustainability

The ultimate goal of establishing Sustainability as a revolutionary concept is to reinforce a well-functioning alignment between the economy, society and the planet's ecosystem. This alignment poses a range of mechanisms that ensure dynamic equilibrium in the interaction between the components of Sustainable Development. It is widely believed that the most prominent statement in this context, is the Rio Declaration 'Agenda 21' at the Earth Summit of 1992. The United Nations Conference on Environment and Development (UNCED) commenced the principles for Sustainable Development with the agreement of more than 178 Governments worldwide. The full Implementation of Agenda 21 and the Commitments to the Rio principles, were strongly reaffirmed at the World Summit on Sustainable Development (WSSD) held in Johannesburg, South Africa in 2002. More recently, a distinguishing initiative has attempted to reflect a comprehensive set of Sustainability principles. The 2030 Agenda for Sustainable Development was adopted by all United Nations Member States in 2015. The recent agenda emphasizes a holistic approach to achieving Sustainable Development for all, building on the principle of "leaving no one behind" (SDGs, 2015). 'Envision2030' promotes the mainstreaming of the establishment of Sustainability throughout its 15-year lifespan with 17 key principles to transform the world (SDGs). Table 2.1 shows the 17 key Sustainable Development Goals (SDGs, 2015).

Table 2.1: The 17 key Sustainable Development Goals

GOAL	Principle	Objective
GOAL 1 No Poverty	End poverty in all its forms everywhere	The primary objective is the reduction and, in the long term, the eradication of poverty
GOAL 2 Zero Hunger	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture	Supporting agricultural growth; Fighting undernutrition/stunting; Strengthening resilience to climatic, economic and political crisis
GOAL 3 Good Health and Well-being	Ensure healthy lives and promote well-being for all at all ages	Address maternal and child mortality, infectious and non-communicable diseases, access to sexual and reproductive healthcare services
GOAL 4 Quality Education	Ensure inclusive and equitable quality education and promote life-long learning opportunities for all	The aim is to strengthen education provision at all levels, and to ensure inclusive and equitable quality education for all
GOAL 5 Gender Equality	Achieve gender equality and empower all women and girls	Promoting Gender equality and women's empowerment is aimed at changing the lives of girls and women by promoting their economic and social rights
GOAL 6 Clean Water and Sanitation	Ensure availability and sustainable management of water and sanitation for all	Focusing on access to safe drinking water and sanitation, wastewater and pollution, transboundary water management and cross-sectoral coordination
GOAL 7 Affordable and Clean Energy	Ensure access to affordable, reliable, sustainable and modern energy for all	Providing access to sustainable energy services and helping the world's poorest and most vulnerable places tackle climate change
GOAL 8 Decent Work and Economic Growth	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	Change focuses on inclusive and sustainable growth for human development in particular in those sectors that have stronger multiplier impact
GOAL 9 Industry, Innovation and Infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	Towards inclusive and sustainable growth and economic integration, other targets on access to financial services and technology
GOAL 10 Reduced Inequality	Reduce inequality within and among countries	Development cooperation focuses on growth patterns that lead to structural transformation and that are conducive to more productive employment, higher incomes and decent work for all, which are central for addressing income inequalities
GOAL 11 Sustainable Cities and Communities	Make cities and human settlements inclusive, safe, resilient and sustainable	Supporting access to water and sanitation, urban mobility, energy and affordable housing, as well as energy efficiency and disaster prevention and preparedness.
GOAL 12 Responsible Consumption and Production	Ensure sustainable consumption and production patterns	Promoting the transition to an inclusive green economy that generates growth and creates decent jobs, supporting the sound management of waste and chemicals
GOAL 13 Climate Action	Take urgent action to combat climate change and its impacts	Helping to facilitate the transition to a climate resilient low-carbon future
GOAL 14 Life Below Water	Conserve and sustainably use the oceans, seas and marine resources for sustainable development	Conventions on marine pollution prevention and on the conservation and sustainable management of marine resources
GOAL 15 Life on Land	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	Promoting sustainable forest management, the fight against deforestation, forest degradation and illegal logging
GOAL 16 Peace and Justice Strong Institutions	Achieve peaceful and inclusive societies, rule of law, effective and capable institutions	Towards achieving peaceful and inclusive societies, rule of law, effective and capable institutions
GOAL 17 Partnerships to achieve the Goal	Strengthen means of implementation and revitalise the global partnership for sustainable development	Promoting innovative financing and the commitment to develop effectiveness, strengthen means of implementation and revitalise the global partnership for sustainable development

(Source: adopted from SDGs, 2015)

A review of the principles implies that an attempt to implement a transition to Sustainability, which is a piecemeal framework focusing on selective aspects while omitting some others, is unlikely to pose successful, lasting outcomes. Consequently, a systemic approach is fundamental. As it reacts with the interdependent nature of reality itself. Therefore, it is of utmost importance to comprehensively incorporate the key Sustainability principles into any attempt at building a rigorous framework for implementation, so that it is intended to meet a range of these principles through the proposed model and this will be reflected in the discussion of the potential findings of this study.

2.4 Sustainability in Construction

It is widely accepted that the construction sector can significantly reinforce the achievement of Sustainable Development; and its role in encouraging environmental protection, economic growth and social progress is undeniable (Heravi *et al.,* 2015; Fenner & Ryce, 2008; Kibert, 2008; Edwards, 2000). The abundant definitions of this concept and the main principles of sustainable housing building are to be highlighted before addressing the underlying impacts of construction activities through the following sub-sections.

2.4.1 The Broadness of Sense

The term of Sustainable Construction (SC) appeared approximately at the same time as the evolution of the concept of Sustainable Development (SD), referring to comprehensive solutions for ecological, social and economic issues (Kibert, 2008). Reviewing the relevant literature reveals that there are tremendous initiatives that aim at conceptualising the concept of Sustainability in the built environment domain including concepts such as Sustainable Construction, Sustainable Building, Sustainable Architecture, and Sustainable Communities. However, the first initiative amongst them, was presented in 1994, by the '*Conseil International du Batiment*' (CIB)[1] as an overarching understanding aimed at conceptualising Sustainable Construction (SC) in a broad domain:

> *"... creating and operating a healthy built environment based on resource efficiency and ecological design" (Kibert, 2008, p.10).*

In the same context, according to Glavinich (2008) the term green building was defined in the American Society of Testing and Materials (ASTM) as a building that provides the specified building performance requirements while minimising disturbance to and improving the functioning of; local, regional and global ecosystems both during and after its construction and specified service life. Meanwhile, Fenner and Ryce (2008) presented a comprehensive vision for green building as follows:

> *"Green buildings may be considered as structures that incorporate environmentally sensitive features and technologies from the initial design phase; they seek to meet or exceed resource and energy consumption targets that are set well above local requirements while taking into account the whole life cycle impact of the structure" (Fenner & Ryce, 2008, p.55).*

[1] CIB is the acronym of the abbreviated French name; the abbreviation has been kept but the full name changed into: International Council for Research and Innovation in Building and Construction.

Similarly, Sustainable Building is a concept which reflects incorporation of the principles of Sustainability with the aim of minimising the impact of building projects on the natural environment, as Godfaurd *et al.* (2005) stated:

> *"... those buildings that have minimum adverse impacts on the built and natural environment, in terms of the buildings themselves, their immediate surroundings and the broader regional and global settings"* (*Godfaurd et al., 2005, p.320).*

Accordingly, Sustainable Architecture can be defined as design which meets human demand whilst having a minimalistic impact on the natural environment (Edwards, 2000). This implies that Sustainable Architecture is mainly concerned with ecologically internal and external buildings. Thus, there seems to be extensive evidence to assert the importance of the role of building projects as a starting point for achieving Sustainable Communities. As Edwards (2000) stressed that sustainable communities can be shown as one of the ultimate goals, which allows people to spend long periods of time in their neighbourhood:

> *"Living in harmony with the environment has become an essential component of the design of homes and neighbourhoods in the third millennium" (Edwards, 2000, p.7).*

Despite the prevalent use of such a range of concepts, truly Sustainable Construction with efficient energy systems, recyclable materials, and full-integrating ecosystems are rare to nonexistent. The reverse impacts of construction activities are apparently shown through a wide range of aspects including raw material consumption, pollution and waste generation, energy use, and health and wellbeing. These issues are discussed in the following section.

2.4.2 Construction Impacts on the Environment

The construction industry is among the most resource-intensive industries worldwide. Therefore, the impacts of construction activities on both humans and the ecosystems is increasingly concerning. Evidently, action is urgently needed to incorporate Sustainability into built environment and building performance (Abidin, 2010; Ding, 2008; Cole, 1998). As the environment and construction activities seem to be closely linked, the building community is deemed as the centric focus in relation to environmental problems (Jain, 2013). Moreover, Abidin (2010) reported the building sector as one of the major contributors to environmental degradation. Whilst, the building community has been classified by a range of scholars (Ding, 2008; Cole, 1998) as apparently demonstrating a careless manner, being financially revenue-motivated, and ultimately portrayed as environmental destroyers instead of protectors. It is undeniable that the impacts of the construction industry to a large extent are irreversible for the surrounding environment, and the ecosystems which act throughout the project life cycle (Ding, 2008). Figure 2.8 illustrates the various stages of a life cycle in a building project, including the harvest of raw materials and production of components in alignment with the stages of planning, design, construction, operation and deconstruction phases.

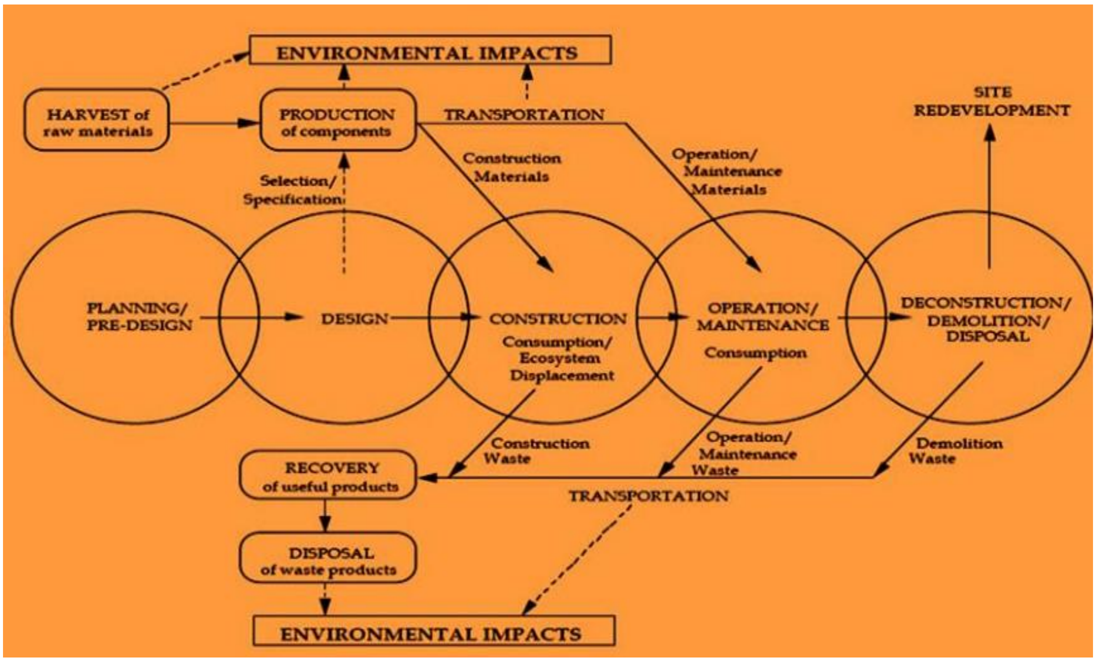


Figure 2.7: Environmental Impact through the Life Cycle of a Building Project (Source: Jain, 2013).

Arguably, although it has a substantial effect on the environment, the period of the construction phases is relatively short amongst the entire project lifecycle. As such, the environmental impacts of the building projects are to be analysed in a manner that ensures accommodating the whole life cycle of a building.

2.5 Shift to Sustainable Homes

Homes not only offer accommodation, but also grant a sense of security while strengthening local communities. Firstly, the concept of home and its perspectives are to be highlighted before addressing the features required for a successful shift to sustainable homes through the following sub-sections.

2.5.1 The Concept of Home

The concept of home has many origins and can be seen from different perspectives. People live in a world of symbols created by themselves, that express their perceptions and intentions in a way that is reflected through a range of objects. Home as a concept is a fundamental notion in people's minds, and for many, has a powerful symbolic charge, as indicated by Lantz (1996). Interestingly, 'home' and 'house' as terms, are very often used interchangeably. The Oxford dictionary defines the terms home and house as synonymous, referring to a building where someone lives (Oxford, 1989), although linguists would probably differentiate between them. The main difference is that a house is concrete or has a physical location, whilst a home can even be something abstract, such as a place in the mind or any location that people think of as the place where they live and that belongs to them. "Home is where the heart is" is a well-known expression, that truly indicates home as somewhere that is both desirable and that exists in the mind, as much as in a specific physical structure. However, reviewing the body of literature (Cooper, 2003; Roaf *et al.*, 2003; Svensson & Wood, 2003; Al-Nuaim, 2000; Huang, 2000; Gaunt & Lantz, 1996; Lantz, 1996; Redvall, 1987), reveals that the concept of home has a number of meanings with integral complexity. As such it is discussed from four distinguished perspectives including; homes as security, as an identity, as a commodity, and culturally charged.

2.5.1.1 Home as a Shelter

Instinctively, each individual as a human, looks forward to living in a secure, comfortable shelter. It is deemed a basic need for all people to keep themselves safe from potential risks such as climates, animals, and criminals, and to have time away from people's eyes to relax and rest. As Lantz (1996) states, home is crucial to survive life. While Roaf *et al.* (2003) describe the buildings as a third skin. Meaning people are protected against the elements with three skins to stay alive. The first is our own skin, the second is a clothing layer, the third is the structure. In addition to this, home can be shown as a perfect gathering place and haven, offering escape from life's hassles and battles. Much thought about, treasured, harboured and longed for as an anchor for one's existence. Whilst others might recognise a home as a precious sanctuary and the subject of plentiful artworks and written products. Therefore, home is a source of positive meanings and feelings, offering a supportive, loving and private place in which to grow up and discover oneself.

2.5.1.2 Home as a Personal Identity

Home is a distinguishing perception for many people as it closely reflects their quality of life. In this sense, owning a home not only relates to a financial perspective, but also to the individual's status. As Al-Nuaim (2000) argues, a house is a clear indicator of their standards of living, directly contributing to people's prosperity, as well as to people's health indirectly. It is one of the top priorities for every homeowner to invest in a house that increases the value of their identity, be it either purchased or inherited. In this context, some scholars (Svensson & Wood, 2003; Lantz, 1996; Redvall, 1987) have demonstrated the interrelationship between identity and home. According to Lantz (1996), the home is an essential part of something, which reflects 'personal sphere', thus representing an extension of an individual. Whilst Redvall (1987) indicated that people seek three values in their homes, namely; identity, privacy and security. Therefore, as Svensson and Wood (2003) emphasised, homes should not only be limited to equipment that fits practical purposes, but rather a complex texture of identity, symbols, ideals and aspirations, that enable the occupants to reflect their identity by reshaping their home environment.

2.5.1.3 Home as a Commodity

From a market perspective, a home can be classified as a commodity, yet its complexity makes it incomparable to other commodities. There are many features that distinguish the investment of dwellings. These characteristics have posed special conditions in the market, which in turn affect not only the preference of housing for the homeowners, but also policy makers in relation to housing demand and supply (Huang, 2000). Housing buildings are very expensive to establish and are considered a long-term investment. They are varied and wide-ranging, while for all people home is a critical necessity (Al-Nuaim, 2000). Another unique characteristic is that a housing project is fixed in terms of mobility. This leads to their availability being dependent on the location, so that the demand of housing is more likely to be sensitive to the density of population in an area. This implies that the demand on housing in urban areas is greater than that of rural locations (Huang, 2000). This also means that home policy for inner cities must be different from that of rural areas, so it is of utmost importance that relevant policies are locally regulated. Therefore, it can be argued that local authorities can play a fundamental role in housing development.

2.5.1.4 Home as Culturally Charged

The home concept can be claimed to be highly ideological and cultural in view of the relationship between identity and home. Therefore, the cultural sustainability of dwellings can be associated to the preservation of housing heritage. As Gaunt and Lantz (1996, p.4) stated, "home is an ideological concept, and it has a personal existential burden". As such, the individual's perception of the meaning of a home can be considered as a social and cultural structure. This implies that socio-cultural features are significant components in structuring the concept of a home. As Cooper (2003, p.19) confirmed, "buildings and settlement patterns are material expressions of the cultures that construct them". Significantly, in western countries like the UK for example, it is recognised that a range of immigrants from traditional societies such as African families, have frequently experienced semi-modern forms in their homeland, leading to major changes in the immigrants' lifestyle. The adaptation of homeowners to their natural habitat, how it changes with time and the progression of technology, all reflect the physical form of a building (Edwards, 2000). Hence, the physical form of a building becomes a part of culture itself. Therefore, one can argue that housing design is considered as an outcome of socio-cultural values, customs and practices. Nonetheless, the forms of housing buildings, as indicated by Chiu (2004), significantly depend on the availability of building resources, climatic conditions, the building capability of the occupants and the aesthetics of specific communities over certain periods of time. Therefore, the transformation of the cultural identity of a place clearly reflects the people's lifestyle, as well as the aesthetic and artistic dimensions of culture, whilst the conservation of housing buildings for aesthetic and heritage values significantly enhances the continuation of a culture.

2.5.2 Sustainable Homes

A sustainable home is a subset of the broader sustainable construction movement. The definition of a sustainable home will be highlighted followed by the key sustainability interventions in housing projects being addressed.

2.5.2.1 Defining Sustainable Homes

In reflection of sustainable thinking which requires employment of a balanced approach and considers environmental, social and economic issues, the sustainable home as a concept refers to homes that are designed to minimise the overall environmental impact. Both during and after construction, in such a way that meets the needs of the present, without compromising the ability of future generations to meet their own needs (Svensson & Wood, 2003). It can be argued that the notion of Sustainability as a general concept, does not represent something new in the domain of housing, as the ultimate goals are consistently set out. As Younger *et al*. (2008) pointed out, the concept of a sustainable home is simply used to describe a process that is applied to the housing projects in order to achieve more re-use and recycling, less waste, lower life-cycle environmental impacts, less maintenance, costs reduction, better reliability, and greater occupant satisfaction. Sustainable homes for many, therefore, have the potential to produce good quality housing with an affordable price both in the short and long term. This practice fundamentally requires an understanding and awareness of economic, social and environmental Sustainability throughout the implementation of projects starting from the initial phase of design to the construction stage. However, a review of the relevant literature (Ahmed *et al*., 2015; Sev, 2009; Younger *et al*., 2008; Hudson, 2005; Chiu, 2004; Best & Valence, 2002; Edwards, 2000) has revealed that many efforts have been established in an attempt to facilitate successful implementation of sustainable homes instead of trying to define them. Nonetheless, a sustainable home from various viewpoints, is considered as not only a fashionable concept, but also as being unrealistic (Edwards, 2000). Meanwhile, others argue that the notion of sustainability as a whole is a philosophical theory as opposed to a stylistic approach (Chiu, 2004). Moreover, a sustainable home is often misunderstood, where the focus is determined by merely adopting efficient energy technologies (Edwards, 2000). Whilst Roaf *et al*. (2005) described an eco-house as a house that is closely connected to the site, society, climate, region and planet.

Against this understanding, it is evident that a complete sustainability implementation necessitates the recognition of ecological and environmental consecrations together with principles associated with the economy and society. Essentially, common considerations for sustainable homes include the use of environmentally friendly materials, efficient water use, renewable energy, maximisation of healthy indoor environment quality, pollution reduction, community cohesion and the assurance of housing affordability. All these considerations constitute the concept of sustainability as a whole and for housing projects particularly. They are intended to be addressed through discussion of the strategies for application of sustainability interventions in the housing industry in the following subsections.

2.5.2.2 Sustainability Interventions in Housing Projects

There are many considerations by which the current performance in buildings, particularly housing projects, can be sustained. Such as producing more environmentally friendly products, whilst maintaining the quality of the production. A review of the relevant literature (Sev, 2009; Hudson, 2005; Santamouris, 2004; Best & Valence, 2002) has revealed that there are three major aspects which highly represent the most effective interventions in regard to sustainability in housebuilding. These aspects are resource efficiency, indoor environment quality, and cost efficiency and will be explained in the following sub sections.

2.5.2.2.1 Resource Efficiency

All building activities involve the extensive use of components extracted from the earth’s resources, such as water, energy and raw materials. During these activities, effects occur that change the ecology of that part of the biosphere (Hudson, 2005). Home developers should regard the creation of a building as a form of resource management. As the non-renewable resources that play a major role in the creation of a building are energy, water, material and land, the conservation of these resources has vital importance for a sustainable future.

1) Site Use Considerations

Land is an invaluable resource on which the built environment is fundamentally dependent. The increasing population growth as mentioned earlier, implies a consistently rising demand for land, particularly in urban areas. Whilst land in various regions has witnessed considerable damage as a result of construction industry activities (Sev, 2009; Best & Valence, 2002). House providers and developers should therefore develop a greater respect for the selected landscape and pay more attention to understanding the adverse impacts of their activities on the soil, ecosystems, water, and habitats. With regards to efficient use of land, one possible solution is the adaptive reuse of an existing building, which can reduce the demand for land, thus alleviating the horizontal expansion of a building and conserving the arable land (Sev, 2009). Notably, urban sprawl is one of the most serious challenges facing many cities worldwide, which necessitates genuine interventions to prevent any further losses of agricultural areas. As Best and Valence (2002) stressed, adopting such a policy as zero expansion of existing urban zones is one of the possible strategies that can promote better exploitation of urban land, as well as encouraging rehabilitation of degraded land for urbanization.

2) Energy Use Considerations

Energy use is one of the most important sustainability issues due to its impact on the environment and society. As mentioned earlier, buildings and particularly homes are dominant energy consumers, which occurs throughout all stages in the project (Santamouris, 2004). The embodied energy of a building represents the total energy required for the creation of it. This can include direct energy used in construction, besides indirect energy, which represents the amount of energy that is required to manufacture the building materials, as well as energy consumed through transportation of these materials and building components (Huberman & Pearlmutter, 2008). As aforementioned, the fossil fuels used such as natural gas and coal, release a considerable amount of CO_2. While operational energy as Thormark (2006) revealed, accounts for roughly 90% of the total building's CO_2 emissions, and is generated from the use of cooling, heating, hot water and the ventilation of energy efficient materials. Nonetheless, the adoption of considerations such as window tinting, reflective roofing, emissivity windows, solar shading, structural insulated panels (SIPs) and insulated concrete forms (ILFs) would be an effective way of minimising heat transfer, improving thermal bridging and maximising the energy performance of a building resulting in a reduction of housing energy use (Santamouris, 2004). The adoption of energy efficiency as USGBC (2013b) suggested, can be achieved through several ways: (i) use of materials with low embodied energy; (ii) design for energy efficient deconstruction and recycling of building materials; and (iii) selecting means of transport with efficient energy and adopting energy efficient technological processes for building constructions.

3) Water Use Considerations

The depletion of water resources has increasingly become an environmental concern in many countries worldwide. It is noticeable that a range of strategies and policies have been established to consider operational water use in the built environment, which represents a significant portion of water consumption, whilst neglecting the embodied water used through the extraction, production and manufacturing of the building materials and components (Yu *et al.,* 2010). However, a review of the literature (USGBC, 2013b; Yu *et al*., 2010; Sev, 2009) has revealed a range of strategies that can be adopted to reduce the amount of water consumed through a building life cycle. These strategies include: (i) use of water-efficient plumbing systems; (ii) minimisation of wastewater by using ultra low-flush toilets and low-flow shower heads; (iii) recycling of used water; (iv) design for low-demand landscaping; and (v) use of rainwater storage.

4) Material Use Considerations

The extraction and consumption of natural resources for construction activities has a direct impact on ecosystems and natural areas (TCPA & WWF, 2003). An extensive amount of mineral resources is consumed in the building industry (Sleeuw, 2011), with most of them considered as non-renewable. As such, the selection of materials as stressed by Ahmed *et al*. (2015) should be sustainably assessed as early as possible within the design stage. A range of factors can be employed to assess the impacts of building materials, for example, this includes toxicity, durability, locality, recycling, and pollution prevention.

i. Toxicity

The use of non or less-toxic building materials are considered more sustainable and less hazardous to both builders and potential users. Many materials adversely affect indoor air quality and severely expose building occupants to a range of health hazards (Ahmed *et al*., 2015). Within building projects, there are many components such as adhesives, paints, sealants, and cleaners that contain 'volatile organic compounds' (VOC), which may release dangerous fumes and affect air quality throughout a building's life (Rossi & Lent, 2006). Therefore, the implementation of intensive air cycling rates both when installing such components and following building occupation is highly recommended (Ahmed *et al.*, 2015).

ii. Durability

Durability reflects the extent to which a particular substance can maintain its original specifications over time (Mora, 2007). It is commonly known that the Sustainability of a building can be enhanced by increasing the durability of its materials. A component, material or system can be recognised as durable when its useful life performance is fairly comparable to the time required for the environment-related impacts to be absorbed by the ecosystem (Malholtra, 2002). Materials that have a longer life are often replaced less than others designed for the same purpose. This can inevitably minimise the consumption of natural resources demanded for manufacturing, as well as achieving money savings. As Mora (2007) stated, the greater the material durability, the lower the resources and time needed to sustain it.

iii. Locality

The use of local-based building material is incredibly helpful in alleviating environmental impacts, by minimising delivery distances, so that less air pollution can be released through the transportation of materials to the building sites (Ahmed *et al*., 2015; Akadiri, 2011; Huberman & Pearlmutter, 2008; Sourani, 2008). The use of local building components and materials is also suitable when considering the risks associated with damage that might occur as a result of the climatic conditions. More importantly, local purchases of building materials significantly enhance national economies (Cole, 1998). While the use of natural substances and components consumes less embodied energy as this often necessitates less processing. In addition to this, natural materials have a lower toxicity than artificial components, so they are less dangerous to humans and ecosystems (Godfaurd *et al.*, 2005). Therefore, incorporating local and natural components into building products is vital to establish the concept of sustainability in housing projects.

iv. Recycling

Waste is one of the most concerning issues, which represents considerable amounts of unwanted materials generated from either construction or deconstruction processes. Reduction of the generated waste within housing projects can inevitably achieve remarkable amounts of resource savings. In this context, Coventry *et al*. (2001) recommended that housing providers play essential roles to reduce construction waste through the initiation of a range of strategies. These strategies included; provision of helpful advice to homeowners; adoption of a clear strategy for waste minimisation at project level; and better building design practices. However, according to Esin and Cosgun (2007) the most successful method for waste-related environmental impact reduction is by initiating a rigorous policy to prevent waste generation from construction activities as much as possible. This should be followed by the commitment to reuse and recycle building waste through construction projects. Reusing building components are considered the best way for the ideal utilisation of available resources and the reduction of construction or deconstruction waste, as this allows recovery of a range of functional components such as tiles, windows, and bricks, instead of transforming them back into raw materials.

v. Pollution

Pollution prevention strategies adopted through the construction processes are fundamentally crucial in the attempt to achieve more environmentally sustainable housing. As Kibert (2008) asserted, careful choice of building components and materials from responsible sources can ensure the provision of environmentally friendly materials, as well as encouraging pollution prevention initiatives. One of the prominent issues is soil pollution as it significantly affects the construction sites as well as the extraction sites of some minerals when hazardous waste is deposited. Wastewater is another major problem threatening the environment and ecosystems. Wastewaters are mainly released into streams, resulting in a wide range of toxic substances. Accordingly, USGBC (2013b) has recommended a range of available strategies for preventing pollution in construction sites, including; minimisation of transportation used for delivering building materials; improvement of an efficient site management; the reuse or recycling of all possible construction wastes; and the adoption of systematic separation for all unavoidable wastes.

2.5.2.2.2 Health and Wellbeing

Improving indoor environment quality is a critical aspect for many homeowners when assessing investment decisions in the housing market. Housing providers should ensure the provision of higher occupants' health, safety, and comfort, so that it satisfies the users requirements. A review of the literature (Archibald *et al.*, 2013; Addis & Talbot, 2011; Sev, 2009) has identified a range of requirements necessary for enhancing indoor environmental quality, including; ventilation, daylighting, thermal comfort, acoustic comfort, security, and aesthetics.

1) **Ventilation and Daylighting**

Natural ventilation reflects the process by which indoor air is naturally replaced without using any artificial equipment to increase the quality of the indoor environment. Adoption of these ventilation strategies has the potential to minimise the energy demanded for cooling or heating buildings (Addis & Talbot, 2011; Edwards, 2006). Daylighting is also an essential factor that enhances the quality of light and reduces energy use. Best practices in terms of daylighting include the distribution and control of light for uniform levels, avoiding glare and reflections (Edwards, 2006). As Armstrong and Walker (2002) pointed out, occupants who have access to a reasonable level of daylight seem to be happier and more productive. While shading strategies, window orientation and controlling, represent key interventions that ensure ideal performance of natural ventilation and daylighting practices. Access to natural ventilation through safely open windows and having eye contact with a surrounding landscape seem to be key characteristics in sustainable home design.

2) **Thermal Comfort**

Improving the specifications related to thermal comfort is a main concern for assessing the Sustainability interventions in housing projects. The degree of air temperature, humidity and controlling systems, are essential determinants of thermal comfort (Archibald *et al*., 2013). The best possible ways to improve thermal comfort and optimise energy efficiency indicators have been suggested by USGBC (2013b) and include the adoption of main building envelope considerations such as low window tinting, reflective roofing, emissivity windows, and solar shading. Also, setting the building location according to solar positions, as well as individual control of thermal distributions, are additional key factors for thermal comfort.

3) **Acoustic and Visual Comfort**

Sound pollution is another issue concerning Sustainability in housing projects. With the controlling of noise released from different sources such as electrical and mechanical equipment classified as important to ensure it (Archibald *et al.,* 2013). Acoustic comfort as suggested by USGBC (2013b), can be achieved by installing suitable wall insulation, proper windows, and high-quality wall framing and materials. There are a wide range of sound insulating materials that can be installed to improve acoustic comfort, these include: straw-bale construction, acoustic ceiling tiles, and hard versus absorbent surfaces. Furthermore, noise generated from HVAC equipment can be alleviated through the appropriate design of ducts and piping systems (Sev, 2009). Another important issue is building aesthetics which should be considered through the design stage, with a view to maintaining cultural and landscaping considerations (Chang *et al.,* 2007). The style of the housing projects should be in harmony with local architectural styles and landscaping consistency (Addis & Talbot, 2011). With aesthetic aspects such as the outdoor layout encouraging the house occupants and raising visual performance and comfort for them.

4) Security and Safety

House security and safety issues are critical factors in a homeowners' decision in relation to housing investments. The main function of a house is to offer a safer place where private human activities with confidential secrecy can take place without any form of fear or distraction (TCPA & WWF, 2013). Generally, people have an intensive concern in terms of house location, as this directly reflects the status of security and social value. While some considerations seem to be beneficial regarding security including locked doors, suitable fences and walls (USGBC, 2013b). However, to some extent, installing barriers in front of a house might affect the aesthetic features of the house particularly when these barriers are extensively used.

2.5.2.2.3 Cost Efficiency

The housing project supply chain of designers, developers, providers, and manufacturers are under increasing pressure to minimize total project cost. As housing represents a large and long-lasting investment in financial terms as well as in other resources (Addis & Talbot, 2011). Cost efficiency is often assessed through the adoption of the "Life Cycle Cost" (LCC) analytical techniques (Lombera & Cuadrado, 2010). The successful implementation of LCC as Lombera and Cuadrado (2010) and Goh and Yang (2009) demonstrated, should involve a meaningful, comprehensive design along with the quantified material and construction practices with selected environmental considerations. However, quantifying the benefits of sustainable homes from a cost perspective must go beyond these typical life cycle costs and include costs and benefits from various dimensions and different stakeholders. Nevertheless, there are three various costs as Goh and Yang (2009) identified, constituting the fundamental principles of LCC, namely: initial, running, and recovery costs.

1) Initial Cost

The initial or acquisition cost refers to the total cost of creating or remodelling the building (Emmitt & Yeomans, 2008). This includes assets such as the cost of land or building, consultancy costs, building components and materials, and the assembly of materials. For many homeowners however, these costs are often the primary concern and considered the main determinant of their investment decisions. The best ways to minimise the initial costs, therefore, are through the selection of less expensive components and materials whilst accelerating the time consumption to assemble these components together on site (Goh & Yang 2009). Other strategies associated with the reduction of initial cost as Emmitt and Yeomans (2008) pointed out, include: (i) using locally sourced materials; (ii) avoiding the use of imported materials; (iii) adopting locally-based building techniques; and (iv) avoiding building marketing conflicts.

2) Running Costs

This reflects the costs in use which are determined by the decision makers, usually at the briefing stage, and the subsequent stages of design and assembly (Emmitt & Yeomans, 2008). The running costs also cover building works related to the fabric of a building (roof, external walls), and services (heating and ventilation), besides regularly scheduled assessments, inspection and adjustments that take place to maintain a building (Arpke & Strong, 2006). According to Emmitt and Yeomans (2008) running cost reduction can be achieved by considering the following strategies: (i) design the key building to be readily accessible for the implementation of regular maintenance; (ii) ensure the required level of skills is available within the competency of labour supply; (iii) use materials with minimum maintenance requirements; (iv) adopt an ideal process through the design phase to portray service life requirements and identify the relating component to such requirements; and (v) provide adequate protection for building materials from destructive elements such as sun, rain, wind, and temperature variations.

3) Recovery Costs

The costs of demolition and material recovery are rarely considered (Emmitt & Yeomans, 2008). This is because the homeowners usually think of selling their houses long before the building is recycled, so that the recovery cost is of little concern to the homeowner who seems to take upon the investment consideration short term. However, if the environmental issues are to be considered seriously, the ease of deconstruction and recycling related issues should be fairly recognised and quantified during the design phase and incorporated into the development budget. In doing so, it is of importance to carefully estimate how long the construction can last and identify the possibilities to change the functional requirements during its lifetime (Emmitt & Yeomans, 2008).

2.6. A Review on Efforts Developing SAMs

There is an extensive body of literature concerned with the development of sustainability-based frameworks in different contexts and regions. These assessment systems have been developed initially on the basis of specific conditions so as to be applicable to the characteristics of the regions for which these systems are designed. The following sub-sections will review the relevant efforts in the literature which sought to develop sustainability assessment tools in various domains, but after a critical debate on the regional appropriateness of SAMs.

2.6.1 A Critical Debate on the Regional Appropriateness of SAMs

Despite most SAMs being developed to fit a certain territory, a range of research (Mao *et al.,* 2009; Rees, 2009; Ding, 2008; Fenner & Ryce, 2008; Cole, 2005; 1998) has indicated that the prevailing SAMs (e.g. BREEAM; LEED) are not fully appropriate for all regions. Moreover, Reed *et al.* (2009) asserted that each SAM technique has its own specific characteristics that are associated with the country of origin, and this can prevent these methods from reaching a global level. In an interesting study conducted by Mao *et al*. (2009) and Ding (2008) a set of factors were determined that are likely to affect the use of SAMs, such as: (i) Climatic Geographical conditions; (ii) Resource consumption; (iii) Population growth; (iv) Construction materials and techniques; (v) Building stocks; (vi) Potential for renewable energy gain; (vii) Appreciation of historic value; and (ix) Government policy and regulation (Figure 2.9).

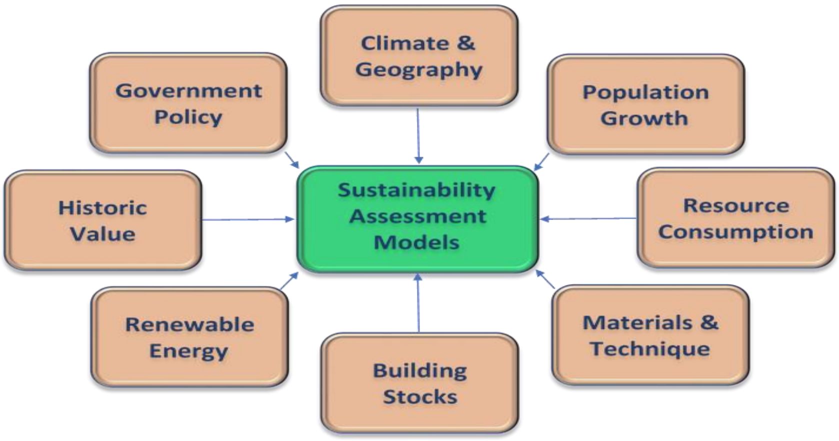


Figure 2.8: Factors Affecting SAM's Appropriateness.

Furthermore, Fenner and Ryce (2008) criticised SAMs applications, referring to a range of deficiencies that affect the majority of SAMs. The most prominent points of concern according to Fenner and Ryce (2008, p.56) are as follows: (i) they are not universally applicable; (ii) they require constant updating; (iii) they require an integrated design strategy; (iv) they rely on designers to estimate the amount of resources consumed by building users while the estimations ignore behavioural issues; and (v) they ignore the 'service lives' of buildings during their 'design life'. In addition, a study by Zuhairuse *et al.* (2009) on the application of a global assessment method (GBTool) for a Malaysian case revealed that the method was not appropriate for Malaysia and many adjustments were required. Significantly, they stressed that each country needs to design its own assessment method (Zuhairuse *et al*. 2009). Meanwhile, an interesting study conducted by Reed *et al.* (2009) aimed at the development of a global SAM revealed that the issues which are addressed in SAMs are generally related to three different levels; the global, local and internal environment. They claimed that one of the global environmental issues is the sourcing and consumption of energy, yet some local issues affect the importance of this at global level. For instance, water is one of the global issues and it is regarded as an important measure in Australia because of droughts, whereas it is not a significant measure in the Northern region of the UK since downpours are very common. Notably, Reed *et al*. (2009) stated that although the absence of a global tool does not prevent the progress of more sustainable buildings, economic, social and cultural aspects can be considered as the main challenges, that have the potential to prevent the achievement of a comprehensive SAM. Sharma's (2010) study in turn, revealed that well-known assessment tools such as BREEAM and LEED are not appropriate for use in the Middle East, particularly the UAE because it lacks a number of social and economic features that need to be met in any logical appraisal of the UAE built environment. Sharma asserted that the LEED rating system adopted in the UAE is not appropriate for desert areas since indicators such as the choice of the site, storm water design, bicycle storage, changing rooms, certified wood, maximising views and daylight canals are of little relevance.

Subsequently, it has been suggested that if the well-known SAMs are to be modified for different regions from ones they are originally based on, there are several significant issues that need to be taken into consideration. For example, despite the fact that in countries such as Libya, watercourses are unfamiliar, watercourse contamination is a criterion that has been assessed and scored through the well-known SAMs. Therefore, it would be rather helpful if decision-makers provided more relevant criteria for sandstorm contamination and dust shielding, since the number of these events is higher than watercourse contamination. Furthermore, some prevailing SAMs do not quite consider sustainable features such as the quality of services and economical aspects. Therefore, it could be argued that the SAMs are developed to raise sustainable building principles through solving critical issues that are related to the local context.

As a result of this review, it has been recommended for this study, that the best possible solution is to investigate accredited experts from Libyan academia, industry and government with regard to applicable categories and criteria that have the potential to reflect a suitable built environment for local conditions, taking into consideration critical principles of cultural and social aspects, economic factors and environmental characteristics.

2.6.2 Overview of Relevant SAMs' Initiatives

An extensive range of studies that focus on sustainability assessment in the built environment, conducted in different contexts and regions, have been reviewed. This review of relevant literature can be demonstrated through three distinguishing orientations. First, studies on new emergent assessment frameworks which document and promote new approaches or tools (Higham & Stephenson, 2014; Mateus & Braganc, 2011), with major contributions to this category tending to focus on the physical and technical features of the built environment. Secondly, comparisons of existing tools which focus on well-known methods (Mardani *et al*., 2016; Alyami *et al.,* 2013; Sev, 2011; Ali & Al Nsairat, 2009; Reed *et al.,* 2009; Haapio & Viitaniemi, 2008). Finally, critiques of existing tools that attempt to focus on their formal features relative to an ideal of genuine Sustainability (Higham *et al*., 2016; Burdov & Vilekov, 2015; Rees, 2009; Chew & Das, 2008; Ding, 2008; Lee & Burnett, 2008; Cole, 2005: 1998; Lee *et al*., 2002).

From another perspective, a number of studies have been conducted in various local regions worldwide, aiming to develop assessment models by incorporating Sustainability features in building projects. For example, Ali and Al Nsairat (2009) developed a green building assessment model (SABA Green Building Rating System) for the Jordanian context. With the SABA model assessing water efficiency as top amongst the seven features identified, with 27.7%. Whilst the rest scored as follows: energy efficiency (23.0%); indoor environmental quality (11.8%); site selection (10.3%); materials and resources (10.3%); economics (10.0%); and waste and pollution (6.4%). In addition, a study by Mateus and Bragança (2011) involved a model for Sustainable Development for residential buildings (SBToolPT) in urban areas, especially suitable for Portuguese standards, society and climate. The SBToolPT model encompasses nine sustainability domains, namely; energy efficiency; water efficiency; land use and biodiversity; materials and waste management; occupant's health and comfort; accessibilities; climate change and outdoor air quality; education and awareness of Sustainability; and life-cycle costs. While, a Comprehensive Assessment System for Sustainable Housing (CASSH) was conceived to evaluate sustainable housing in regard to Malaysian tradition and was conducted by Bakar and Cheen (2011). The CASSH system consisted of three major levels; the outcome, design measurement indicators, and sustainability criteria level. It sought to reflect sustainable housing either under construction, new development or refurbishment. From economic perspective, Mulliner *et al*. (2013) used the COPRAS method in Liverpool to evaluate sustainable housing affordability in the UK context. This study compared three different residential areas in accordance with a set of 20 weighted criteria. The results showed that compared with the use of only one economic-based approach, its recognition to environmental and social criteria significantly affected the calculation of affordability for a specific area. Similarly, Sourani’s (2008) study aimed to develop a framework to aid UK public clients in incorporating sustainability interventions in construction projects' procurement strategies. This included a set of 17 social sustainability criteria, 12 economic sustainability criteria, and 13 environmental sustainability criteria. A further study in Sri Lanka conducted by Chandratilake and Dias (2013) established a rating system that encompassed weighting criteria using six domains (site, energy efficiency, water efficiency, materials, indoor environmental quality, waste and pollution) in the national context. Alyami *et al*. (2013) in turn, presented a Saudi Environmental Assessment Model. The SEAM scheme comprised of a list of 92 indicators for assessing sustainable residential buildings, divided into ten major categories (site quality; energy efficiency; indoor environmental quality; water efficiency; pollution; waste management material; quality of services; economic features; cultural features; and management and Innovation).

Accordingly, based on a comprehensive study on the UK social housing, Higham and Stephenson (2014) suggested a set of 49 project success criteria, grouped into six principle areas (Built Environment, Local Environment, Market Dynamics, Local Economy, Society, and Governance). In contrast to the Chinese built environment, where Yu *et al*. (2015) presented an assessment tool for green store buildings, that included seven major categories (landscape, water efficiency, energy efficiency, indoor environment, material and resources, operation management and construction management). Burdova and Vilcekova (2015) in turn, presented a Building Environmental Assessment System (BEAS) which was developed in the Slovak Republic, it encompassed a large range of environmental, economic and social indicators that represented the Slovak standards and rules. While, more recently, Mardani *et al*. (2016) presented a hierarchical framework for assessing and ranking the significant factors of energy-saving technologies and solutions in the ten biggest Iranian hotels. Finally, a study by Abdul-Rahman *et al.* (2016) presented a ranking sustainability model of Fuzzy Weighted Hierarchy for Triquetrous Sustainability (FWH-TS), which integrated various environmental, economic and social indicators and criteria for housing. Ultimately, a review of the aforementioned initiatives has revealed that although many authors have developed a wide range of national sustainability assessment systems, there is no agreement on the nature and extent of the indicators to be measured. As Higham *et al.* (2016, p.156) state:

> *"There exist significant conflicts between the models proposed regarding their detail, the measurement and evaluation approach, and the nature of their overarching features, so a suitable structured framework to assist project teams involved in the delivery of sustainable building projects is lacking".*

It is also clearly notable that relatively little has been written on sustainability assessment methods for the built environment in the context of developing countries (Ali & Al Nsairat, 2009; Chang *et al.,* 2007) and even fewer have examined the characteristics distinguished for the Libyan built environment (Elgadi *et al.,* 2016; Shawesh, 2016; Shibani & Gherbal, 2016). This study, therefore, is built on the claim that it is essential to develop an applicable sustainability-based assessment model to effectively deliver sustainable homes in the Libyan building sector.

2.7 Chapter Summary

Through the development of people's living standards and the industrial revolution, population growth has increased, and natural resource depletion has reached detrimental levels, which have led to negative effects on the natural environment such as global warming and climate change. Consequently, this situation requires new visions and meaningful approaches that collectively consider multi-dimensional development. Yet, Sustainability is widely varied in terms of its definition, there is consensus that it should engage with three key dimensions, namely: environmental, social and economic. Sustainability in the construction field, and particularly homes, reflects better performance when it ensures the incorporation of issues such as resource efficiency, waste reduction, pollution prevention, indoor environment quality, and cost efficiency. The adoption of multi-criteria assessment techniques accommodates a wide range of Sustainability-based aspects is one of the most effective ways to successfully deliver Sustainability interventions into housing projects. However, there is a crucial need to consider the region-related critical principles of cultural and social aspects, economic factors and environmental characteristics. The identified gap of "developing an applicable Sustainability assessment model for housing projects" will be subjected to further discussion in chapter 4 with the aim of careful synthesis of a theoretical framework through the integration of a range of well-established models, but after addressing the housing industry in Libya which is presented in the chapter 3 that follows.

3 The Housing Industry in Libya

3.1 Chapter Overview

This chapter seeks to describe the context of Libya through an extensive literature review. A brief background is initially provided about the current state of Libya, including topographic and geographical features, the construction and housing industry and socio-cultural aspects, along with the relevant challenges and constraints. The main housing types and housing provisions in Libya are described in some detail, followed by an exploration of the public housing provided and the demand for it. The discussion will highlight the key issues concerning sustainable development and their influences on the Libyan housing sector which leads finally to examining a range of challenges facing sustainable homes and Sustainability initiatives in the Libyan context. Towards the end of this chapter, an effort is made to (i) justify the need for sustainable homes practices within the Libyan housing sector; (ii) highlight potential barriers that may impede the realisation of sustainable houses in Libya; (iii) review relevant Sustainability-driven initiatives in the country.

3.2 Introducing Libya

This section attempts to introduce Libya as the central focus where the research has taken place. In light of this, the main purpose of the sub-sections is to explore the key features of the context of the study including geographical characteristics, construction and housing industry and socio-cultural aspects.

3.2.1 Topography and Geography

Libya is located in the centre of the hot, dry region in the north of Africa, and it has the longest of coasts amongst the African countries on the Mediterranean Sea, stretching for 1770 kilometres (1100 miles). Libya lies between (20° to 34º N) and (10° to 25º E), covering a geographical area estimated at (1,750,000 km^2) which is considered the 17th largest country in the world (by size). As shown in Figure 3.1 below, Libya is bordered in by Tunisia and Algeria in the West, Niger in the southwest, Chad and Sudan in the south, and Egypt in the East. According to Azlitni (2005), Libya can be distinguished with three main topographical zones, namely (i) the coastal lands in the North along the

Mediterranean Sea, which accommodate the majority of the population and social and economic activities; (ii) two ranges of mountains, the Western Mountain in the Northwest and the Green Mountain in the Northeast; and, (iii) the desert or Sahara lands. Up to 90 per cent of Libya's total area is classified as arid and semi-arid lands. The main characteristics of arid lands according to United Nations Convention to Combat Desertification (UNCCD), are high and extreme temperatures, low and variable rainfall, desertification, drought and scarcity of water, and sand or dust-storms (UNCCD, n.d.).

Figure 3.1: Libya's location. (Source: Dabaiba. 2018)

Libya's climate is both Mediterranean and semi-arid, so the climate in the northern coastal and mountainous regions is characterised by a warm summer and relatively mild and short rainy winter, while the southern region and the interior desert are influenced by the Sahara's climate, which has a long, hot and dry summer with very extreme temperatures, and a dry winter with warm days and very cold nights. There is light to negligible rainfall throughout all of Libya and roughly 2% of the country receives the adequate rainfall required for agriculture. As a result, Libya takes more than 95% of its water supply from underground resources (Abdudayem & Scott, 2014). With an annual growing rate of approximately 3.5%, the total population of Libya is 6,733,620 people, according to most recent estimates of 2012, which means that the state of Libya is one of the least densely populated countries in the world; it is estimated as low as 3 inhabitants/km^2 (indexmundi, 2018).

Against this background, it is clear that the expanded area alignment with the small population size and the scarcity of water is one of the most serious challenges for the Libyan government to deal with. This inevitably forces the public utilities system and infrastructure networks to be extended to thousands of kilometres around the country which demands a large amount of energy for construction and operation (Elshukri, 2000). Therefore, topography, climatic conditions, and shortage in water supply have the potential to affect the development of communities and cities in Libya. It can be argued that in arid and semi-arid countries and in Libya in particular, the built environment cannot be efficiently assessed without gaining a full understanding of geographical and climatic circumstances in which the construction projects are established.

3.2.2 Construction and Housing Industry

Libya is a country dealing with the same challenges that many other developing countries are facing, namely the conflict of interest between economic growth and environmental preservation. Libya's economy is primarily based around the nation's energy sector, which generates 95% of export revenue, 80% of GDP. The International Monetary Fund (IMF) estimated that Libya's real GDP growth in 2018 was 16.7% (IMF, 2018). The World Bank defines Libya as an 'Upper Middle-Income Economy', alongside only seven other African countries. As a result of Libya's GDP growth, Libya has been able to provide an extensive level of social security, particularly in the fields of housing (MHU, 2015). Between (2012 and 2016), the construction industry grew at an average annual rate of 5.17% (IMF, 2018), and the contribution of the construction industry to the Libyan Gross Domestic Product (GDP) is approximately 5.2%, employing about 3.2% of the total labour force (IMF, 2018). Recently, the construction sector has witnessed an extraordinary movement due to the vast range of infrastructure projects that were completed across different industries, such as the power sector, water infrastructure and housing, along with an ambitious programme for built environment development (Shawesh, 2016).

Despite the enormous investment in the construction industry within the past five decades, the construction industry in Libya is still underdeveloped and undergoing major research. In the early 1950s, when funds were limited, and the country was emerging from the Italian occupation, construction was of limited scale and value

(Elgadi *et al.,* 2016). In these early years, construction in general and the building industry in particular, was considered a social activity. In addition, building skills were transferred from one generation to another, and building products reflected the values and cultures of the people. During the oil boom that followed in the 1970s, the building industry played a key role in social and economic development processes (Gherbal, 2015). Traditional constructions were replaced by concrete-based modern architectural styles (Elgadi *et al.,* 2016). As a result, the country experienced a tremendous increase in the scale and volume of construction activities, and this trend continued until the early 1980s when the construction industry suffered several setbacks, including the elimination of local private construction companies and their incorporation into the public sector (Gherbal, 2015). The construction industry came to a halt in the mid-1980s due to the huge drop in oil revenues and during the last decade, the political problems facing Libya have noticeably contributed to the economic difficulties that are affecting the construction industry.

Housing is an important intervention in the social and economic development plans in Libya. For instance, more than 70% of the built environment in Libya has been classed as residential buildings (Gherbal, 2015). The high rate of population growth in Libya, as mentioned earlier, has led to several housing problems such as slums and poor conditions in the housing provision. This has resulted in a strong government intervention in the housing sector. In the past two decades, the issues of public housing need and housing shortages have received close attention from policy makers, planners and researchers in Libya. Several government departments and organizations have conducted studies in order to estimate future needs for housing units and to determine the scale of housing shortages (e.g. MHU, 2015; G.C.P, 2012). Many previous studies have concluded that the housing shortage has increased sharply since 2010, and that the state should take urgent action to alleviate the social, cultural and economic impacts of this problem. For example, the Ministry of Housing's report confirmed that there is a serious housing crisis. The report estimated that the housing shortage was around 200,000 dwelling units, whilst the national housing need would be 1,164,134 dwelling units between 2014 and 2033 in order to absorb the housing backlog and to meet the demands of population growth. This, according to MHU's (2013) annual report, will be met by implementing 50,000 units per year. In addition, more than 81 per cent of the demand for housing would be in urban areas, with the rest in rural and agricultural areas (MHU, 2015). In light of this potential demand for new housing units, the housing sector will need to increase significantly in the coming years. This indicates that intensive demand and the significant development in the housing industry will necessitate consuming a large amount of energy, raw material and water supply, which will lead to aggravating the environmental effects (Gherbal, 2015). The housing sector in Libya, therefore, places high levels of pressure on the reserves of natural resources, as the building operations have negative impacts on the environment through their excessive consumption of sources and energy.

3.2.3 Socio-Cultural Aspects

Socio-cultural and religious values in Libya play a very important role in controlling and directing the behaviour and preferences of people towards housing properties. The traditional social structure of Libya consists of a system of units of allegiance. A strong tribe or clan membership and family ties still persists today. The homogeneous Islamic community is still structured around, first, the nuclear family, then the extended family, the sub-clan, the clan, the sub-tribe and then, at the top of the hierarchy, the tribe itself and the composite of several tribes (Daze, 1982). The extended family consists of the husband, his wife, and their married sons including their families. In the extended family, which represents a unit of production and consumption, labour was divided between the men, who had the responsibility for the outside commercial activity including farming, and the women, who had the sole responsibility for home management, the raising of children and some types of household production of some artefacts or tapestries. The composite family consists of all the family members living together under the same roof. This means the parents, their unmarried sons, and daughters as well as their married sons with their wives and children, and the grandparents, who traditionally spend the latter part of their lives in one of their son's homes. In typical households each marital couple occupies a separate room, unconnected with the rest of the house but opening onto a central courtyard. These circumstances have governed the shape of Libyan houses which should be considered through the design process of housing constructions. A number of authors (e.g. Amer, 2007; Shawesh, 2000) have referred to a range of issues related to Libyan socio-culture, highlighting that: (a) privacy in Libyan society is a priority consideration within housing spaces; (b) the separation of age and sex and guests have long determined the roles played within the family; (c) the extended family and elderly people have special and high status in the society; (d) the way of life of the Libyan people has many aspects that should be considered in external and internal spaces; (e) the way of preparing meals in the kitchen, the need to have storage places and the way of serving food to guests and family members requires more internal spaces; and (f) safety and security are priorities in Libyan life.

In traditional Libyan towns, the unique characteristics of society are underlined in the use of decorative additions to the space, such as stone benches for men to sit outside, special shaded coverings and use of vegetation. The positioning of key public housing, Mosques and markets is also an important way of signalling cultural identity, in establishing the relationship between people, buildings and space. Privacy is an interpersonal boundary-control process, which is given greater attention in the Libyan houses. Houses in Libya provide physical fences to prevent anyone accidentally overstepping the limits into private spaces. When these barriers are not provided, people are likely to feel uncomfortable and activity levels diminish. Another very inferential aspect of life is the role of women and men in Libyan society. According to Chowdhury (1992), the Islamic religion and position of women in Islamic society plays a significant role in shaping housing and the built environment. In an Islamic society, women are not permitted to mix freely with men, but they must be allowed to carry out their daily activities in comfort and without feeling exposed. These are the things that distinguish one society from another, and every effort should be made to ensure these aspects are respected. Each yearly cycle is broken up with various important social and religious events, which also, as stressed by El-Fortea (1989), should continue to be celebrated so that society does not lose its identity. Therefore, it is important to consider these significant features and their influences on the social, cultural, and economic environment when conducting any research in this region, such as investigating assessment tools for Libyan residential buildings.

3.3 The Main Types of Housing in Libya

The housing in which people live is indicative of the level of a country's development. In Libya, the rapid economic and social changes following the oil development resulted in a growing desire from its inhabitants for better accommodation. According to Gherbal

(2015), three major types of dwelling units can be distinguished: traditional houses, apartment complexes, and villas.

1) Traditional houses are defined as a conventional dwelling type, built in rows with a plot of land of 150-200 M^2 with 2 to 3 rooms (Figure 3.2). These houses are the dominant type of construction in Libya and represent about 70% of the housing provision (Gherbal, 2015). Most of these have been constructed by the public sector.

Figure 3.2: An Example of Traditional Houses

2) Apartment complexes, which are found in many districts of Libyan cities, aim to shelter many families within a limited, high-volume space. They are typically between two and five storeys (Figure 3.3). The ground floors can be used for commercial purposes by converting them into shops which could be rented as retail for different functions including groceries, bakeries, barber shops or laundries. They represent a type of residence for the middle class of Libyan society, who cannot afford to build their own independent house. This type of dwelling unit is the dominant pattern in the central business districts and the area surrounding it.

Figure 3.3: An Apartment Complex in Libya

3) Villas are defined as a luxury form of housing. Most of this type of dwelling has been constructed by the private sector. All these types of dwelling have separate gardens and surrounding walls (Figure 3.4). The villa is characterised by a courtyard and fence which protect the boundaries of the villa. The Libyan villa, which does not usually exceed two storeys, houses one family. The total area of the plots for these dwellings is usually between 500-700 M2.

Figure 3.4: A Typical Villa in Libya

3.4 Housing Provision and Government Programmes

Housing in general falls into two major categories: conventional and nonconventional. Almost all housing provision in Libya is conventional and provided by public and private firms (Gherbal, 2015). These major providers are subdivided, as Omar (2003) demonstrated, into further categories, as shown in Figure 3.5 below. Housing developed by the private sector in Libya can be classified into two categories. These are individuals who build dwelling units for themselves and co-operatives which build dwellings for their members. Housing provision through the public sector can be classified into three categories. These are low-income housing, dwellings for investment and dwellings for employees.

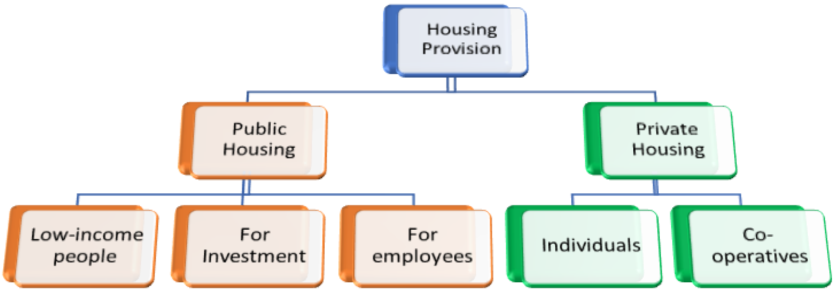


Figure 3.5: Housing Provision in Libya. (Source: Omar, 2003, p.118)

3.4.1 Public Sector

The housing investments in this sector primarily are organised by the national public housing programmes. The governmental scheme, as MHU (2015) indicates, aims at the development of urban regeneration, slum clearance and supplying the housing demand due to the population growth. The housing policies as well as the number of units and their descriptions are in general determined by the Ministry of Housing and Utilities. The public housing investment and its relations, such as selection of locations, financing issues, and construction processes, are in charge of the government through its agencies and organisations on the bases of the desired targets and specific priorities (MHU, 2015). The public housing scheme is mainly regulated by two major governmental parts; the Ministry of Housing and Utilities, and the Housing Associations. Under the public housing sector, investments are usually implemented for standard housing designs at predetermined locations. These schemes were fundamentally established to meet housing demands for low-income groups (MHU, 2015). In addition to housing for individuals, the Ministry of Housing and Utilities, which is in charge of providing adequate dwellings for beneficiaries, has built dwellings for the public services sectors (e.g. health and education). Various types of houses have been implemented by the housing association in an attempt to satisfy people's needs but there is a lack of data in relation to this, making it hard to demonstrate sufficient, up-to date details about the actual number of dwellings implemented by the housing associations in Libya. Despite this, three main types of housing schemes that are implemented within public housing development can be distinguished, including:

- ***High-Rise***

High rise housing schemes are commonly seen in larger cities such as Tripoli, Bengasi and Misurata where population density is relatively higher. This form of housing development is considered as the best solution for meeting the increasing housing demand, while at same time, conserving the limited land in such areas. However, the disadvantage of this form of housing scheme is clearly seen through a range of social and physical problems. The occupants of this form of housing in both developed or developing countries, as revealed by Omar (2003), criticise the high-rise housing owing to their experiences of higher rates of vandalism, crime and mental health disorders.

- ***Medium density***

Medium density housing development is a more common type of housing investment than high density units in Libya. This form of project can be seen outside as well as in the inner areas of some cities which have a relatively lower population density such as Sirte, Sabha and Zawiya. Medium density housing schemes are provided with two to four stories, each unit comprising two or three bedrooms. As observed by Omar (2003), this larger group of housing developments lacks maintenance management. As such, the deterioration of most of these units is clearly evident, which then leads to reducing the expectancy of their lifespans.

- ***Low Density***

Low density housing developments are typical public dwellings in all cities in Libya. This form of housing investment is the style that is prevalent amongst the Libyan people and provided in most cases by the Ministry of Housing and Utilities through the Housing Associations and government organisations. This type of housing is often built with single or two stories in the form of attached, semi-detached and detached. Each unit contains three or four bedrooms and each project comprises 200 to 300 units to (Gherbal, 2015). As it is so widespread, the central focus of this study will be particularly on this type of dwelling.

3.4.2 Private Sector

The majority of housing provision has been implemented by the Libyan private sectors. The private sector in Libya has built up nearly 60% of the total housing units in the country (ODAC, 2012), with financial support provided through banking loans to individuals and housing co-operatives. Private housing providers in general are building up dwellings with one to three story houses. The modern style of Libyan private houses is the villa and this type of dwelling is detached with gardens on three or four sides. The private sector, as Shawesh (2016) states, is deemed the most active in the provision of the housing construction, yet it has not been able to meet the extensive demand of housing services.

The public housing style which will be given most consideration throughout this study is mainly made up of conventional private and conventional public housing providers, which are to some extent implemented based on the government planning standards (Omar, 2003). The government policies emphasise the role of housing associations and private individual housing with the aim of achieving an effective contribution of the private sector in an attempt to meet the national demand of housing (GCP, 2012). The MHU’s (2015) programme involves the basic principles that underlie housing development in Libya, including:

- Local authorities in charge of providing adequate dwellings to low-income families;
- Sufficient housing loans made available for eligible individuals through banking systems;
- Maintenance processes recognised regularly through specialised companies with a defined system;
- Industrial investment areas provided with special dwellings with all educational and health facilities;
- Housing acts, regulations and measures relevant to ownership and bank guarantees revised in light of the government housing policy; and,
- Land for housing constructions provided through coordination with local authorities.

Despite the government’s effort to meet the housing demand, GCP (2012) indicated that the housing sector in Libya is still suffering from a shortage in the supply of dwellings.

Although the recent housing policy aims to provide dwellings for beneficiaries, there is not clear evidence that those people have been involved in the housing construction process. The stated housing authorities are organising, controlling and directing the housing investments with their own decisions, whilst household needs are being ignored (Omar, 2003). The absence of clear policy to regulate and facilitate land provision for housing investment, as GCP (2012) asserted, leads to inadequate availability of plots for establishing new projects as well as an increase in land prices, meaning that many people build their own houses outside the urban master plan (Omar, 2003). According to GCP (2012), the major problem in the housing crisis is that the quality of most public housing is far from satisfactory, and poorly maintained. This is particularly true of the high-rise projects, which might seem to be of a high standard, but do not reflect national socio-cultural traditions, in addition to the management of their maintenance being hard to organise amongst the actual residents.

3.5 Major Issues Concerning Sustainable Development in Libya

Although it is not easy to comprehensively cover all issues of concern, an attempt is made here to highlight those which are believed to be the major obstacles. To facilitate the discussion of this major section, a range of prominent aspects has been demonstrated as follows:

3.5.1 Energy Supply

The Libyan government has given this source a high priority during the last three decades. As a result of this, electricity power is now available in most of the country (Abdul-Rahman *et al.,* 2016). The electricity power is supplied to the consumer through a continuously extending system of electric power networks with voltage of 220kV, 30kV and 11kV. However, according to IEA (2018), the relevant indicators are concerning for in 2016, which is the most recent year for which comparable data are available, Libya was ranked 99th globally in relation to electricity consumption, using 28.48 bn kWh which means 4,680 kWh per capita (Figure 3.6). The average Libyan consumption of electricity is roughly two times more than the average Indian person, though still about quarter of the average in the UK.

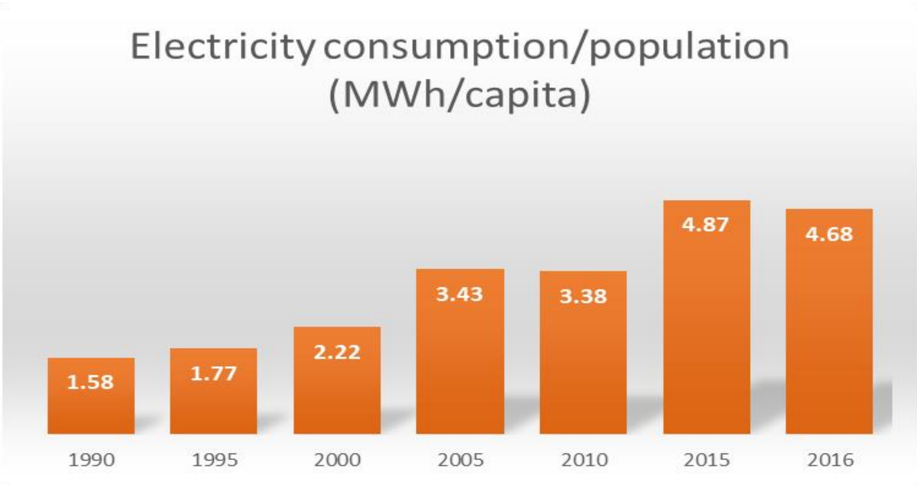


Figure 3.6: Libyan Electricity Consumption/Population. (Source: IEA, 2018)

Likewise, in relation to gas consumption, in the same year Libya was ranked 60th globally in relation to natural gas consumption, consuming 3.76 bn m^3 (Figure 3.7), which means 704.36 m^3 per capita (IEA, 2018). The average Libyan consumption of natural gas is again roughly two times more than the average Indian person, but still about 70% of the average in the UK.

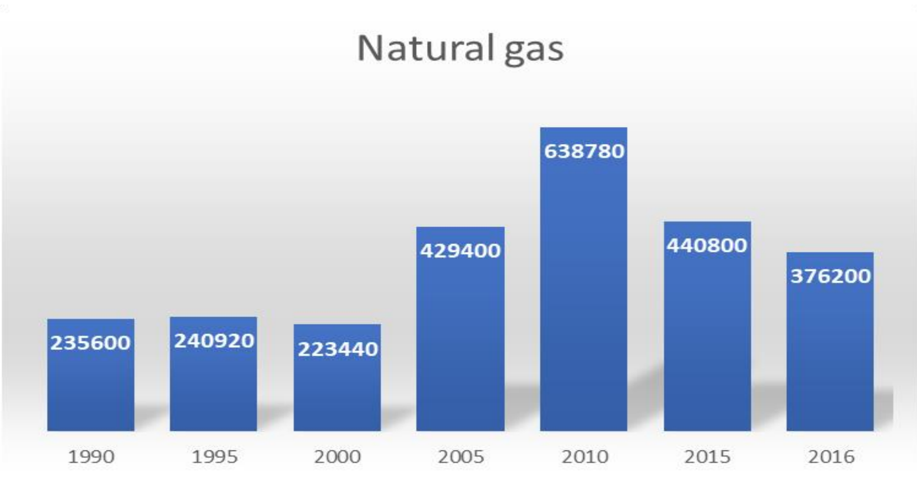


Figure 3.7: Libyan Natural Gas Consumption. (Source: IEA, 2018)

The need to adopt efficient energy systems has been reflected in many publications (e.g. Abdul-Rahman *et al*., 2016; Almansuri *et al*., 2009), which have emphasised adopting energy efficiency as one of the most important aspects for enhancing sustainable development in Libya. In this context, according to Almansuri *et al*. (2009), air conditioning consumes about 80% of the energy used in Libyan homes. The HVAC system is likely to be critical for embedding Sustainability and this indicates that the housing sector plays a fundamental role in addressing the issue of Sustainability.

3.5.2 Water Resources

Water consumption is likely to become an increasing national problem as water demand exceeds the volume licensed for abstraction, with the shortfall being met from ground water (MWR & CEDARE, 2014). As reported, the state of Libya is relying largely on groundwater to satisfy its water demand whilst it is struggling with situations of severe drought which has put a great strain on its water supply, especially in relation to the quality of water required to meet the bespoke standards. With very limited perennial water resources of only ephemeral rivers or wadis, the Libyan government has undertaken a massive project known as the Great Man-Made River Project (GMMR). GMMR provides approximately 6.5 million m^3 of freshwater per day to supply water for the Northern cities of Libya which make up around 70% of Libya's population (Abdudayem & Scott, 2014). Groundwater (including fossil groundwater) provides over 95% of the water withdrawn. The remaining is divided between surface water, desalinated water and wastewater, as stated by Abdudayem and Scott (2014) (Figure 3.8).

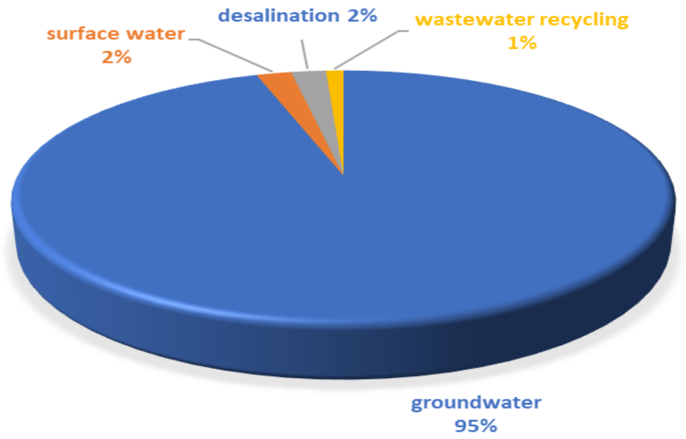


Figure 3.8: Libyan Water Resources Distribution. (Adapted from Abdudayem and Scott, 2014)

The figures indicate that approximately 5830 million m^3 of fresh water in 2012, which is the most recent year for which data are available, was withdrawn from reservoirs and underground aquifers, from which 20% of Libya's water is used domestically for recreation and occupant amenities (e.g. swimming pools), and irrigation, with over 50 per cent of this used for flushing WC's and washing (Abdudayem & Scott, 2014). The national targets indicate that a sustainable groundwater abstraction should not exceed 3650 million m^3/year, despite only 650 million m^3/year coming from renewable groundwater and 3000 million m^3/year actually coming from fossil water (CEDARE, 2014). Due to the fact that fossil groundwater is not included in the renewable water resources, the current water withdrawal is more than 8 times the annual renewable water resources, whilst more than half of the domestic water supplies were from the GMMR (MWR & CEDARE, 2014). Accordingly, people in Libya are not charged for water use, as water supplies are taken for granted. As Abdudayem and Scott (2014) have asserted, this has led to thoughtless behaviours towards the consumption of water and not valuing this limited resource which results in even further waste and less efficient distribution. As a result, the development of practical ways to reduce water demand has become a top priority.

3.5.3 Emissions and Waste Recycling

As Shawesh (2016) has observed, the Libyan energy industry is considered the largest single contributor to Libyan greenhouse gas emissions. The use of fossil fuel, which is a non-renewable resource, produces the bulk of Libyan energy, generating more than one third of Libyan carbon emissions (Shawesh, 2016). The national figures also show that a significant amount of carbon emissions is produced as a result of the energy consumed during the operation of facilities in Libya. In 2016, the most recent year for which data are available, Libya was ranked 58th globally in relation to CO_2 emissions, realising 43 Mt (IEA, 2018), which means 2.31 emissions per unit of GDP (Figure 3.9). The average Libyan consumes two times more energy than the average global citizen, 4 times more than the average Brazilian person, but still half of the average in the US.

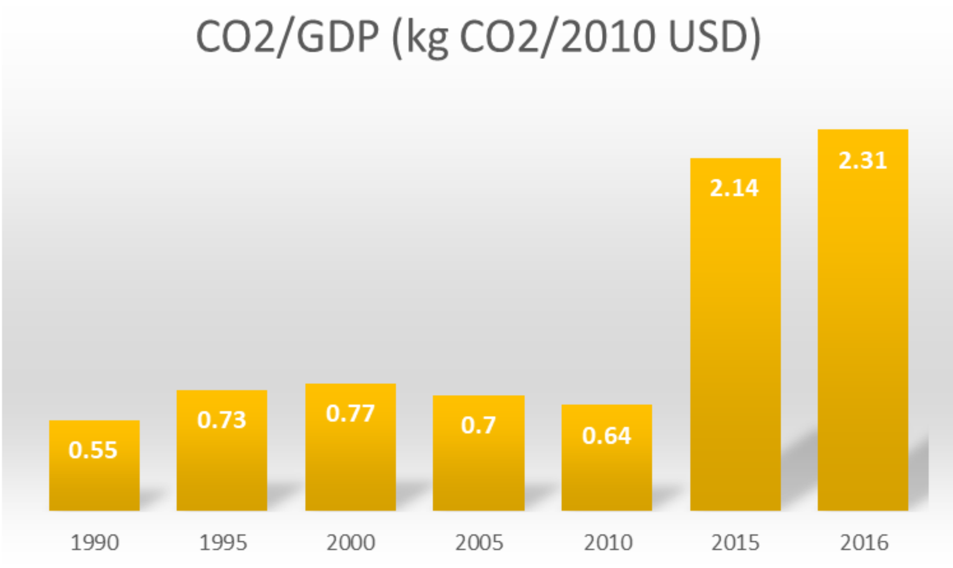


Figure 3.9: Libyan CO_2 Emission/GDP. (Source: IEA, 2018)

In this regard, the development undertaken by the Libyan construction industry in general extracts about 90% of non-energy minerals for use as aggregates and raw material for construction products (Ahmed *et al*., 2015). This development accounts for approximately 10% of the Libyan carbon emissions as a result of extraction and transportation of these materials (Ahmed *et al*., 2015). Renewable energy sources should be promoted not only for reasons related to minimising reliance on the finite and diminishing sources of fossil fuel (e.g. coal, oil, gas, etc.), but also for reasons related to reducing pollution and tackling climate change.

The waste issue, particularly from dwellings, is another concerning problem. In Libya, the Ecological Protection Agency (EPA) state that the landfill situation is now critical, with local authorities having to resort to transporting waste further and further afield or else burning it and releasing pollution into the air (Jain, 2013). They further stressed the consequences of high levels of waste, both in reducing the future availability of resources as well as creating unnecessary demands on the transportation system. According to Elgadi *et al*. (2016), approximately 28 Million tons of municipal waste were generated in Libya in 2016, and a total of 15 Million tons of this was collected from households, which is more than half a tonne of household waste per person. Waste from Libyan homes is generally collected by Local Authorities through regular waste collections or recycling schemes. As Ahmed *et al*. (2015) demonstrated, housing waste is difficult to recycle due to high levels of contamination and a large degree of heterogeneity, and often there is insufficient space for its disposal in large cities. Accordingly, Libyan local authorities, as Ahmed *et al*. (2015) reported, have a lack of waste recycling management, and adequate storage should be provided for waste in order to facilitate appropriate waste management. The size, type and number of containers should also be set out by the waste collection authority to ensure best practices in this respect.

3.5.4 Road Networks and Traffic

Although during the past four decades the Libyan government has provided a great deal of investment to tackle the issue of road networks, this sector is still considered a serious challenge due to the high levels of vehicle accidents. Road traffic accidents are increasingly being recognized as a growing problem facing nearly all the world's countries, developed as well as developing. Horribly, according to The World Health Organization (W.H.O) statistics, almost 1.25 million people are killed in road traffic accidents each year worldwide (90% of deaths occur in developing countries) and an additional 50 million people are estimated to be injured (half of them are seriously injured or disabled) (W.H.O, 2018). The increase in the number of vehicles on the roads is a phenomenon that has been observed in parallel with economic growth, particularly in recent years. The number of private cars in Libya, according to Yahia and Ismail (2013), has increased four times in a decade, rising from 675,000 in 2000 to 2,200,000 in 2010. Road traffic accidents in Libya are responsible for the deaths of 6.5 people daily (Yahia & Ismail, 2013). In its Global Road Safety report 2015, W.H.O named Libya as the nation with the highest rate of road traffic deaths with approximately 73 deaths per 100,000 people every year mainly as a result of high driving speed and poor road conditions as stated by Mohammed *et al*. (2017). Figure 3.10 shows The Countries with the Most Road Traffic Deaths.

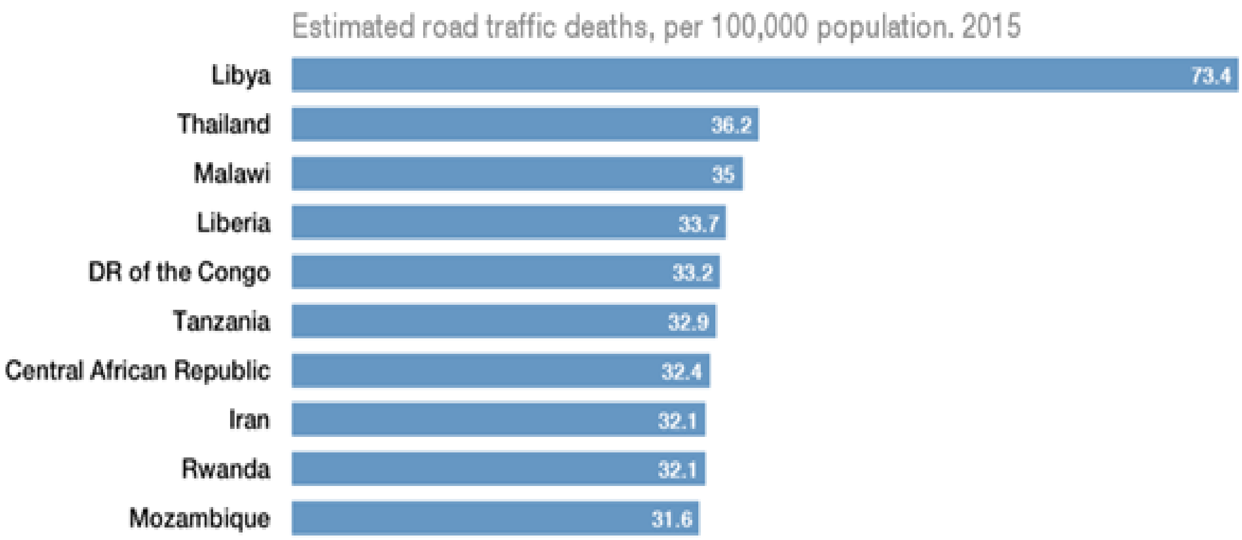


Figure 3.10: The Countries with the Most Road Traffic Deaths. (Source: W.H.O, 2018)

According to General Traffic Police Administration's (2010) statistics, the death rate in the young age group of 20 to 34 was 34% of the total deaths, while fast driving was the first major leading cause of fatal accidents in Libya accounting for 65% of the total fatal accidents (Mohammed *et al*., 2017). The road traffic accidents in Libya have reached epidemic proportions and it is now the third leading cause of deaths in the country (W.H.O, 2018). It is a sad reality that road traffic accidents in Libya are the greatest single cause of death for young people and women and children are also being killed in these terrible road accidents. In addition to fatalities, the level of vehicle ownership has led to increased levels of congestion and pollution, particularly in more densely populated areas. As stressed by Yahia and Ismail (2013), traffic accidents in Libya are an economic and social problem, a burden and loss for the country, and they result in Libya being one of the worst affected countries in the world for road traffic accidents and a death rate of 6.5 people daily. This constitutes a serious challenge for the Libyan government and one that they should pay great attention to.

3.6 Sustainable Homes in Libya

Using the available literature, this section highlights the need for considering Sustainability in the residential buildings sector in Libya through investigating the government commitments towards public housing, followed by exploring the potential challenges that may be encountered along with possible drivers and initiatives that have already been established to achieve Sustainability in the Libyan housing sector.

3.6.1 Public Housing Commitments and Policies

The Libyan government has acknowledged the concept of sustainable development which was integrated within its policies, vision and mission plans such as act No.23/2003 'RE-Structure of the Agency of Urban Planning' (Libya-GOV, 2003). Libya is active in international Sustainability activities which are reflected through events such as organising the international conference on Sustainable Architecture and Urban Development in 2009, and through organising the 2017 workshop on the Draft Strategic Framework for Libya for 2019-2020, which brought together the United Nations Development system and the Ministry of Planning. The Draft Strategic Framework outlines the intended shared objectives of the United Nations and the Government of Libya to support the Libyan people and build a path towards sustainable peace and development (UNSMIL, 2017). Libya, however, needs to incorporate the international principles of Sustainability such as "Vision2030" - being one of the important documents - into the housing planning process.

The Libya government promotes its commitment through adopting a comprehensive planning period of time each twenty years. The planning process is supported by an analytical study covering all planning levels (regional, sub regional and urban) with the aim of achieving urban plans that look forward to satisfying the various needs of the population, whilst not compromising the environmental, social and economic equity among them. In relation to this, the current government planning program (Third Generation Plans 2000-2025), as Azlitni (2005) states, seeks to achieve the following objectives:

a) Determining the development targets annually through analysing the socio-economic conditions;
b) Identifying the development requirements of the built environment in accordance with the outputs of the analysis process conducted upon the national socio-economic conditions;
c) Determining the demand of manpower and setting out an effective method for its employment, along with a comprehensive education plan to meet this demand;
d) Allocating plots of land for housing projects and public services investments on the basis of sophisticated planning approaches;
e) Determining the requirements for the urban development in accordance with the population growth;
f) Implementing integrated utilities networks with the most sophisticated techniques;
g) Protecting the natural environment and addressing the problem of the informal urban sprawl on the arable land; and,
h) Addressing the population concentration in certain cities (e.g. Tripoli and Benghazi) through optimising the distribution of the planning development across the Libyan cities.

In response to such objectives, many national institutions have been created for promoting and optimising environment performance towards Sustainability principles, for instance, 'The Libyan National Centre for Standardization and Metrology' (LNCSM) and 'Research Centre for Building Materials and Construction' (RCBC) which devote their efforts to encouraging contractors to adopt sustainable development and producing environmentally friendly products through spreading awareness and consultation services (UPA, 2006). In this regard, the Ministry of Housing and Utilities (MHU, 2015) state the following broad guidelines and principles which reflect to some extent a sense of sustainable development: (i) adequate locations and quarters are to be allocated to the new housing investments for private and public sectors with reasonable prices; (ii) efficient physical integration of the housing projects with the basic services and utilities such as schools, hospitals, gardens; (iii) suitable design of houses taking into consideration the space and living system of the potential owners; (iv) the harmony of building designs with the surrounding environment as well as utilising the locally available building materials; and (v) rigorous policies regulating the housing construction processes to improve project performance and overcome the relevant obstacles as well as conducting studies on minimising the project costs through optimising the support decision systems.

Although Libya has recently taken several initiatives and processes in sustainable development of the country's policies and plans, environmental and social concerns continue to represent weak aspects in the quest for Sustainability in Libya. The weaknesses found in the field of sustainable development in the housing sector, which have been mentioned frequently, can apparently be related to the absence of Sustainability-based comprehensive frameworks alongside clear, robust indicators. These limitations lead to deficits in sustainable development practices, making the interpretation of sustainable development lacks a comprehensive perception and realisable process.

3.6.2 Application Challenges and Sustainability Initiatives

The need to consider Sustainability has been made evident throughout the discussion presented in the previous sections, and it is unfortunate to witness that the application of sustainable housing is still relatively absent in the Libyan context. For example, house buildings continue to depend heavily on air conditioning as Almansuri *et al.,* 2009 emphasise, and this consumes massive amounts of electricity. The design of Libyan dwellings tends to lay stress on a luxurious style of living without paying adequate attention to the principles of sustainable housing design. For instance, comparing to the rest of the world, Libyan houses are considered relatively large spaces provided with air conditioning systems which are often running continuously. Among the concerning issues that have been raised with the excessive use of air-conditioning are acoustic and health-related concerns as well as an increased demand for energy (Almansuri *et al.,* 2009). As reported, poorly designed dwellings in hot countries like Libya leads to consuming nearly 80% of the total electricity for air conditioning and refrigeration purposes. As a result of the rapid population growth, and a high level of economic growth and increased urbanisation, the residential housing sector not only is booming, but also accounts for more than half of the total country's energy demand, while the rest is divided by governmental (14%) and commercial (32%) use (Abdul-Rahman *et al.,* 2016). Figure 3.11 shows the electricity consumption by sectors in Libya.

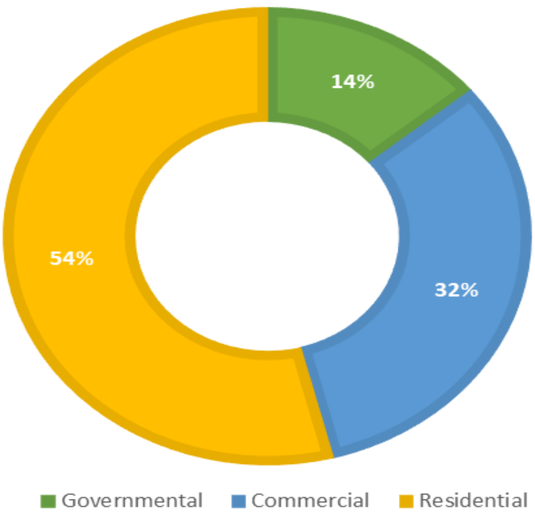


Figure 3.11: Electricity Consumption by Sectors in Libya. (Adopted from Abdul-Rahman *et al*., 2016)

In fact, due to an increasingly rapid electricity demand (≈ 7% / year), according to the Energy Information Administration's (EIA) report, Libya has become the fastest growing consumer of energy in North Africa (EIA, 2013). Another disappointing issue is that electricity generation is entirely dependent upon the unsustainable practice of burning fossil fuels, which is not only considered to be the main cause of climate change, but also has major environmental impacts on air, water and land (Abdul-Rahman *et al.*, 2016). In addition, despite the abundant availability of renewable energy sources, the use of sustainable energy technologies such as solar photovoltaic panels are still rare in Libya (Abdul-Rahman *et al*., 2016). Whilst Libya as a developing country has no obligation to cut its greenhouse emissions under the Kyoto Protocol, one would hope that such ratification could make a powerful push towards embracing Sustainability practices in the country.

With regard to the issue of water, Libya is considered to be one of the driest regions in the world and is facing serious challenges relating to rapid growth in water demand. As aforementioned, Libya has no permanent rivers or lakes and the country depends heavily on desalination plants to bring water supplies to a population scattered across a very large space. The government has been tackling the issue of increasing water demand, which is manifest in the domestic sector, by the development of a massive project, known as the Great Man-Made River Project (GMMR) (Abdudayem & Scott, 2014). As aforementioned, however, because there is a very low price for water as well as for energy, this leads to generating thoughtless practice in relation to the use of water and energy. According to Ngab (2007), Libyan homes consume approximately 28% of the total water use in Libya, the rest of which is dominated by the agricultural sector (70%), whilst the industrial activities count for only 2% (Figure 3.12).

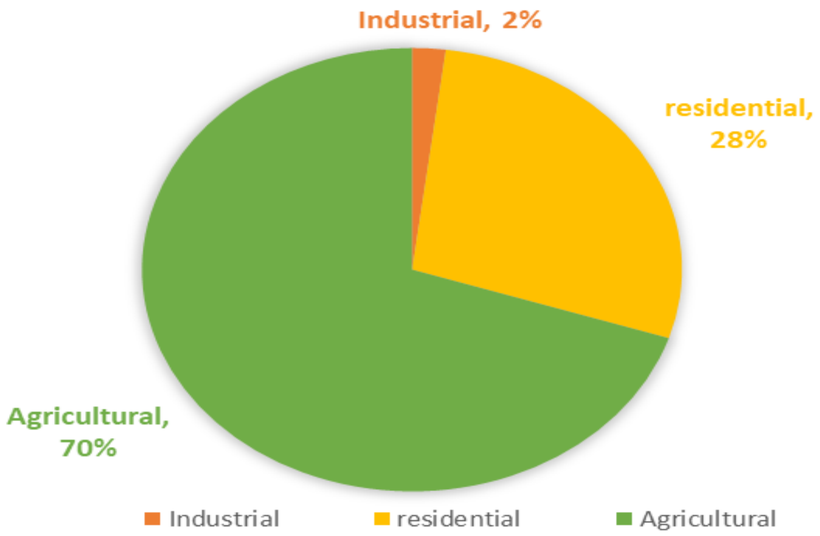


Figure 3.12: Water Consumption by Sector in Libya. (Adopted from Ngab, 2007)

Therefore, it is evident that there is a pressing need to improve the efficiency of energy and water consumption in Libyan dwellings through the application of sustainable home principles. Recent studies (e.g. Elgadi *et al.,* 2016; Mohamed, 2013; Almansuri *et al.,* 2009) indicate that heavily subsidised electricity and water prices have created a lack of awareness with regard to resource consumption and environmental concerns, in addition to a shortage of regulations and policies in terms of sustainable home practices. These factors are believed to be amongst the most significant barriers to promoting the concept of Sustainability in housing investments in Libya.

In addition to the energy and water crises, according to Almansuri *et al.* (2009), the size of contemporary Libyan house lots is another pressing issue. The new Libyan dwelling development schemes are spacious, taking larger plots of land for as the villa forms are the preference of many homeowners, their spaces exceed the average in many other countries (Elgadi *et al*., 2016). As a result of this prevailing preference along with the increasingly rapid population growth, it is becoming more expensive to obtain a sufficient plot of land for housing. Not only have government subsidies shrunk, but also the prices of building materials are continuously increasing. Almansuri *et al*. (2009) list a number of factors that can slow down further development, including: (a) delays in the development of public services and utilities as compared with the rate of population growth and housing development programmes implemented; (b) growing shortage of house supply; (c) shortage of qualified practitioners; (d) growing depletion of the natural environment; and (e) shrinking the supply of land resources. Almansuri *et al*. (2009) go further to identify a range of effective measurements related to degradation of land resources, particularly in the city of Tripoli. This includes: (i) providing a sufficient supply of land that must meet the programmes of urban development; (ii) modernising high-density housing schemes in certain residential districts; and (iii) utilising certain arable areas to alleviate urban development, while protecting the natural environment.

Furthermore, Elgadi *et al*. (2016) point out some issues related to invasion of privacy that have arisen as a result of the contemporary homes movement in Libya. For instance, it is argued that recent building regulations allowed apartment complexes to have more storeys than they used to have, without placing any restrictions on the number of windows and balconies on elevations. The privacy of low-rise buildings has, therefore, been invaded by these high-rise buildings (Mohamed, 2013). Another design-related fault identified in the literature is the extensive use of glass as a material for building facades, as people started to complain about the glare caused by the harsh sun. Although reflective glass can be used, it still cannot bear the intensity of the sun's heat. Consequently, the building gains heat through the glass which leads to a greater use of air-conditioning. The cleaning requirements for a glass facade can also be problematic (Elgadi *et al.,* 2016). Accordingly, although current Libyan homes look modem and give an impression of prosperity and wealth, it is noted that the design of modem houses in Libya is no longer based on vernacular homes, whose principles to some extent are in line with that of sustainable homes (Mohamed, 2013). Vernacular homes, however, are dependent on the use of local building materials and resources. They also adopt passive design and low-energy strategies that lead to reducing the need for both air conditioning and lighting requirements (Almansuri *et al*., 2009).

Most importantly, as frequently quoted in the literature and expected to be of grave significance in the case of Libya, the country lacks a proper building code which has long been considered as one of the major problems that Libyan homes face. Mohamed (2013) believes that many developing countries, including Libya, simply adopted the building codes and regulations of those in developed countries without attempting to adapt them to their local context through taking into account climate and locally available materials. Authors, including Elgadi *et al*. (2016), pointed out that the planners of major cities (e.g. Tripoli and Bengazi) realised that copying western styles was not always suitable to the local climate, nor did it correspond with people's needs and habits. In this regard, Almansuri *et al.* (2009) draw on the example of the city of Tripoli. They state that the city has experienced extensive growth and architects, urban planners, engineers and contractors from all over the world have participated in the process of its modernisation. These endeavours, as Almansuri *et al*. (2009) argue, have produced an incoherent entity, which does not relate to either local society or the indigenous character, and has led to the emergence of a disunified home identity. Another critical issue which is widely mentioned, is the lake of awareness across all levels with regard to the potential benefits of sustainable homes. That is fuelled by a mere focus upon initial costs as opposed to multiple dimension appraisal of housing projects, as argued by Higham and Stephenson (2014). This study, therefore, is conducted to fill this gap through developing a Composite Sustainability Index for residential buildings in order to aid the decision making support towards efficiently shaping sustainable homes in the Libyan context.

The literature review in relation to Sustainability interventions in the Libyan context reveals that, although extensive studies (e.g. Shawesh, 2016; Ali *et al.,* 2011; Amer, 2007; El-Hasia, 2005; Abbas, 1997) focus on the development issues for the Libyan built environment, only a few studies have addressed specific aspects relevant to sustainability-related features of housing for the context of Libya. For example, Omran *et al*. (2012) point out the critical success factors that are most important to the success of construction projects in Libya whereby feedback ability is ranked first followed by project monitoring, coordination effectiveness, design of education organisation structure and decision-making effectiveness. Whilst Shebob (2012) focuses on issues which influence the success of building projects through investigating delay factors affecting construction projects in Libya, a study by Ismail *et al*. (2009) employs the quality management and environmental management systems for applying an integrated management system in order to assess and monitor the construction processes and activities status in building projects. Another relevant initiative was a publication entitled 'Do courtyard houses provide the ideal climatic solution in hot climate regions?' (Almansuri *et al.,* 2009). Although the focus of this study was on sustainability-based solutions for architecture to reduce energy consumption of houses, there was a tentative reference to some factors related to sustainable homes such as, the need for achieving harmony with nature, proper insulation and the shading of houses, harnessing natural ventilation and natural light and green roofing as well as a few energy and water conservation measures. Nevertheless, it is unfortunate that the recommendations of this study have not been translated into action as it lacks detailed targets and specific norms. An extensive study by Mohamed (2013), which focuses on the phenomenon of urban fragmentation at the neighbourhood level, has investigated different urban typologies in the city of Benghazi. This study considers the main characteristics of the sustainable city, namely: (i) urban liveability which includes designs for thermal comfort and privacy intervention; (ii) accessibility represented by the level of spatial connectivity and urban diversity; and, (iii) environmental sustainability measured by green solutions embedded and sense of ecological footprint. This study faces limitations at different levels including its boundaries related to the focus on urban areas, whereas the investigation of the physical form and the process of city building along with both landscaping and socio-economic and cultural aspects are essential to the idea of sustainable development. More recently, a study by Elgadi *et al*. (2016) identifies a set of indicators for sustainable neighbourhoods in Tripoli, reflecting economic, environmental, social, and institutional dimensions. Indicators in Elgadi et al.'s (2016) study were developed to measure progress of the urban and community features, unlike the current study which is determined to identify a sustainability-based tool for precisely assessing building projects in Libya. The absence of comprehensive frameworks or approaches and the lack of sustainable development indicators in Libya has motivated the current study to address the topic of selecting a sustainability index for housing projects.

3.7 Chapter Summery

The review conducted through this chapter revealed that, in many construction companies, the concept of sustainability is now the norm, but they have not fully complied with environmental and social policies and practices. Thus, they need to improve their image and show greater commitment to the principles and regulations of sustainable development. Despite the effort that has been made, there are many indications that the housing sector is still facing a number of obstacles and there is still a housing shortage, whilst the quality of homes is unsatisfactory. Additional gaps have been identified in the adoption of a monetary-based approach to evaluate investments, as the project-level decision support system appears to lack a comprehensive evaluation tool that can guide and optimise the targeted performance. It is clear that there are no rigorous regulations, or sustainability standards, which would ultimately ensure and embed the principles of sustainability in housing projects in Libya. It has been widely argued that setting a coherent set of codes is one of the most successful ways to notably promote sustainable practices in relation to epitomising efficient energy and water usage. Since the initiatives highlighted in this chapter are modest when compared to other world efforts, more research is required to assist housing professionals to incorporate sustainability interventions in housing projects, and thereby to address the environmental, social and economic challenges encountered in the Libyan context. This study therefore hopes to respond to this need, aiming to achieve a marked shift in the country towards sustainable homes. Whilst this chapter has discussed the housing context in Libya, the next chapter is concerned with the development of a theoretical framework for sustainable homes.

4 The Development of a Framework for Sustainable Homes

4.1 Chapter Overview

This chapter presents a comparison between four various Sustainability Assessment Models (SAMs) (i.e. BREEAM, LEED; GBCA; DGNB) established in different regions throughout the world (i.e. the UK; USA; Australia; Germany). This attention to the use of these various models is a result of examining different environments and climates which enabled an insight to be gained into the underlying development of SAM, leading the study to draw the theatrical rationale underpinning the empirical research. This chapter therefore highlights the most important features that help to provide a comprehensive understanding of the structure and development of the prevalent SAMs, including the development orientations, category classifications and criteria structures, before coming up with the integrated analysis of the well-established SAMs.

4.2 The Principles of Sustainability Assessment Models

The essential task of SAM is to efficiently evaluate a building's performance through rigorous systems that ensure to what extent it complies with identified features and standards. The subsequent subsections address the main features of SAM including its principles, typology and rating systems.

4.2.1 The Development of SAMs

The building industry and housing sectors in particular have started to rethink and reorient their practices in an attempt to make significant changes relating to the reduction of environmental impacts. This shift was inevitable as a result of the growing awareness of the need to optimise the housing sector performance as well as to meet the increasing demand for the adoption of environmentally friendly products (Ding, 2008; Cole, 2005). The most significant roles of Sustainability Assessment Models (SAMs), as stated by Cole (1998), mainly revolve around three major objectives: (i) evaluating building projects in terms of the maintenance of natural resources and the impacts on the ecosystem; (ii) evaluating building projects in terms of the user's health and safety; and, (iii) presenting weighting systems for the identified standards so as to denote priority.

In response to this insistent demand, the early 1990s witnessed the emergence of the concept of "Environmental Building Assessment Method" (EBAM), paving the way towards the desired ambitions for the building industry. "Building Research Establishment" (BRE) is considered the UK institution that had the first initiative in this regard, establishing a set of standards for optimising decision support systems and assessing building performance (BRE, 2011). BRE pointed out that EBAM has the potential to play a prominent role through promoting the demand of sustainability applications in building projects, thereby stimulating the various stakeholders to adopt low environmental impact products (BRE, 2011). Increasing numbers of countries have subsequently established their own schemes in an attempt to improve building performance and raise the ecological values in the building sector (see Section 4.3, p.78). In line with this, a variety of assessment tools can be classified in terms of their development roots. As Poston *et al*. (2010) demonstrate, there are three main roots that have been adopted to develop SAMs, which can be specified as follows: (i) models based on Green Building Challenge (GBC) frameworks; (ii) models based on BREEAM and LEED tools based on the analysis of other existing tools; and, (iii) models developed based on cultural considerations as a unique assessment criterion. However, as Poston *et al.* (2010) assert, BREEAM is considered a common reference for most assessment methods and is therefore involved in the development of the majority of existing tools. Consequently, this study will also develop a sustainability assessment model for housing projects based on BREEAM, in addition to a set of well-known methods including LEED, GBCA and DGNB.

4.2.2 SAMs Typology

In order to classify the complexity of SAMs, various institutes and agencies have assessed the available tools. For instance, the ATHENA Institute and 'International Energy Agency' (IEA) created a classification system that defines the fields of assessment and eases analysis within specific bounds (IEA, 2017; Haapio & Viitaniemi, 2008). The typology classification system assessment tool formed by the ATHENA Institute is made up of three levels (Trusty, 2000). This system aims to provide a guideline for the various tools available to assess the building design process including the screening phase, priority setting and tackling specific concerns such as CO_2 emissions (Trusty, 2000). The three levels of the ATHENA classification system are as follows:

***Level 1*:** Product comparison tools and information sources. This level of classification (notably economic and environmental aspects) is primarily utilised at the procurement stage in making comparisons and choices. Examples of these tools are Environmental Resource Guide, LCExplorer, SimaPro and BEES.

***Level 2*:** Whole building design or decision support tools. Tools at this level centre on data of the life cycle costs as well as the effects on the environment and energy efficiency. Furthermore, they adhere to formal standards and guidelines such as ISO, ASTM and ASHRAE, contributing greatly to level 3 tools such as ATHENA, EcoQuantum and ENVEST.

***Level 3*:** Whole building assessment frameworks. These tools largely cover environmental, economic and social issues concerning sustainable development and include BREEAM, GBTool, CASBEE, GBCA and DGBN.

Moreover, Supporting Tools according to Trusty (2000), might be a fourth category in this system, offering more general support for the various tools notably in the stage of the design process. This level can be used for screening, raising priorities and treating particular concerns such as CO_2 emissions. Green Building Advisor, Green Balance and Baseline Green are a small example of supporting systems.

Accordingly, the IEA Annex 31 project defined five categories of assessment tools for measuring energy-related environmental impact of buildings (IEA Annex 31, 2017). This includes:

1) Energy modelling software;
2) Environmental LCA Tools for Buildings and Building Stocks;
3) Environmental Assessment Frameworks and Rating Systems;
4) Environmental Guidelines or Checklists for Design and Management of Buildings; and,
5) Environmental Product Declarations, Catalogues, Reference Information, Certifications and Labels.

It can be noted that all the tools classified in the ATHENA classification belong to the second or third category in the IEA Annex 31 classification, and there is a broader field of classified systems within the IEA Annex 31 classification than in ATHENA. The ATHENA classification, as Trusty (2000) asserts, depends on the location and purpose of use of assessment processes, while the IEA Annex 31 encompasses energy modelling software, various environmental standards and guidelines, checklists, product declarations and certifications. In addition, the IEA Annex 31 (2017) differentiates between interactive software and passive tools as the former relies more on information technology. However, ATHENA classification level 1 and 2 tools depend more on information technology than those of level 3. In the ATHENA classification, level 1 tools are used mostly for product comparison while level 2 and 3 tools are utilised for the environmental assessment of a whole building.

However, for comparison to be more effective, Trusty (2000) states that, the contrast should be within the classification level. For instance, in the ATHENA classification, Level 1 tools should only be compared with other Level 1 tools and not with those of Level 2 or 3. In this way, it is possible to evaluate and compare inter-level differences, uncover any weaknesses and allow for future development. Thus, the study is interesting in the development of ATHENA level 3 which corresponds with the third class in the IEA Annex 31 model, building sustainability assessment frameworks and rating systems.

4.2.3 Rating Systems

Given the fact that not every criterion can be seen as equally important, the weighting method is considered the heart of any SAM scheme (Ding, 2008; Chew & Das, 2008; Cole, 2005). A weighting system comprises a means to manage perspectives for credit distribution (Cole, 2005). The weighting system often includes a calculation procedure (weighting coefficient, rating formula and benchmarking expression), providing a single result indicating a clear level of sustainability achieved. The SAM systems employ various strategies for assessment, for instance, the BREEAM employs a weighted system that prioritises sustainability criteria, while LEED uses a simple additive method (1 for 1) in which all criteria are weighted equally. However, making an assessment without a weighting system inevitably leads to criticism, because it is still the only approach proven to comprehensively evaluate and prioritise complex issues relating to sustainable development (Lee, 2013). Therefore, when intending to develop a new SAM, it is appropriate to offer a customised weighting system to meet local and regional priorities, ensuring that the study will develop its own rating system that will structure a reliable assessment tool for sustainable homes in the context of Libya.

4.3 Overview of the Prevailing SAMs

Extensive schemes of SAM have been presented in different countries around the world. These assessment systems have been developed initially on the basis of specific conditions so as to be applicable to the characteristics of the regions for which these systems are designed. For example, in the UK, there is the Building Research Establishment Assessment Method (BREEAM), in the USA the Leadership in Energy and Environmental Design (LEED), the Green Building Council Australia (GBCA) in Austria, there is the German sustainable building certificate (DGNB), and the Comprehensive Assessment System for Built Environment Efficiency (CASBEE) in Japan. In addition, there are extensive models that are based on Life Cycle Analyses, for instance, EcoQuantum in Netherlands, EcoEffect in Sweden, Environmental impact analysis for buildings ENVEST in the UK, Building for Environmental and Economic Sustainability (BEES) in the USA, Athena Sustainable Materials Institute Life Cycle Assessment (ATHENA) in Canada, and Life Cycle Assessment (LCA) in Finland. A range of the most widely used SAMs adopted in various nations is encapsulated in Table 4.1 below.

Table 4.1: The Various SAMs Around the World

No	***Tool name***	***Country***	***Year***	***No***	***Tool name***	***Country***	***Year***
1	BREEAM	UK	1990	2	PassivHaus	Germany	1991
3	Austin Green Building Program	US	1992	4	BEPAC	Canada	1993
5	Colorado Built Green Housing	US	1995	6	HK-BEAM	Hong Kong	1996
7	HQE	France	1996	8	LEED	US	1998
9	GBTool	International	1998	10	EEWH	Taiwan	1999
11	EarthCraft House	US	1999	12	DDC	US	1999
13	SDS	Australia	1999	14	HQAL	Japan	2001
15	Built Green Alberta	US	2001	16	BEAT	Denmark	2001
17	FGBC	Florida, US	2002	18	ARE Scorecard	Australia	2003
19	GEM	UK	2003	20	Go Green	Canada	2004
21	Green Globes	US	2004	22	ProtocolloItaca	Italy	2004
23	BASIX	Australia	2004	24	Docklands ESD Guide	Australia	2005
25	Green Mark	Singapore	2005	26	Green Communities	US	2005
27	NAHB	US	2005	28	LiderA	Portugal	2005
29	EnviroDevelopment	Australia	2006	30	Code for Sustainable Homes	UK	2006
31	AccuRATE	Australia	2007	32	Minnesota GreenStar	US	2007
33	BEES	US	2007	34	Living Building Challenge	US	2007
35	Green Star NZ	New Zealand	2007	36	LEED-Brazil	Brazil	2008
37	First Rate	Australia	2008	38	GOBAS	China	2008
39	Green Star	SA Africa	2008	40	DGNB	Germany	2008
41	LEED- India	India	2008	42	Green Building Index	Malaysia	2009

4.4 Justification of an Integrated Analysis of the Four SAMs Selected

It is widely acknowledged that when developing a new Sustainable Assessment Method (SAM) to begin with an integrated analysis of reliable methods is required (Sleeuw, 2011; Poston *et al.*, 2010; Cole, 2005). In following up this orientation, this research aims to develop a theoretical framework through conducting an integrated analysis of a range of well-established and globally recognised SAMs. As aforementioned, this study targeted four common methods in use, namely "The Building Research Establishment Assessment Method" (BREEAM); "Leadership in Energy and Environmental Design" (LEED); "German sustainable building certificate" (DGNB); and "Green Building Council Australia" (GBCA), and then compared their parameters in order to aggregate the key categories and criteria, thereby establishing the proposed framework of the research. A wide range of national SAMs worldwide (see Table 4.1 above) have been established on the basis of well-known schemes such as BREEAM and LEED so that the focus was initially oriented towards the well-established tools rather than those were generated on the basis of which.

For this study, the adoption of the four models in this study have been driven by the basis of many motivating considerations. The selection of these well-known models is initially dependent on the credibility and reputation of the institutions that launched and operated them as well as their success in the marketplace. Globally, BREEAM and LEED are the leading methods in relation to building assessment methods, operated by well-known institutions (i.e. BRE and USGBC) that have a significant record in their domain. A case in point, 560,000 buildings have been assessed and certified by BREEAM, with roughly 2.25 million projects registered for certification cross 76 countries (BREEAM, 2018). Similarly, the USGBC have calculated that the number of projects certified and registered under LEED reached around 90,000 by the end of 2018, covering 165 countries (LEED, 2018).

The final two methods are selected for slightly different reasons. GBCA and DGNB were chosen because of their comprehensive nature since they more closely consider issues related to economic and social dimensions. They are also widely considered the most comprehensive methods of sustainability in the building sector (Tupenaite *et al.,* 2017; Markelj *et al.,* 2014; Ebert *et al.*, 2011; Khezri, 2011; Poston *et al*., 2010). In addition, GBCA has been chosen because it was originally established in Australia with differences in environmental characteristics - particularly the climate - allowing for more diversity and enriching the comparison planned.

4.5 Models Comparison Overviews

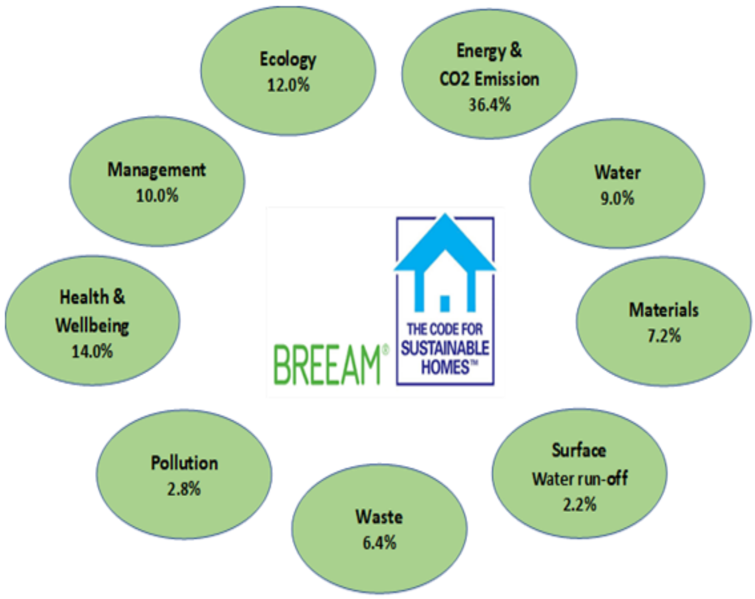
Methods such as BREEAM and LEED have attracted the attention of researchers as they provide rigorous development systems (Tupenaite *et al.,* 2017; Markelj *et al.,* 2014; Sleeuw, 2011). This chapter presents a comparison of the four various Sustainability Assessment Methods (SAMs) (BREEAM, LEED, GBCA, DGNB) established in different regions over the world (the UK, USA, Australia, Germany). See Appendices 1. 2, 3 and 4 for more details.

4.5.1 BREEAM

BREEAM is the world's leading SAM for master planning projects, infrastructure and buildings. It recognises and reflects the value in higher performing assets across the built environment lifecycle, from new construction to in-use and refurbishment (BREEAM, 2018). In 1990, BREEAM initiated and began functioning through BRE which is an independent institution that has a long history of about 100 years for testing and training and it is mainly known as a consulting organization that provides experience and consultations in all parts of the built environment as well as the linked industries. The scope of BREEAM covers various types of schemes including BREEAM Buildings (i.e. New Construction; Refurbishment and Fit Out), BREEAM Communities, and BREEAM Infrastructure New Construction (BREEAM, 2018). In recent years, BREEAM schemes have been developed and operated by National Scheme Operators (NSOs) in accordance with the Code for a Sustainable Built Environment. This resulted in launching the "Code for Sustainable Homes" (CSH) in 2007 as a sustainability assessment method for rating and certifying the performance of new homes. CSH currently represents a national standard for use in the design and construction of new homes with a view to enhancing continuous improvement in sustainable homes (BREEAM, 2018). BRE act as advisors on technical standards in relation to development and maintenance and manage implementation of the system through evaluation and certification services, under contract to the "Department of Communities and Local Government" (DCLG). Recently, the 2017 version of the BREEAM has been linked with the International WELL Building Institute (IWBI), which is expected to make it easier for projects pursuing both standards (BRE, 2018). Moreover, all BREEAM activities are formally documented and certified by 'International Organisation for Standardization' ISO 9001 which has offered a set of sustainability-based requirements for building assessment (BRE, 2016).

Credits and Percentage Points

The latest version of BREEAM "Code for Sustainable Homes" (CSH) was in 2010, and it consists of 34 individual assessment issues, separated into nine categories (i.e. Energy and CO_2 emissions, Water, Materials, Surface Water Run-off. Waste, Pollution, Health and Wellbeing, Management, and Ecology), each addressing a specific home related sustainability impact, as shown in Figure 4.1 below.



BREEAM Categories	*Available Credit*
Energy & CO2 Emission	31
Water	06
Materials	24
Surface Water run-off	04
Waste	08
Pollution	04
Health & Wellbeing	12
Management	09
Ecology	09
Total	107

Figure 4.1: BREEAM's categories "The Code for Sustainable Homes" (Adapted from BRE, 2010)

Rating System

The issues identified in CSH are employed to assess a performance target of the intended project and each criterion can be awarded numbers of credits. The weighting factors show the contribution made by each category to the total performance recognised and rewarded by the Code. This establishes the Code level or rating for the housing project. The Code certificate illustrates the rating achieved with a row of stars where a blue star is awarded for each level achieved and the total available score is expressed as 100 per cent. The aggregated credits in BREEAM produce an ultimate single score as follows: one star (36-47); two stars (48-56 points); three stars (57-67 points); four stares (68-83 points); five stars (84-89 points); and six stars (90-100 points) (BRE, 2010). Figure 4.2 below shows the six levels of BREEAM's rating system.

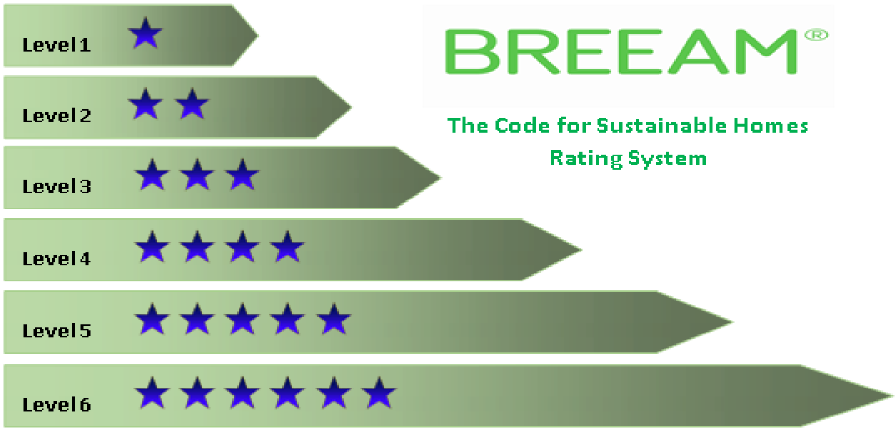


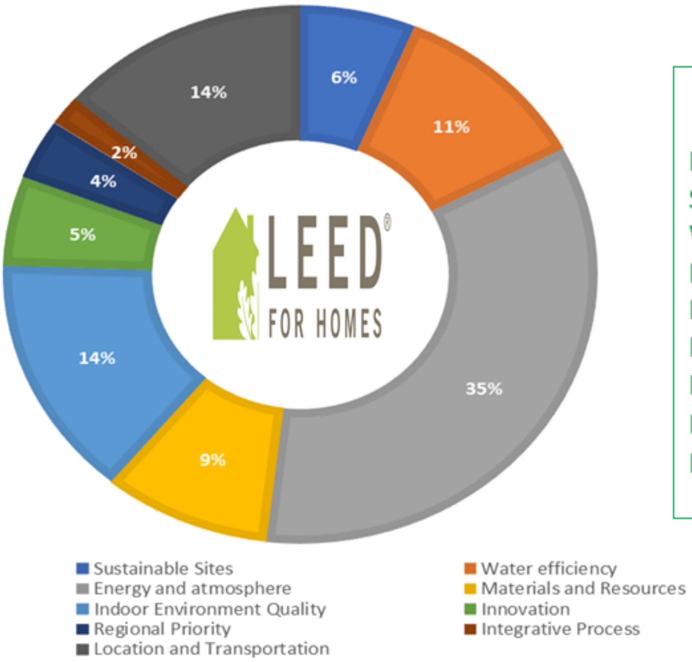
Figure 4.2: BREEAM's rating system "The Code for Sustainable Homes" (Adapted from BRE, 2010)

4.5.2 LEED

LEED is a voluntary certification program developed by the "U.S. Green Building Council" (USGBC), providing an inclusive assessment method (LEED, 2018). LEED was launched in 1998, known as the LEED 1.0 version which actually was influenced by BREEAM approaches (Sleeuw, 2011). LEED v4 is the most resect version of LEED, designed to be flexible and improve the overall project experience. LEED covers various types of building project, including BD+C (Building Design and Construction), ID+C (Interior Design and Construction), O+M (Building Operations and Maintenance), ND (Neighbourhood Development), and Homes (LEED, 2018).

Credits and Percentage Points

LEED for homes design and construction grants a maximum of 110 credits through 61 criteria split up into nine categories. These categories assess a broad range of features related to sustainability in housing projects, including Location and Transportation, Sustainable Sites, Water efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environment Quality, Innovation, Regional Priority, and Integrative Process. Each aspect is assigned with numbers of credits which are awarded based on the performance targets. The total available credits are 110 points. Figure 4.3 visualises the credit systems adopted in LEED for homes and for facilitating the comparison, percentage points were estimated.



LEED Categories	*Available Credit*
Location and Transportation	15
Sustainable Sites	07
Water efficiency	12
Energy and atmosphere	38
Materials and Resources	10
Indoor Environment Quality	16
Innovation	06
Regional Priority	04
Integrative Process	02
Total	110

Figure 4.3: LEED' Categories "Homes Design and Construction (v4)" (Adapted from: USGBC, 2013b)

Rating System

For calculating the achieved credits, LEED, unlike BREEAM, adopts a simple additive approach (1 for 1) with all criteria being weighted equally, rather than using a weighting system. LEED promotes four different ratings: certified (40-49 points); silver (50-59 points); gold (60-79 points); and platinum (≥80 points) (USGBC, 2013a), as shown in Figure 4.4 below.

Figure 4.4: LEED's Rating System for Homes Design and Construction (v4). (Source: LEED, 2018)

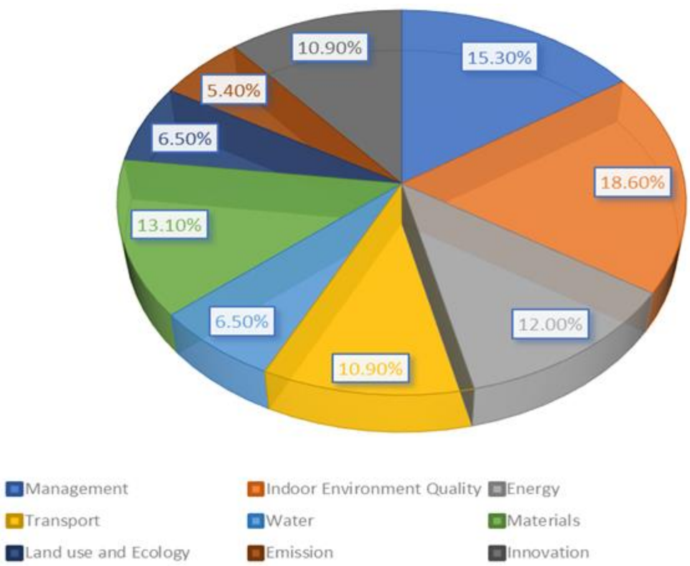
4.5.3 GBCA

Green Building Council Australia (GBCA) or well-known as 'Green Star' is an Australian rating system, developed by the Green Building Council Australia in 2003 (GBCA, 2018).

GBCA was designed based on various SAMs such as BREEAM and LEED (Roderick *et al*., 2009) and was originally developed to accommodate buildings' requirements in hot climates, where issues such as solar shading and cooling systems are of considerable significance (Roderick *et al*., 2009). GBCA produced this method to comprehensively facilitate delivering the requirements of the environment and people in their buildings through different purposes: to minimise the impact of buildings on the environment (environmental perspective); to reinforce the health and productivity of the buildings' users (social/user perspective); and to achieve cost savings (economic/financial perspective) (GBCA, 2018). There are four GBCA schemes available for certification: (i) performance; (ii) design and as built; (iii) interiors; and, (iv) communities. The latest version of these models is 'GBCA – Design and As Built v1.2'. This was released in 2017 to assess the sustainability outcomes from the design and construction of new buildings or major refurbishments across nine holistic impact categories (GBCA, 2018).

Credits and Percentage Points

The 'GBCA Design and As Built v1.2' encompasses a set of 67 criteria, which are grouped into nine categories, namely Management, Indoor Environment Quality, Energy, Transport, Water, Materials, Land Use and Ecology, Emission, and Innovation. Each cluster is a source of sustainability impact which is supposed to be assessed against a desired performance and awarded credits. The 'GBCA Design and As Built v1.2' presents 91 points in total. Figure 4.5 illustrates the credit systems adopted in GBCA, whilst percentage points were generated to facilitate the intended comparison.



GBCA Categories	Available Credit
Management	14
Indoor Environment Quality	17
Energy	11
Transport	10
Water	06
Materials	12
Land use and Ecology	06
Emission	05
Innovation	10
Total	91

greenstar DESIGN & AS BUILT
GBCA

Figure 4.5: GBCA's Categories "Design & As Built v1.2". (Adapted from GBCA, 2018)

Rating System

The total number of points achieved through the process of assessment in the 'GBCA Design and As Built v1.2' can be compared against the available points in the rating tool which describes the sustainability attributes of the project on the basis of 1-3 Stars (10–44 points), 4 Stars (45–59), 5 Stars (60–74 points), and 6 Stars (≥75) (GBCA, 2018), as shown in Figure 4.6 below.

Figure 4.6: GBCA's rating system "Design & As Built v1.2". (Source: GBCA, 2018)

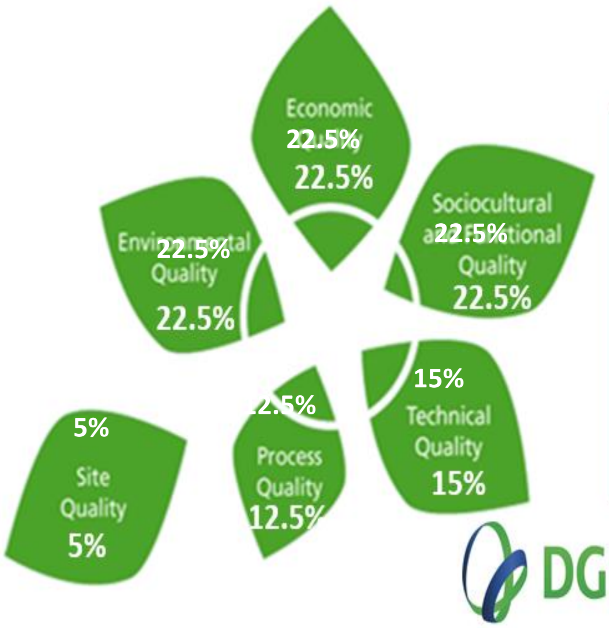
4.5.4 DGNB

'German sustainable building certificate' (DGNB[2]) is the first German method for assessing and planning buildings in reference to sustainable building principles (DGNB, 2018a). The basic system for assessing the sustainability quality of buildings was jointly developed by the DGNB and the "Federal Ministry of Transport, Building and Urban Development" (BMVBS) in 2009. While the BMVBS has precisely specified this basis for the self-assessment of federal buildings, the DGNB has developed a complete certification system for a wide range of building uses and quarters (Ebert *et al.,* 2011). The DGNB was designed for different types of buildings, including existing buildings, new buildings, inside rooms, and quarters. DGNB currently is one of the leading SAMs worldwide, representing the certification systems of the second generation as a result of its comprehensive consideration that takes equal account of environmental, economic and social aspects as well as its holistic view of the building's entire life cycle (Khezri, 2011; Ebert *et al*., 2011).

[2] (DGNB) *Deutsche Gesellschaft für Nachhaltiges Bauen*

Credits and Percentage Points

The sustainability concept of the DGNB system is broad and extends beyond the well-known three-pillar model. It considers all essential aspects of sustainable construction, including the six subject areas of ecology, economy, socio-cultural and functional aspects, technology, processes and location which in turn, are split down into 151 criteria. Each single criterion can receive a maximum of 10 points and has its own weighting rate, but it is possible to increase this rate depending on certain features (DGNB, 2018b). Likewise, the six categories have their own credits as well as the weighting factors, as shown in Figure 4.7 below.



DGNB Categories	Available Credit
Environmental Quality	19
Socio-cultural & Functional quality	21
Technical Quality	20
Site Quality	09
Process Quality	23
Economical Quality	09
total	101

Figure 4.7: DGNB's Categories "New Residential Building (NWO)" (Source: DGNB, 2018a)

Rating System

Each category of DGNB is weighted in the overall score of the ranking system like the BREEAM. The combination of the evaluation points with the respective weighting of a criterion calculates the concrete degree of fulfilment for the six subject areas. The DGNB awards the DGNB certificate in silver, gold or platinum on the basis of the level of points collected as ≤50%, ≤65%, and ≤80% respectively (Figure 4.8).

Figure 4.8: DGNB's rating system "New residential building (NWO)". (Source: DGNB, 2018a)

4.5.5 Synthesis: Towards a Framework for Sustainable Homes

To fully gain insight into the four systems described here, each method is reviewed in order to integrate the commonalities of their categories and criteria and to comprehensively consolidate their merits into a proposed model. The review and integrated analysis conducted on these models reveals that, although they were established in different contexts and their classifications vary, there are lots of commonalities between each set of categories and criteria. The analysis process first determines the most common set of categories, followed by integrating the similarities between the criteria adopted in the examined models. Finally, a collective overview of the integrated analysis is addressed.

4.5.5.1 Integrative Data Analysis Scheme of the Set of Categories

From an integrated analysis of the four SAMs (i.e. BREEAM, LEED, GBCA and DGNB), it is noticed that the models examined provide systems involving similar sets of categories, except the DGNB which, although it is considered the most comprehensive tool, it has the most integrated set of categories among the four models reviewed, for example, it uses the Environment Quality cluster to reflect a wide range of issues including energy, water, waste and material efficiency. In contrast, although they use a variety of terminology, BREEAM, LEED, and GBCA have the same number of categories. As shown in Table 4.2 which exhibits the integrative data analysis scheme of the sets of categories, there are a wide range of commonalities between the four tools. The integrated analysis resulted in a set of seven major categories which most probably reflects the sustainability related features in housing projects.

Table 4.2: An Integrative Data Analysis Scheme of the Four Models' Categories

<table>
<tr><th rowspan="3">Categories Integrated</th><th colspan="8">Category Distribution</th></tr>
<tr><th colspan="2">BREEAM</th><th colspan="2">LEED</th><th colspan="2">GBCA</th><th colspan="2">DGNB</th></tr>
<tr><th>Categories</th><th>%</th><th>Categories</th><th>%</th><th>Categories</th><th>%</th><th>Categories</th><th>%</th></tr>
<tr><td rowspan="2">Management & Process</td><td>Management</td><td rowspan="2">22</td><td>Sustainable Sites</td><td rowspan="2">9</td><td>Management</td><td rowspan="2">21.8</td><td rowspan="2">Process Quality</td><td rowspan="2">12.5</td></tr>
<tr><td>Ecology</td><td>Integrative Process</td><td>Land Use and Ecology</td></tr>
<tr><td>Materials Efficiency</td><td>Materials</td><td>7.2</td><td>Materials and Resources</td><td>11</td><td>Materials</td><td>13.1</td><td rowspan="6">Environmental Quality</td><td rowspan="6">22.5</td></tr>
<tr><td rowspan="2">Water Efficiency</td><td>Surface Water Run-off</td><td rowspan="2">11.2</td><td rowspan="2">Water efficiency</td><td rowspan="2">13</td><td rowspan="2">Water</td><td rowspan="2">15.3</td></tr>
<tr><td>Water</td></tr>
<tr><td>Energy Efficiency</td><td>Energy & CO2 Emission</td><td>36.4</td><td rowspan="3">Energy and atmosphere</td><td rowspan="3">40</td><td>Energy</td><td>12</td></tr>
<tr><td rowspan="2">Waste & Pollution</td><td>Waste</td><td rowspan="2">15.4</td><td rowspan="2">Emission</td><td rowspan="2">5.4</td></tr>
<tr><td>Pollution</td></tr>
<tr><td rowspan="2">Health & Wellbeing</td><td rowspan="2">Health & Wellbeing</td><td rowspan="2">14</td><td>Indoor Environment Quality</td><td rowspan="2">23</td><td>Indoor Environment Quality</td><td rowspan="2">18.6</td><td>Socio-cultural & Functional Q.</td><td rowspan="2">37.5</td></tr>
<tr><td>Innovation</td><td>Innovation</td><td>Technical Quality</td></tr>
<tr><td rowspan="2">Location Quality</td><td rowspan="2">---</td><td rowspan="2">00</td><td>Location and Transportation</td><td rowspan="2">18</td><td rowspan="2">Transport</td><td rowspan="2">10.9</td><td>Site Quality</td><td rowspan="2">27.5</td></tr>
<tr><td>Regional Priority</td><td>Economical Quality</td></tr>
</table>

Accordingly, as shown in Figure 4.9, which illustrates the performance of the four models on a clustered column graph, there is an obvious disparity between the four SAMs when weighing their categories. For example, BREEAM appreciates energy efficiency more than water efficiency compared to LEED which is more concerned with health and wellbeing. The greatest issue for concern in GBCA is the management and process category unlike LEED where this matter is recorded as the lowest score in its system. The health and wellbeing and location quality features were very clear in DGNB in comparison to the other systems, which is a positive aspect favouring human wellbeing. In line with this, DGNB appears more balanced through the rest of the bespoke categories with more consideration of social respects. Otherwise, BREEAM omits the location quality-related issues which represents an obvious area of critique.

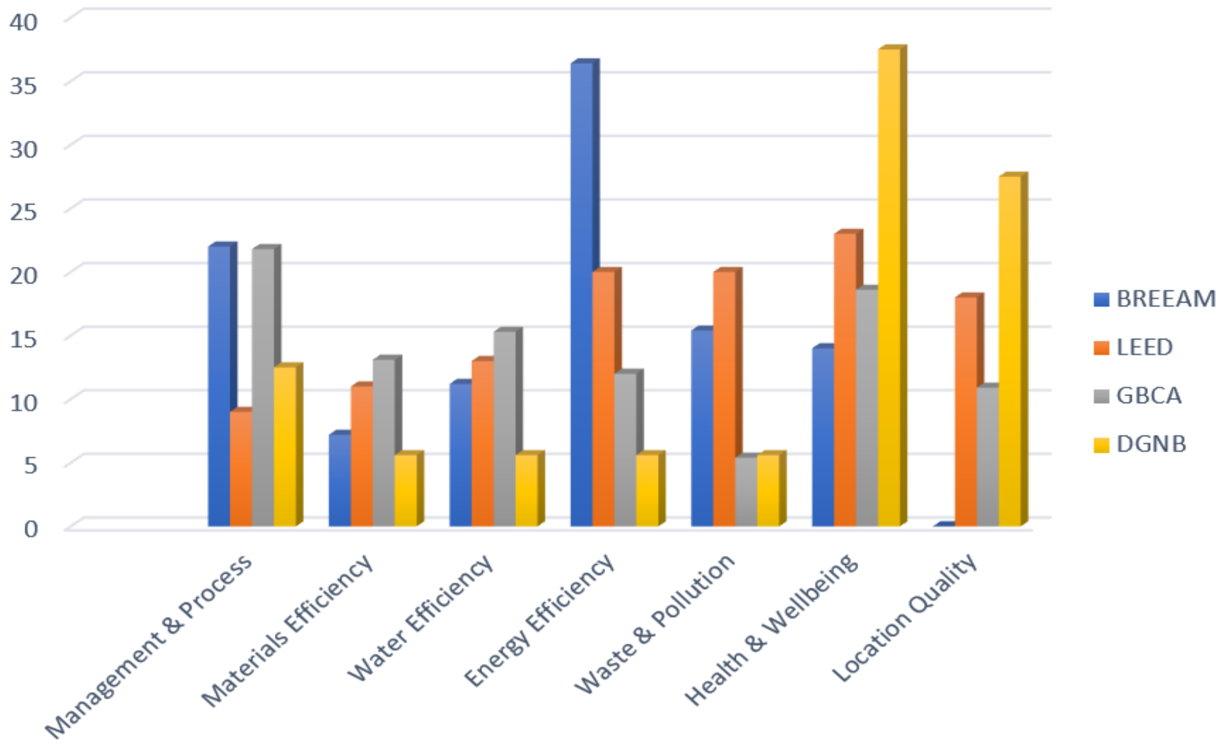


Figure 4.9: The Performance of the Four SAMs over the seven categories

4.5.5.2 Integrative Data Analysis Scheme of the Sets of Criteria

Since they are widely different in their criteria systems, the sets of criteria cannot directly be compared, as Markelj *et al*. (2014) and Sleeuw (2011) noted. Each system employs an extensive set of criteria (see Appendix 5), using different terms for assessing different demands so that it is quite difficult to constitute a perfect comparison. In attempts to integrate the examined models, the commonalities in the criteria systems which are shown in harmony have been defined and properly represented in a single criterion which have then been aggregated in a comprehensively integrated analysis. Table 4.3 summarises the integrative data Analysis scheme of the sets of criteria which generates the theoretical framework of sustainability-based assessment for housing projects.

Table 4.3: An Integrative Data Analysis Scheme of the Four Models' Criteria

Criteria			Integrated Analyses			
			DGNB	BREEAM	LEED	GBCA
Management & Process	1	Ecosystem Enactment	•	•	•	•
	2	Independent Commissioning Agent	•			•
	3	Potential Natural Risks	•	•		
	4	Environmental Management Plan (EMP)	•			•
	5	Minimise Life Cycle Cost	•	•		
	6	Integrative Process	•		•	
	7	Preliminary Function Test	•		•	
	8	Innovation Challenge	•	•	•	•
	9	Home User Guide	•	•	•	•
	10	Circular Economy	•			•
	11	Accredited Professional	•		•	•
	12	Monitoring of Construction Site Impacts	•			•
Materials Efficiency	13	Environmentally Friendly Materials	•	•	•	•
	14	Responsible Sourcing of Materials		•	•	•
	15	Materials Reuse & Recycling Potential	•			
	16	Use of Locally Available Materials			•	
Energy Efficiency	17	Energy Primary Demand			•	
	18	High-Efficiency Appliances & Monitoring		•	•	•
	19	Daylight Access Rate	•	•	•	•
	20	Hot Water System Use			•	•
	21	Efficient HVAC System	•		•	•
	22	Use of Thermal Insulation	•	•	•	
	23	Renewable Energy & Alternative Strategies	•	•	•	•
Water Efficiency	24	Potable Water Demand	•	•	•	
	25	Irrigation System Use	•	•	•	
	26	Grey Water System Efficiency	•			•
	27	Water Appliances Efficiency				•
Waste & Pollution	28	Low Light &Noise Pollution	•			•
	29	Low Refrigerants Rate				•
	30	Waste Treatment & Recycling Facilities	•	•	•	•
	31	Polluted Emissions Reduction	•	•	•	
Health & Wellbeing	32	Natural Ventilation Level	•		•	•
	33	Sound Absorption & Insulation	•	•		•
	34	View out & Aesthetic Aspects	•			•
	35	Safety Protection & Fire Security	•	•		
	36	Cooling and Heating Comfort & Control	•		•	•
	37	Illumination Quality & Control	•	•		•
	38	Internal Layout Functionality & Visual Comfort	•	•	•	
	39	Cultural and Architectural Heritage			•	•
	40	Maintainability & Flexibility	•			•
Location Quality	41	Considering Transportation Accessibility	•		•	•
	42	Pedestrian and Cyclist Safety	•			•
	43	Community Services & Facilities	•		•	
	44	Car Parking Capacity	•			•

4.5.6 Overview of the Integrated Analysis

Having reviewed the well-known models and extracted the set of categories and criteria, the study has established its theoretical framework of sustainable homes. Based on this understanding, key sustainability-based assessment features for sustainable homes can be described as follows:

i. Management and Process

The main management subject of almost all SAMs are management of site activities and the construction procedure, with the aim of guaranteeing the protection of environmental and social factors, as well as a suitable level of commissioning. The 'management and process' aspect is assessed in BREEAM through the 'Management' and 'Ecology' Categories, whilst in LEED, this objective is involved in the categories of 'Sustainable Sites' and 'Integrative Process'. Likewise, GBCA embeds this cluster in the 'Management' and 'Land Use and Ecology' categories, whilst it appears in the category of 'Process Quality' in DGNB. It is evident that BREEAM has founded the most notable sustainability management principles, whereas in this respect, LEED and GDNB are relatively weak. GBCA has trends which are similar to those of BREEAM, dealing with management issues in a separate category with greater consideration of construction process planning criteria.

ii. Materials Efficiency

An essential objective of sustainable homes policies is guaranteeing the effective and optimum practice in terms of material use. As Sleeuw (2011) and Sourani (2008) assert, building materials are a vitally important category in almost all SAMs, because of their complex lifecycle procedure from extracting raw resources until the disposal phase. The Materials and Resources category was brought from LEED terminology, whilst BREEAM and GBCA preferred using merely 'Materials' to reflect this objective. Likewise, DGNB embeds this within the 'Environmental Quality' section. To some extent, GBCA has additional and much more precise criteria in this category. LEED, unlike BREEAM, places emphasis on maintenance of construction materials and their reusability, whilst the use of finishing materials and the responsible source of materials are relatively given less importance in its framework. In terms of the consideration of environmental loading, GBCA emphasises the reduction of the usage of non-renewable resources, whilst concurrently preventing the use of materials with pollutant elements.

iii. Energy Efficiency

As Figure 4.9 shows, energy efficiency has the greatest value of credits that are spread within the SAMs' groups, placing great importance on energy design, renewable energy strategies, energy conservation and monitoring. The category of Energy Efficiency is covered in BREEAM using the 'Energy and CO_2 Emission' category, whilst in LEED, this objective was involved in the category of 'Energy and atmosphere'. Whereas GBCA embeds these objectives within the 'Energy' category, and within the category of 'Environmental Quality' in DGNB, additional criteria have been embedded in BREEAM such as Internal and External lighting, insulant 'Global Warming Potential' (GWP) and Ecolabelled goods. This can be traced back to BREEAM relying on the Green Guide to Specification, which includes over 1500 specifications applied in different forms of buildings (BRE, 2018). While renewable resources are generally considered to be strong in assessing energy efficiency, this area is not quite as important in the DGNB.

iv. Water Efficiency

Water conservation is considered to be one of the most crucial issues throughout the world. As a result of it being a finite and valuable resource, the evaluation systems aim to efficiently take action regarding water use. The Water Efficiency category adopts LEED terminology, whilst GBCA assesses this objective using the category of 'Water'. Likewise, BREEAM spreads it between the Surface Water run-off and Water categories, whereas the DGNB embeds this in the 'Environmental Quality' section. GBCA examines the criterion 'Alternative Sources' under Environmental Loading (GBCA, 2018), which allows it to be closely connected to evaluation within the category of water efficiency. This is because in some regions of the world, water stored still makes up the largest water supply.

v. Waste and Pollution

The hazardous emissions, harmful materials, potential natural risks, and pollution are all considered essential in SAMs (Environment-agency, 2018). Waste treatment and recycling systems applied with sophisticated waste management have the potential to protect humans and the environment from any negative consequences of waste risk, as well as maintaining the characteristics and advantages of treatment, management, and recycling (BRE, 2016). Waste and Pollution appears in GBCA through the 'Emission' category, whilst LEED uses the 'Energy and Atmosphere' category to satisfy this aspect. Likewise, BREEAM spreads it between the 'Waste' and 'Pollution' categories, whereas in DGNB, this was incorporated into the category of ‘Environmental Quality’. These features are assessed differently by these four systems. For example, BREEAM evaluates the factors that can potentially increase global warming and its linked effects and aftermath; it accomplishes this by assessing refrigerant leaks and hazardous emissions of the greenhouse gases such as Carbon dioxide (CO_2). LEED, GBCA and DGNB include the Heat island impact criteria, whereas BREEAM does not.

vi. Health and Wellbeing

Health and Wellbeing is considered to be one of the most important objectives in all SAMs, with the aim of providing a suitable healthy level of sound, light, ventilation and thermal comfort, along with protecting the occupiers from harmful substances and adulterating microbes that may be released from interior material (BRE, 2018). The Health and Wellbeing cluster has adopted BREEAM terminology, whilst LEED and GBCA spread it between ‘Indoor Environment Quality’ and ‘Innovation’ categories. Likewise, DGNB embeds this into two sections, namely ‘Socio-cultural and Functional Quality’ and ‘Technical Quality’. The dominant criteria in LEED and GBCA are provision of outdoor air and the system of HVAC (Heating, ventilation, and air conditioning), whereas the central criteria in BREEAM are lifetime homes and sound insulation, in addition to illumination and light. All these criteria are extensively covered by DGNB, with some focus on sonic environment unlike LEED which has underestimated acoustic performance.

vii. Location Quality

There are some building features that make a higher quality of operation and attendant services. These have indirect but important impacts on social aspects. These criteria have objectives to guarantee a perfect communication level, by easing availability to public services, important facilities and suitable provision for the road users including drivers, cyclists and pedestrians. Location Quality category is not clearly considered by BREEAM, but it was a major focal point in LEED which spreads it between the ‘Location and Transportation’ and ‘Regional Priority’ categories. Similarly, GBCA embeds this objective in the ‘Transport’ category, whereas it is incorporated into the categories of ‘Location Quality’ and ‘Economical Quality’ in DGNB.

The framework which has been developed here might be the most convincing data source to facilitate the following empirical research. The identified features mainly indicate most possibilities of the features required to assess housing projects in relation to sustainability. The research argument, therefore, is that housing designers and providers may find the aforementioned clusters valuable in shaping sustainable homes within the context of Libya's built environment. The proposed framework is developed with the aim of facilitating the further discussions through the subsequent research stages.

4.6 Chapter Summary

The review of the SAMs led to several advantages of this research. First, understanding sustainable evaluation method and rating system has led to the identification of weaknesses in existing and leading well-established methods. The literature has shown that the prevailing methods of assessment (e.g. BREEAM, LEED) are not applicable to the assessment of the built environment in Libya. The literature defined a range of shortcomings in the recognition of regional variations, including restrictions on available resources, local architecture, specific environmental conditions and other economic and socio-cultural factors. This chapter also, has reviewed and compared the most reliable and common SAMs in the global context (i.e. BREEAM, LEED, GBCA and DGNB). Particular consideration has been given towards the sustainability-based criteria and weighting system in each method, with a focus on identifying the commonalities between them. Certain criteria that are considered in both GBCA and DGNB including Economic and Social quality, have been highlighted for consolidation into the proposed framework, in addition to the most important criteria assessed by BREEAM and LEED. This integration aims to achieve superiority through an aggregation of the most reliable criteria that enable the measurement of building performance relevant to sustainability. The integrated analyses of the four tools has extracted 44 criteria grouped into seven categories, namely: (1) Management and Process; (2) Materials Efficiency; (3) Water Efficiency; (4) Energy Efficiency; (5) Waste and Pollution; (6) Health and Wellbeing; and (7) Location Quality. The framework of the study has been established which paves the way towards the achievement of the objectives, facilitating further discussion through the empirical stage of the study, which is presented in Chapter Six after addressing research design demand in the chapter that follows.

5 Research Design and Methodology

5.1 Chapter Overview

Once the literature review has been accomplished and the theoretical framework drawn up, an extensive review of a variety of the research methodological strategies existing in the literature is conducted to ideally identify the most appropriate methodology for this study. This chapter answers three key questions: What is the study's philosophical position? What is the research methodology? And how can the adopted method be employed? These queries need to be thoughtfully addressed through rationally scientific application. To meet the research aim defined, a single focus group interview followed by questionnaires are the tools chosen to be the most appropriate methods for this research. The reasons for this choice of instruments will first be addressed. Then, the sampling strategy, data collection and analysis will be discussed.

5.2 Methodological Design Models

Research work can be described as an investigation of the pursuit of knowledge (Saunders *et al.,* 2016). As opposed to other fields of knowledge, research follows a systematic process during which data is collected, analysed, and presented in a suitable manner for further use (Mertens, 2009). This process is aligned essentially with the research purpose, aims and objectives (Marshall & Rossman, 1999). According to Blessing and Chakrabarti (2009), research design can be defined as a systemic approach aligning with a set of supporting techniques and guidelines to be employed as a model for conducting a research study. Research design, as Blessing and Chakrabarti (2009) emphasise, assists researchers to specify their research areas and identify idealistic methods for addressing the undertaken issues. The overall research strategy can be drawn out through identifying the philosophical perspectives in relation to the research design.

Reviewing the relevant literature has revealed that there is no consensus upon this subject nor its terminology. From Crotty's (1998) perspective, there is a powerful interrelationship between the theoretical philosophy, methodology and methods adopted, and the researcher's stance or epistemological assumptions. Crotty (1998) goes on to assert that one of the problems related to research models is not only the puzzling array of theoretical perspectives and methodologies, but the fact that the terminology applied to them is often inconsistent or even contradictory. Figure 5.1 portrays the key research components and their relationships.

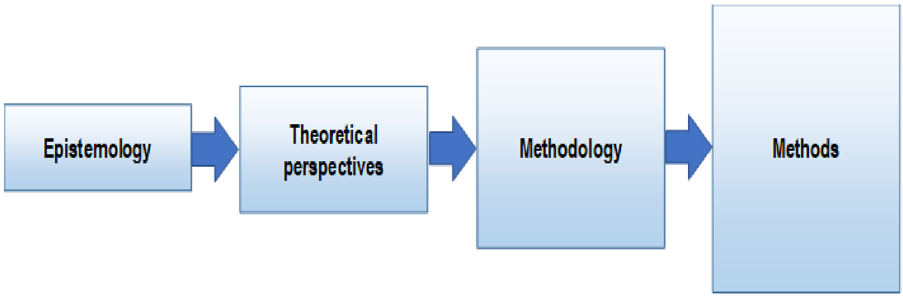


Figure 5.1: Relationship Between Methodological Research Components. (Adapted from Crotty, 1998)

According to Crotty (1998), to generate the desired data for a certain research study, the choice of methods is closely linked to the decisions made for the research methodology. Likewise, the methodological interventions are rather derived from the theoretical perspective adopted which is in turn, influenced by the researcher's epistemological assumptions.

From the perspective of the Nested Model, which attracted wide interest amongst researchers and was developed by Kagioglou *et al*. (1998), philosophical research falls into a set of three different perspectives, namely philosophies, approaches and techniques (Figure 5.2).

Figure 5.2: Nested Research Methodology Model. (Adapted from Kagioglou *et al*., 1998)

The most striking features of the Nested Model is that it represents a simple way to reflect the key components of the methodological research, distinguishing between the principle classifications with centric focus on the research approaches and techniques.

Accordingly, Saunders *et al.* (2016) developed the Nested Model into an 'Onion Model' which encompasses six layers, namely philosophy, approach, methodological choices, strategies, time horizons and procedures. The outer layer in Saunders *et al.*'s (2016) Onion reflects research philosophy, down to the research techniques for data collection and analysis in the centre of the research onion (Figure 5.3).

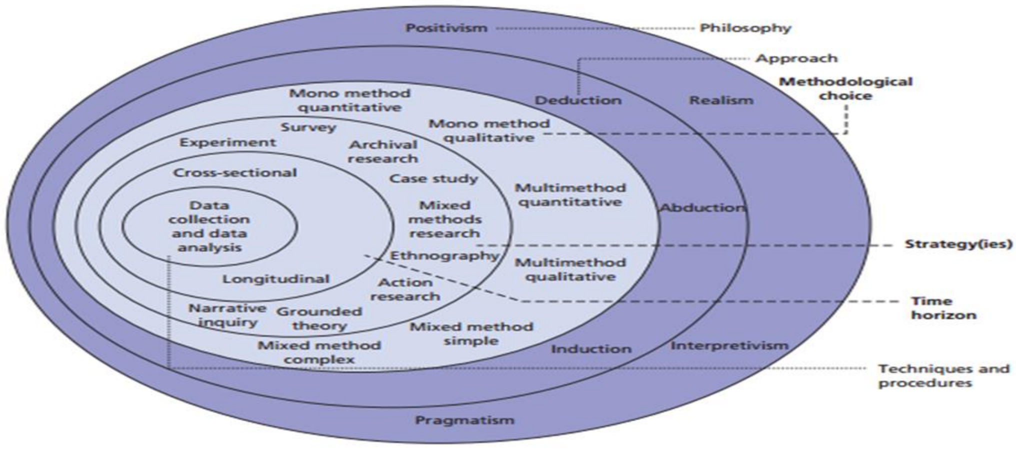


Figure 5.3: Saunders' Research Onion Model. (Source: Saunders *et al.*, 2016, p.164)

It is clear that the Onion Model presents a wider perspective, providing clear guidelines on how to develop research design through a broad spectrum of perspectives. Saunders *et al.*'s (2016) research onion for many seems to be a preferable guide for illustrating research methodological design because of its systemic structure and comprehensiveness.

With this in mind, the rest of this chapter on the methodological design is delivered in response to the research onion's structure, starting with the research philosophy in the section that follows.

5.3 Research Philosophy

The fundamental enquiry any researcher should clearly respond to is the need to determine the research philosophy and its underpinnings. As Dainty (2008) and Creswell (2013) emphasise, it is of the utmost importance to comprehend research philosophy at the early stage of the research. Saunders *et al.* (2016) consider the research philosophy in the first layer of their research onion, defining it as a viewpoint that reflects the worldview and theoretical belief structure underpinning the research strategy. The research philosophy can be understood as a cluster of how and why queries, which influence and orient the research approach (Bryman, 2015). Essentially, there are three pivotal philosophical perspectives: ontology, epistemology and axiology (Bryman, 2015). These assumptions as Saunders *et al*., (2016) and (Braun & Clarke, 2013) emphasise, need to be defined, as they confine and guide the research paradigm, thereby representing the following principles:

- ***Ontological assumptions*** mirror the relationship between the world, human interactions and human practice, so they are mainly concerning the nature of reality.

- ***Epistemological assumptions*** reflect the validity of knowledge, so they are mainly concerning the methods that should be used to explore and establish the truth.

- ***Axiological assumptions*** refer to the impacts of researcher's values on the study, so they are linked to the researcher's influences.

To this end, as Gary (2014) concludes, ontology looks certainly at understanding '*what is'*, while epistemology seeks to understand '*what it means to know*'. As such, it is vital for both the researcher and the reader to understand the ontological, epistemological, and axiological perspectives which are adopted to underpin the nature of the study (Bryman, 2015). The following subsections highlight the principle research philosophy followed by justification of the philosophical stance adopted in this research being addressed.

5.3.1 Ontological Perspective

Ontology, as mentioned earlier, is a methodological concept used fundamentally to reflect the researcher's view and assumption towards the nature of reality on the basis of the relationship between the world and human interactions (Dainty, 2008). However, the literature does not identify a clear nor specific stance pertaining to ontological positions of research. Dainty (2008), for instance, emphasise two ontological positions; they could be either objectivist or constructivist. Objectivism is related to phenomena which are thoughts that exist independently, whilst constructivism explains how phenomena are constructed as a result of interaction with the human's perceptions so that constructivists are dependent and constantly subject to change. Accordingly, subjectivism was also identified by Crotty (1998) as an ontological stance, whilst Hepburn (2003) went on to further suggest two perspectives of the research ontology specifically in social sciences, namely realism and relativism to be among the wider research philosophy spectrum. According to Easterby-Smith *et al*. (2002), realism has an objectivist stance in essence, due to its independent existence of human interactions, even though it is understood through a social context. As such, for realist researchers, variables such as culture, tradition, and the organization exist and act independently of the observer (Gray, 2014). In contrast, relativists assume that there are multiple realities and ways of accessing them. In this sense, there seems a wide consensus that the realist stance is suitable to conduct research in Construction Management (CM) research domain (Dainty, 2008; Crotty, 1998). As such, CM researchers try to interpret the independent reality through constructing humans' perceptions and understandings.

5.3.2 Epistemological Perspective

The principle assumptions pertaining to epistemology are linked to knowledge acquisition. As Creswell (2013) explain, epistemological philosophy concerns the creation and distribution of desired knowledge. This includes issues such as the adequate knowledge, knowledge sources, knowledge structure and limitations (Dainty, 2008). Creswell (2013) asserts that identifying the epistemological position is essential to draw out precise assumptions about how and what knowledge should be generated for certain research. As such, these assumptions essentially influence the research methodology as well as the potential contributions of the research.

A positivist epistemology in this essence is often shown within the natural science fields. Interpretivist philosophy is based on the humans' understanding structure which is constituted through their interactions with the phenomenon (Creswell, 2013). This implies that interpretivism is in line with the perspective that assumes social interactions shape reality (Saunders *et al*., 2016). Creswell (2013) goes further in identifying a four-epistemology philosophy. This includes positivist, constructivist, interpretivist and pragmatist stances.

Positivist Epistemology

The objectivist ontology as mentioned earlier assumes that there is a single reality or truth and this reality also is independent of humans which often aligns with natural sciences (Cohen *et al*., 2013). Within social science, positivists believe that social phenomena are governed and oriented through specific rules and theories (Dainty, 2008), whilst the social research in turn, tries to generate these theories by which independent reality can be interpreted and comprehended (Creswell, 2013). This implies that a social object exists regardless of its recognition by humans (Crotty, 1998). Thus, the ontological stance of positivism is objectivism, since the researcher is non-interactive with the phenomenon, whilst the focus remains that reality is real and independent (Bryman, 2015; Gray, 2014). The positivist purists adopt deductive processes based on hypothesis or theory testing, employing quantitative instruments in an attempt to understand a phenomenon (Gray, 2014). As a result, positivism as an epistemological stance can be employed in social phenomena in the same way as in the applied world using theory-led approaches through deductive processes. However, Mertens (2009) criticises the application of positivist assumptions within social objects in terms of the ignorance of critical factors that can influence human behaviour and thus data collection such as culture, loyalty and experience.

It can be argued that issues such as the sustainability phenomenon within the construction of the built environment could be shown as a positivist pursuit as long as a building physics approach is adopted but it can also be seen as a response to a socially and culturally interpreted phenomenon. Sustainability is characterised as a complex phenomenon (Conard, 2013), and as Waas *et al*. (2011) argue, sustainability reflects social values that people are perceived, making it impractical to investigate aspects related to sustainability with a deductive approach. As aforementioned, this research is approaching the issue from the perspective of housing sustainability in which the nature of the building and the requirements of sustainability are influenced by cultural, climatic and religious requirements, which in turn, are socially constructed. Therefore, adopting a positivist paradigm purely is unsuitable for satisfying the core enquiry of this study.

Interpretivist Epistemology

The interpretivist epistemology seems to be a major anti-positivist stance, looking for '*culturally derived and historically situated interpretations of the social life-world'* (Crotty, 1998, p.67). The interpretivist epistemology is based on the belief that individuals create their own perceptions according to their own experiences, knowledge and consequent actions (Crotty, 1998). Gray (2014) emphasises that interpretivists assume that knowledge is what individuals perceive to be true, with no single reality nor independence. As such, there is no direct one-to-one relationship between subjects, 'humans', nor the object 'world'. This implies as Crotty (1998) concluded, that the interpretivist's view is based on the fact that the world is interpreted through the classification schemata of the mind. Interpretivism has its ontological foundation in subjectivism or relativism (Braun & Clarke, 2013; Gray, 2014), and therefore, interpretivist pursuits have to acknowledge that meaning is interpreted essentially in accordance with the development of perception resulting in interaction between individuals and phenomenon (Crotty, 1998), whilst keeping in mind, this phenomenon exists beyond the person's experience. In this sense, interpretivist researchers also tend to follow an inductive process to carry out their research (Creswell & Clark, 2011).

From a sustainability perspective, an interpretivist stance seems to be suitable to address issues related to sustainability in construction in which complexity and vagueness are evidently witnessed, as highlighted by both Higham (2014) and Waas *et al*. (2011). This allows the potential participants to express their perceptions associated with the sustainability in housing investments, setting out the concept as a normative model requiring a sense of quantification, reliability, and verifiability (Conard, 2013), which are difficult to be driven through following a purely inductive approach. As such, whilst an interpretivist stance was adopted within certain parts of this research, it does not seem entirely sufficient to meet the research process of deduction that is required to generate the desired model of the study.

Constructivist Epistemology

Constructivists believe that the social world exists as a result of social interactions so that the social phenomena are constructed on the basis of individual perceptions (Dainty, 2008). As such, a social objective is not discovered but instead constructed (Crotty, 1998). This implies that there is no single truth, but multiple realities depending on time and context, which means it has subjectivism or relativism ontology. According to this perspective, the constructed knowledge, as Dainty (2008) argues, might not represent the truth, rather it merely reflects the individual experiences. The main focus of constructivists, therefore, is to narrow the chasm between objectivist and subjectivist stances (Dainty, 2008), whilst following an inductive process to investigate phenomena being researched (Creswell & Clark, 2011).

For this study, the aim was to investigate various experts' perceptions in relation to sustainability phenomena based on their engagement in the housing sector. However, it can be argued that sustainability-oriented investigation is based on two sets of enquiries: social structured and numerical underpinnings. This leads to inevitably adopting the philosophical position of pragmatism.

Pragmatist Epistemology

The school of pragmatism "mixed or hyper methodology" emerged to benefit from advantages and alleviate the weaknesses of positivism, constructivism and the interpretivist paradigm. Pragmatism is based on the belief that the problems are sovereign, not the methods used to understand them (Creswell, 2013b). As such, the pragmatists' claim is fundamentally towards knowledge, preventing any precise ontological and epistemological stances. The ontological stance of pragmatism understands the reality that it may be singular, but that multiple reality also exists or is known as 'critical realism' (Maxwell, 2008). Pragmatist pursuits acknowledge both objective and subjective stances since they use quantitative and qualitative data collection to inform the phenomena, so they adopt mixed methods and follow an abductive process, which is extracted from both induction and deduction (Creswell, 2013a). In the abductive approach, researchers are often swinging between inductive and deductive ones, building a theoretical perception of the phenomenon based on the participant's experiences and understandings (Cohen *et al*., 2013). Mixed method approaches have a genuine interest from pragmatist purists, owing to their ability to provide sufficient instruments fitting with multiple tasks, aligning with both the depth and the breadth of data collection (Creswell, 2013a).

For the purpose of this study, it seems clear that the pragmatist paradigm is more suitable to fulfil the main task of the study. Adopting this perspective allows the researcher to freely move between epistemological stances in a way that facilitates employing the desired research instruments in order to offer the best solution to the problem being researched.

5.3.3 Axiological Perspective

The axiological position refers to the researcher's values in their research. This influence plays an important role in comprehending the research findings. Valid axiological positions are either value free or value laden. Within a positivistic assumption the researcher axiologically is assumed to be detached from what is being researched which means they are values-free and unbiased. As Saunders *et al*. (2016) explain, a value free assumption can be traced back to the fact that the data collection is independent from the researcher. In contrast, interpretivists assume that the researcher is attached to the research data so the researcher's influence is present and value laden and therefore it should be acknowledged that the data is biased by many social factors such as culture, experiences and perceptions (Mertens, 2009).

5.3.4 Philosophical Stance Adopted and Justification

In order to justify the appropriate research design, researchers should approach their work in light of the aforementioned assumptions. Nonetheless, the literature of research philosophy relevant to Construction Management (CM), as Dainty (2008) observed, has not yet had a robust philosophical foundation upon which a researcher could draw a reliable design. Instead, the discipline can be seen to be swinging away from social science whilst chasing applied knowledge (Dainty, 2008). In fact, as advocated by Dainty (2008), this leads to be confused between a wide range of conflicting theories and philosophies.

On the other hand, the broad spectrum of methodological philosophy makes it more flexible for researchers to adopt the most relevant to the nature of the inquiry. As discussed in detail earlier, adopting positivism, interpretivism or constructivism solely, would not deliver the desired data. In addition, the position of the pragmatist stance has been determined for this study based on the fact that the nature of the subject area - sustainable homes – is a poorly defined phenomenon characterised by uncertainty and complexity, as discussed earlier, therefore requiring an exploratory stance through an inductive process and with a qualitative method. However, developing a sustainability-based assessment model needs some form of norm orientation that allows for quantitative evidence. The decision to adopt the pragmatist philosophy through this research is clearly shown in line with Higham (2014), Fellows (2010), Greenwood and Levin's (2005) views which explain that the more effective research is the more comprehensive investigation conducted that allows for the integration of multiple perspectives. Therefore, it is assumed that a pragmatic perspective can provide an overreaching comprehension of the phenomenon being researched. This stance is believed to allow the researcher to freely choose from a wide range of research instruments in order to accomplish the main task of this study.

Moreover, since this research aims to examine the current sustainability practices in Libya's housing sector, and due to the engagement with various participants in this process and the fact that their perceptions are socially constructed, the research axiologically falls mainly on the value laden stance.

In summary, the philosophical assumptions underpinning the research methodology have been discussed which allows for the philosophical position underpinning the methodology to be established. In relation to this understanding, justification of the methodological decisions made for delivering this study is offered after highlighting the possible research approaches presented by the relevant literature in the section that follows.

5.4 Research Approach

Research approach, as Saunders *et al.* (2016) point out, is linked to theory development, enabling researchers to meaningfully meet the research targets. As Bryman (2015) explains, guiding research by a theory is a critical issue because of its influences on the research design. The principle objective of identifying a theory to research is to link the phenomenon researched with the body of knowledge (Bryman & Bell, 2015). In this sense, the research approaches are divided into two key types, inductive and deductive approaches. Induction or a down up process moves from the specific to the general, employed when establishing a qualitative research study with no development of a theory (Gray, 2014). Inductive logic is theory loaded, based on evidence and general inferences which might eventually lead to generate a theory. As such, the theory would be developed on the basis of evidence collected through qualitative inquiry. By contrast, deduction or an up down process moves from the general to specific or theory to hypotheses, starting from conceptual or theoretical structure and developing so it can then be empirically and rationally tested (Gray, 2014). Deductive logic is considered as data-driven using quantitative inquiry. As such, deduction can be seen as a predictive process or theory tested. In addition to this, the third orientation represents a combination of the previous inductive and deductive logic, which is referred to as abduction where the researcher mixes both qualitative and quantitative evidence in line with the pragmatic philosophy (Saunders *et al.,* 2016).

This research uses secondary data and conducts integrated analysis of well-established sustainability together with an examination of the complex sustainability interventions in housing investments through constructing various experts' perceptions, which implies adopting an inductive process. Further investigation has also been conducted in order to obtain an overarching vision and to predict the most applicable sustainability indicators for Libya's housing projects which require a deductive logic. As such, a pragmatist stance was needed to establish the desired model, therefore, an abductive process is required to fully achieve the targets of the study.

Having justified the research approach of the study, the next layer of the research onion, the methodological choices, will be discussed in the section that follows.

5.5 Methodological Choices

Methodology is defined by Saunders *et al*. (2016) as the theory of how inquiry should proceed. In other words, methodology drives the research effort along its path. Conventional research methodologies have for a long time been trapped between two choices, quantitative or qualitative research (Bryman, 2015). Quantitative inquiry is based on objectivist ontology and positivist epistemology along with a deductive process, whilst qualitative inquiry has subjectivist and interpretivist stances in the form of induction. As such, quantitative research is often employed to test hypotheses in natural sciences, whereas qualitative research is employed to investigate social phenomena. However, the relative value of quantitative and qualitative has increasingly become the focus of controversial debate, leading pragmatists to bring forward a view of the world that is not an absolute unity, so that pluralist research designs can be acknowledged. For many scholars (e.g. Bryman & Bell, 2015; Creswell, 2013b; Tashakkori & Creswell, 2007), both quantitative and qualitative research have their problematic issues which most often result in biases, so that a combination of different methodological perspectives in one inquiry paradigm is critical to overcome the weaknesses in each approach while enhancing the validity of the overall output of a research study. The pragmatist researchers are willing to carry out a variety of approaches for collecting and analysing different evidence rather than sticking merely to a single methodological stance (Mertens, 2009). In relation to this, Creswell (2013a) asserts that researchers should choose their approaches depending on determinants such as the nature of research questions, researcher experience, and the audience. The next sub-sections highlight in detail the main distinguishing attributes of qualitative, quantitative and mixed method methodology.

5.5.1 Qualitative Methodology

Qualitative research is more likely to perceive human experience and knowledge since it is typically associated with social and cultural investigations. Creswell (2013b) describes qualitative research as 'an inductive, interpretive, and naturalistic approach' to the study of people, cases, phenomena, social situations, and processes in their natural settings in order to reveal the perceptions that people consider regarding the phenomenon being researched. Qualitative research employs a relatively small sample size of participants and relies on words as data, rather than numbers (Braun & Clarke, 2013). With an adequate number of participants, qualitative research tends to produce narrow but rich data, with detailed descriptions and complex narratives from participants (Braun & Clarke, 2013), capturing facets of social reality while considering and examining differences within data so as to understand and interpret the essence of a phenomenon (Braun & Clarke, 2013). Qualitative research, as Creswell (2013b) indicates, can benefit researchers to gain a deep insight into complexities. Qualitative data is collected via means such as open-ended surveys, interviews, focus groups, observations, or ethnographies (Creswell, 2013b). Qualitative methodology basically, as Braun and Clarke (2013) explain, has two principle distinctions which are: (i) inductive, this is because the research starts from the specific and ends with a general phase which means a down-up approach, so it is used to develop theories; and, (ii) subjective, this can be traced back to researchers' value interference throughout the research process.

Qualitative methodology has some distinct strengths as Creswell (2013b) indicates. A qualitative approach offers the option of selecting a small sample size to deeply focus on, considering participants' perceptions as the main source of data. A qualitative approach is ideal for carrying out research of complex phenomena because it provides more detailed descriptions of individuals' experiences. However, the qualitative methodology has its own weaknesses. It may not be sufficiently rigorous, lacking in validity and reliability, and it is unlikely its findings will be applied in a systematic, consistent manner (Creswell, 2013b). The generalisability of results, as Bryman (2015) indicates, is also an issue, seen as a weakness that affects the findings of qualitative research.

5.5.2 Quantitative Methodology

Quantitative research is typically associated with the natural sciences that are intended to investigate natural phenomena. This form of research involves the explanation of a social science phenomenon using mathematical based approaches. As Creswell (2013a) demonstrates, quantitative methodology is a type of empirical research into a social phenomenon or human issues through the testing of theories consisting of variables which are measured with numbers and analysed with statistics in order to determine whether or not the theory explains or predicts the phenomenon. It often seeks to examine relationships between variables in order to interpret or predict a phenomenon (Bryman, 2015). The quantitative data collected is often broader than qualitative, but has less depth (Creswell, 2013b). Therefore, quantitative research is unlikely to collect complex detailed data. Rather, quantitative research simplifies the diversity of responses in order to establish a generalisation of the findings (Saunders *et al*., 2016). Quantitative research is attributed with two characteristics, which are: (i) deductive, this means that it is used to test theories because it starts from general and ends with specific level or up-down approach; and, (ii) objective, this means it detaches the researcher from the researched (Braun & Clarke, 2013).

In a social science domain, the most common quantitative method used is the survey technique. The advantage of adopting a quantitative survey approach is that it employs a large sample which is more representative (Creswell, 2013b). Data collected can also be statistically analysed via advanced software (Creswell, 2013b). A quantitative approach offers a clearer summary of key components of findings that are applicable for re-researching by other researchers (Braun & Clarke, 2013). However, there are also weaknesses affecting quantitative methods since they require the participants' perspectives to fit into pre-determined response categories (Braun & Clarke, 2013). As Bryman (2015) indicates, employing such methods for examining social reality might not reflect the genuine realities of the participants. Creswell (2013a) also notes that quantitative research usually misses out participants' perceptions and understandings from the collected data, confirming that statistical samples in quantitative methods are unlikely to represent particular social groups or individuals' perceptions.

5.5.3 Mixed Methodology

A mixed approach is a sort of research that allows researchers to combine both qualitative and quantitative methods. As Tashakkori and Creswell (2007) identify, a mixed methodology is:

> *"research in which the investigator collects and analyses data, integrates the findings, and draws inferences using both qualitative and quantitative approaches and methods in a single study or program of inquiry" Tashakkori and Creswell (2007, p.12).*

Mixed methodology employs inductive and deductive or also known as an abductive approach (Creswell & Clark, 2011). Thus, mixed approaches benefit from two types of evidence, qualitative data which is extracted directly from the participants' perceptions and provides rich descriptive details, whilst quantitative data which enhance objectivity and generalizations as numerical are derived from an extensive sample size (Cohen *et al*., 2013). Mixed approaches, as Creswell and Plano Clark (2011) advocate, pay greater attention to the actions and consequences of the research, and its primary focus is on the research question rather than the method itself.

It is agreed that there are considerable advantages to using a mixed approach. The use of mixed methodology can minimise the weaknesses of the two quantitative and qualitative approaches (Creswell & Clark, 2011). Offering researchers the flexibility and ability to be integrative (Maxwell, 2008), mixed methodology can address both sets of questions, providing the depth of qualitative understanding and the breadth of quantitative techniques which strengthens the data collection and reinforces the findings (Cohen *et al*., 2013). Moreover, this approach is useful when either the quantitative or the qualitative approach alone would not be adequate for addressing the research questions. Another advantageous point, as highlighted by Creswell and Clark (2011), is that the findings of a mixed approach are generalizable.

In light of this, it can be argued that the broad spectrum of methodological philosophy and instruments makes it more flexible for a researcher to adopt the most relevant approach to the nature of enquiry. For this study, as mentioned earlier, a mixed methodology approach is adopted to fulfil the aim of study. Further justification for this decision is provided in the section that follows.

5.5.4 Methodological Approach Adopted and Justification

The theoretical model of this study addressed within the previous chapter together with the research objectives have explained the main features of the methodological approach that should be employed. Initially, the principle purpose of this study is to provide a decision support system to promote sustainable development in the Libyan housing projects. This stems from the central aim of the study, namely: "*To customise an applicable* *composite index for assessing Libya's sustainable homes*". To respond to this aim, it is appropriate to set the concept of sustainable homes as a normative model determining the relevant criteria that enables the assessment of their characteristics against the potential performance. The exhaustive review of existing literature revealed no robust research has been conducted to date to investigate the key sustainability indicators for housing projects in Libya (Elgadi *et al*., 2016; Shibani & Gherbal, 2016; Almansuri *et al*., 2009). Consequently, it was determined that the research would have to initially provide an inductive exploration of the meaning of sustainability within the Libyan context, and specifically the factors likely to influence sustainable design and construction. In line with this, the concept of sustainability, as defined by Waas *et al.* (2011), is:

> *"Sustainable Development implies societal and normative choices, which are ultimately based on the values we maintain" (Waas et al., 2011, p.9).*

This makes it difficult to derive a set of sustainability-based criteria purely from the concept of sustainability with a deductive approach. Sustainability is evidently a poorly defined, complex, and vague construct, which, as Braun and Clark (2013) state, requires a deep investigation through qualitative data underpinned by interpretivist assumptions. Therefore, a deep discussion and rigorous understanding about what future homes demand to meet the sustainability requirements is needed. However, a purely qualitative research design would present some limitations for the attainment of this aim. For example, difficulties in applying it (i.e. access or interpretation), data analysis, and generalisation of findings (Creswell, 2013b), whilst qualitative research would also present distinct strengths such as being more interactive, as researchers structure the meaning from the participants' experience and knowledge, applying an adequate sample in depth, flexibility, and convenience (Bryman, 2015). Thus, an inductive approach that allows reflection and discussion is an important approach for satisfying a part of the inquiry in this study.

On the other hand, the nature of the research seeks to justify a set of criteria to develop an assessment model, and this epistemologically demands a sense of objectivity in its process, requiring a quantitative method underpinned with an objectivist stance and statistical techniques for data collection and results. As Cohen *et al*. (2013) advocate, a quantitative approach presents quantitative evidence, enhancing the objectivity and generalisation. As a result, mixed approaches through an abductive approach extending across the boundary between qualitative and quantitative approaches is inevitably needed to efficiently respond to the questions identified through the study in hand.

In using such an approach, a researcher can use a variety of combinations of mixing the methods to carry out research depending on the timing, integration level and priority given to the quantitative or qualitative aspect of the research (Creswell & Plano Clark, 2011). In this sense, the mixed methods approach, according to Bryman (2015), can be conducted using four key techniques: (i) triangulation, which is used in parallel quantitative and qualitative approaches; (ii) exploratory, which involves sequential use with qualitative proceedings; (iii) explanatory, involving sequential use in reverse order; and, (iv) embedding one type of method to supplement other techniques. Amongst various combinations, for this study, exploratory sequential mixed methods approach is considered the most appropriate approach because it mainly gives the priority to an interpretivist stance with the inductive process as a predominant method. Starting with qualitative evidence can help to get in-depth data regarding the crucial determinants influencing sustainability in housing investments, then moving on to the positivist stage with a deductive process and quantitative evidence to build up a solid worldview by which the researcher gains insights into the phenomenon of interest. Even though the two stages are separate, they are connected later through the data interpretation and discussion. Hence, this methodological design, as advocated by Creswell and Clark (2011) and Morgan (2007), is distinguished as being easy to apply and preferable to non-experienced researchers.

Against the understanding of Saunders *et al.*'s (2016) onion, together with the methodological considerations defined for this research and described earlier, it can be concluded that the pragmatic paradigm is consistent with the purpose of the study. Consequently, a mixed methods approach adopting an abductive two-phase process with a qualitative inductive process at the outset followed by a quantitative approach to rank and sort the emergent variables whilst ensuring generalisability, is the methodological decision that is considered appropriate for this study. This can be traced back to the nature of the subject area of the study which is concerned with sustainability in housing investments as a poorly defined phenomenon characterised by uncertainty and complexity and needing an exploratory stance via an inductive process with qualitative method. Developing an assessment model for sustainable homes in Libya implies the need to utilise a statistic approach which allows for obtaining quantitative evidence and gaining rigorous findings.

5.6 Research Strategy

The research strategy is a methodological inquiry by which meaningful research can be carried out in order to respond to certain goals. As asserted by Saunders *et al.* (2016), the research strategy should be in line with the philosophical assumptions adopted for the study, so as to ensure consistency and harmony between the research design and consequently, realise robust results. This also implies that an appropriate research strategy decision is made on the basis of research objectives, taking into account the time limit, resources available as well as research experiences (Bryman, 2015). Reviewing the relevant literature reveals that there are a wide range of research strategies that exist in the knowledge fields. According to Saunders *et al.* (2016), there are five different types of research strategy: experiment, survey, case study, action research and ethnography. Denscombe (2010) further divides this group into two strategies of grounded theory and phenomenology. Furthermore, Yin (2014) suggests history and archival analysis to be among the research strategies which facilitate the conducting of research, especially regarding historical events. However, Yin (2014) has been criticised for ignoring key research strategies such as action research and ethnography in his classification, despite their importance in relevant research studies. Nonetheless, the critical issue remains as to whether or not the research strategy adopted is able to deliver the desired data by which the planned targets are achieved.

In relation to this understanding, research strategies as summarised by Sexton (2003), can be incorporated into a research philosophical continuum, as shown in Figure 5.4.

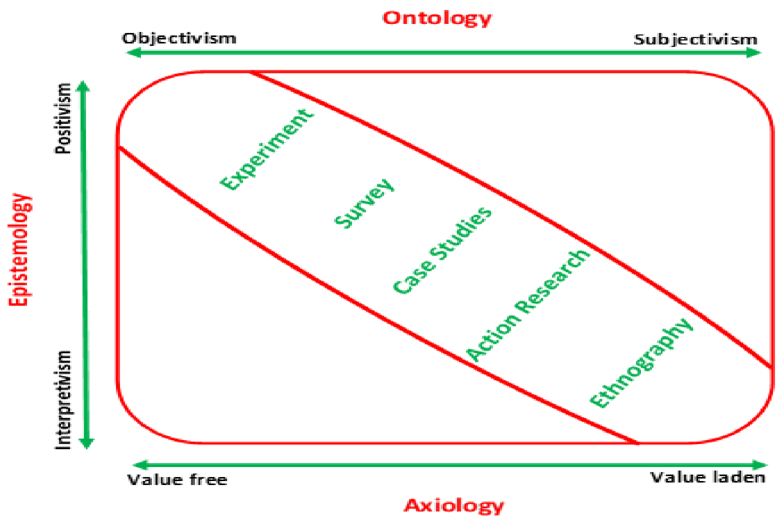


Figure 5.4: Research Strategies Incorporated into Philosophical Stances. (Adapted from Sexton, 2003)

As shown in Figure 5.4, a range of research strategies can be adopted based on the philosophical continuum, namely ontology, epistemology and axiology. This includes experiments, surveys action research, ethnography, and case study approaches. A brief review of these strategies is presented as follows:

Experimental Studies Strategy

The experimental research is a study that closely adheres to a scientific research design. However, the term of experimental study has a wide range of definitions. In the strict sense, experimental research is what is called a true experiment (Yin, 2014). There are three key types of experiments identified by Yin (2014): laboratory experiments, field experiments, and natural experiments. Typically, an experiment is designed to examine the influence and relation between variables in certain quantitative phenomena by controlling the tools, participants and environment. The scientific experiment is established based on a hypothesis that can be manipulated by the researcher, and variables that can be measured, calculated and compared (Yin, 2014). The data then is collected, and results are presented to determine whether to support or reject the hypothesis. An advantageous aspect of experiment research is that it has an objectivist stance and is value free, so that makes the outcomes more valid, and reliable. As the ontological assumption of this study leans towards the relativist stance, the use of experiments is unjustifiable. Experimental studies are carried out in certain environments that are controlled and in which the context and the phenomena are separated.

Survey Based Studies Strategy

Survey study is a type of research strategy which is valuable to social science, involving the collection of evidence from a specific sample of elements drawn from a defined population (Saunders *et al*., 2016). There are various survey techniques a researcher can adopt. These techniques are broadly distinguished into two types according to instrumentation and according to the span of time involved. One technique includes the questionnaire and the interview, whilst the other is comprised of cross-sectional surveys and longitudinal surveys. Cross-sectional surveys involve the collection of data at a single point in time from a sample drawn from a specified population. This strategy is used to document the prevalence of particular characteristics in a population. By contrast, longitudinal surveys aim to collect additional evidence from independent samples drawn from the same population at more than one point in time. Whilst the main advantage of using surveys is that a large amount of data is generated, there is a primary limitation of survey research, where surveys are deemed relatively expensive and time-consuming. However, many cost-saving approaches can be implemented (Maxwell, 2008). Saunders *et al*. (2016) is of the view that surveys can test phenomena, but their ability to investigate the context is still questionable. In contrast, as reported by Maxwell (2008), the combinations of both quantitative 'questionnaires' and qualitative 'interviews' data can be highly beneficial, allowing a researcher to meet various aims. This study, therefore, adopts a survey-based study strategy because it concerns sustainability interventions in the housing sector which requires the researcher to be engaged with as many stakeholders from different perspectives in order to customise a set of criteria for sustainable homes in Libya. Furthermore, this strategy helps to verify and generalise the research findings. Therefore, a survey-based study strategy is considered the most suitable research strategy that can deliver efficient evidence needed to address the research objectives. Thus, the decision to adopt a survey-based study has been justified in this section by considering the nature of the study and its philosophical assumptions, and more justification for this choice is provided in the subsequent sections.

Case Study Strategy

A case study strategy as defined by Yin (2014, p.18) is "an empirical query that investigates a phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident". As such, adopting a case study can assist researchers in investigating the phenomenon, allowing them to gain an in-depth picture of the relationships and processes within the phenomenon. The case study has the ability to provide various evidence through observations, documents, artefacts, questionnaires and interviews, but as Yin (2014) points out, the case study strategy is shown to be strictly close to qualitative approaches. According to Yin (2014), case studies can be carried out with three different purposes: exploratory, descriptive and explanatory, in which a researcher can employ single or multiple case designs, either holistic or embedded. As reported by Yin (2014), a case study strategy is suitable in the case of questions related to a contemporary set of events over which the researchers have no control, allowing researchers to investigate the relevant problems from different aspects and various levels in which in-depth evidence can be generated. However, this particular study does not intend to deeply explore the current practices related to sustainability in the housing sector; instead, it mainly seeks to investigate various perceptions of the sustainability phenomenon related to housing investments, and therefore the case study strategy is deemed unsuitable for this research inquiry.

Action Research Strategy

The aim of adopting action research is to contribute regarding practical problems in an immediate situation and towards the goals of social science by joint collaboration within a mutually acceptable framework in order to enhance current practice (Carr, 2006). The development of the action research strategy, as reported by Day *et al.* (2006), was established in the education domain. Action research strategy is described as iterative activities involving a range of continuing actions such as diagnosing, planning, and evaluating (Saunders *et al*., 2016). The participants in action research have a critical role, conceiving the practice with the aim to reform performance as well as improving their own understandings (Day *et al.*, 2006). Despite delivering in-depth evidence regarding the phenomenon being researched, action research strategy would not be a suitable strategy in this study because it is not the intention of this research to evaluate the in-depth current practices of the housing sector nor to influence the attitudes of the participants; instead, it seeks to explore applicable sustainability-based indicators.

Ethnography Strategy

Ethnography as a social science research strategy concerns the description of people or small-scale societies by considering the researcher ethnographer as a research instrument. As defined by Harris and Johnson (2000, p.13), ethnography is “a written description of a particular culture - the customs, beliefs, and behaviour - based on information collected through fieldwork". Saunders *et al.* (2016) define an ethnography study as a strategy that is “highly time consuming and takes place over an extended time period as the researcher needs to immerse herself or himself in the social world being researched as completely as possible”. This study does not intend to study physiology or behavioural patterns of the participants or understanding of the culture of a population, rather, it is concerned with the construction of experts’ perceptions of the most effective sustainability based interventions in housing projects, and hence, the ethnography strategy is not suitable for this study.

5.7 Time Horizon

The time horizon layer, as described by Saunders *et al.* (2016), has been divided into two types, namely cross-sectional and longitudinal. This classification was determined based on the time period involved for the research to be carried out. In this regard, the study can be classified as a cross-sectional study, which is limited to particular times and a particular phenomenon (Saunders *et al*., 2016). Although the research instruments applied are distributed at different points in time, these techniques are concerned with the same study. The approach, therefore, remains a cross-sectional study. In contrast, a longitudinal study allows for data to be collected at more than one point in time in order to examine a particular phenomenon and control changes and development over time (Saunders *et al*., 2016). The study therefore does not consider examining changes of a particular phenomenon over a particular time, rather it is bound to a time schedule of PhD studies, so this means cross-sectional is the time horizon of the study.

5.8 Research Techniques and Data Analysis

Having discussed various philosophical assumptions, methodological approaches as well as the research strategy adopted along with identifying the time horizon, the foundations are now laid to be able to discuss the research techniques adopted for this study. It is suggested, based on previous understanding, that a focus group interview and questionnaire are sufficiently appropriate to fully accomplish the research targets in this study. These techniques will be the focus of the discussion through the upcoming sub-sections, followed by addressing the analysis tools and strategies adopted to report the results of this research.

5.8.1 Research Techniques

The study as mentioned earlier has adopted a pragmatic methodology which allows for the use of both qualitative and quantitative evidence. From this perspective, a focus group, and questionnaire survey have been subsequently conducted since it was evident that they were suitable for gaining a response to the research queries.

5.8.1.1 Focus Group Technique

Focus group interview is considered as the first empirical research method to be used through the ongoing study. Focus group technique has become one of the principle research techniques used in business and management, providing insights into how people think and obtaining a deeper understanding of the phenomena being studied (Litosseliti, 2003). It is highly recommended that to gain deep and rich data, the focus group should be designed in a proper manner using an adequate number of participants with the aim of establishing a rigorous focus group session to ensure investigating the phenomenon being researched.

Intent and Justification

This study aims to conduct a single focus group interview in order to reinforce the discussion undertaken through the literature review and guiding the objectives of data collection from the next step of the questionnaire. As reported by Saunders *et al*. (2016), the adoption of focus groups particularly in exploratory research can facilitate designing the subsequent phases of surveys through identifying the required questions that should be delivered. However, the technique of focus groups has been adopted instead of just individual interviews because the latter was not advisable as it was considered insufficient to deliver the desired data which tends to be normative in essence (Litosseliti, 2003). The economic perspective is critical, but other benefits from adopting focus groups will be raised if it was compared to interviews. Whilst it can be beneficial to generate in-depth data, conducting interviews seems an expensive proposition that can exceed the available resources, whilst focus groups can give the researcher the ability to more economically capture deeper data than individual interviews (Boyce & Neale, 2006). In addition, as Boyce and Neale report, group interaction and non-verbal communication are other key advantages of focus groups. The interaction between interviewees in focus groups can effectively encourage and promote best solutions and suggestions whilst highlighting any similarities or disagreements between viewpoints (Boyce & Neale, 2006). Litosseliti (2003) goes further to assert that the focus group is an ideal instrument to generate ideas through brainstorming sessions and achieving a shared understanding of the examined phenomenon. Non-verbal communication is also vital data that is captured through holding a session of focus group. Interviewees in focus groups often react differently to certain issues (Litosseliti, 2003). This type of interaction can provide significant data reinforcing the analysis process. As such, the focus group as pointed out by Cooper (2011), allows the researcher to observe the way in which participants collectively make sense of an issue while constructing meanings around it. Furthermore, typical interviews fundamentally depend on the moderator ‘researcher’ who manages the session of interviews through his or her questions which more often delivers unconscious cues to the participant thereby influencing the responses in a particular way (Boyce & Neale, 2006). In the avoidance of such bias, the researcher was eager to remain neutral and to not offer hints nor suggestions that might affect the participants' views. Therefore, the main rationale for the adoption of the focus group technique was to overcome the disadvantageous aspects of the interview, allowing the participants to fully engage with the phenomenon under consideration, as advocated by Litosseliti (2003), and obtaining a great level of consensus regarding the themes examined, whilst it allows the researcher to compare and complement the results (Boyce & Neale, 2006). On the other hand, it might be argued that other methods such as the Delphi questionnaire is appropriate for this phase of the study. The basic idea of Delphi studies is to use expert opinions in iteration processes to solve the problem and to use anonymous feedback (Linstone & Turoff, 2011). It has believed that through frequent responses, the information returned as feedback results in a better judgment than a simple questionnaire. The preference between the method of the Delphi survey and the focus group, as argued by Loo (2002), depends on the characteristics of the research subject, the structure of the group of experts and the present framework conditions. For this study which seeks to customise a set of sustainability-based criteria for housing projects, the focus group is at an advantage compared to the method of Delphi survey because the former allows more space for discussion and brainstorming between participants than those in the Delphi questionnaire. Moreover, the Delphi questionnaire would have been too time consuming and seems riskier because of the potential drawbacks of the Delphi technique as absorbed by Linstone and Turoff (2011). As such, taking into account these attributes, the focus group technique is deemed more preferable for this study.

Nonetheless, the focus group in turn has some disadvantageous aspects, especially related to the moderator, the person who facilitates the focus group session. The moderator plays a critical role in focus groups. A well-skilled moderator is able to promote and guide discussions in accordance with the desired targets whilst a poor moderator dominates the conversation and prevents the participation or loses the focus of discussion. The optimal control over the focus group session, however, is not easily achieved by the facilitator as the tendency for the interviewees to move away from the point of the research remains high (Boyce & Neale, 2006). This disadvantage, however, can be overcome if a facilitator is well-skilled in relation to the session management. The moderator, 'the researcher', in the focus group can benefit from being a lecturer enabling them to manage the session in a sufficient manner. The justification for choosing the focus group for this phase, therefore, is that the participants are more likely to express different perceptions towards sustainable homes, whilst the interaction and dynamics occurring between those participants would allow for effective sharing of their knowledge which eventually optimises the outcomes.

Design and Data Collection

The primary aim of conducting a single focus group interview was to collect data about the most effective interventions related to sustainability in housing investments and to use the results to construct the subsequent phase of the large-scale questionnaire. In this sense, the focus group agenda has held a fourfold objective, including: (i) examining the position of the sustainability assessment in the housing sector in Libya; (ii) investigating the current practice delivered to assess the housing investments; (iii) investigating the main features that have been over-looked or underestimated within the prevalent schemes; and, (iv) delivering the most important sustainability-based features which are characterised in the Libyan built environment. These themes have been designed to be delivered in the form of open-ended questions as this can promote discussion in the focus group session (Boyce & Neale, 2006). The facilitator in the focus group session, as suggested by Saunders *et al.* (2016), should prepare an organised script for the focus group session in order to explain to participants the targets, rules, and other information that is thought to be important. Thus, the researcher prepared a script for the session of the focus group which put the participants in the situation and made clear the duties and rights that should be considered. Additionally, as suggested by Litosseliti (2003), the location that the focus group is intended to be held in, should also be safe, comfortable and adequate for conducting a conversation. To ensure this, the focus group was held in the University of Tripoli in a convenient, integrated hall (see Section 6.2.1, p.136 for a detailed discussion of design and procedure).

Sampling Quality and Size

Another critical issue raised is who should be involved in this discussion and the structure of the focus group sample. As Bryman (2015) reports, establishing the expertise of the participants affects the quality of the outcomes. In contrast to quantitative research, as asserted by Bryman and Bell (2015), the sampling in research with a qualitative perspective is less significant as this concerns more the quality rather than the quantity. Again, according to Cooper (2011), a focus group does not utilise random or probability samples, instead, it is more likely to follow a purposive sampling strategy. Random samples give the chance of each subject in the entire population to be equally selected. By contrast, in non-random samples, the chance of each subject being selected from the population is not equal. The purposive sample as a sub-set of non-probability sampling, encompasses members with characteristics of the overall population helping to gain greater insights into the phenomenon being researched (Cooper, 2011). Purposive sampling, as defined by Cooper (2011, p.167), is "a research sample that allows researchers to choose subjects for their unique characteristics or their experience, attitudes or perceptions". The purposive sample is generally employed to examine precise demands that need specific conditions for potential participants where this query is not possible to be achieved with a random sample (Creswell, 2013b). From Saunders *et al.*'s (2016) perspective, purposive sampling is a technique for selecting members who can enable researchers to achieve efficient responses to their research questions.

With this understanding, the sample for the focus group interview was purposely selected. The rationale for adopting a purposive sample is that the study looks for experienced and knowledgeable academics and professionals whose core research subject is sustainable homes. The potential participants can be selected by designing a set of criteria that should be met for participation requirements in accordance with the study query (Creswell & Clark, 2011). A review of published studies (e. g. Bryman, 2015; Cohen *et al.,* 2013) highlights a range of criteria of which experts should be qualified. This can include: (i) publications in the field; (ii) signs of professional eminence such as leadership, membership, or holding office in a professional society or organisation; (iii) peer judgment and recommendations; (iv) honours by professional societies; (v) self-rating of the expertise in the relevant area; (vi) presentations made at national conventions; (vii) relevant years of experience; (viii) selection for comment by national or regional media on relevant issues; and, (ix) the number and importance of patents held. Therefore, it is important to carefully design the group expertise to ensure that the focus group generates rigorous results.

In light of this background, participants for the focus group have been selected based on 1) expertise in sustainability and housing investments so that they have all participated in at least two into journal articles, conferences related to the subject area; and 2) interest in developing criteria for sustainable homes. Therefore, the participants are supposed to not only have theoretically thought about the concept of sustainability, but they also were engaging within various actions associated with sustainability in built environment (e.g. books, research, conversations, responsibilities, etc.).

Aligning with this, as Saunders *et al*. (2016) reported, some participants are likely to feel uncomfortable in expressing themselves in front of a group of people with whom they are not familiar. As such, it is suggested that a sampling strategy of horizontal slicing, which means selecting subjects from closely similar backgrounds, can be helpful to reduce these adverse influences (Saunders *et al*., 2016). In consideration of these issues, the researcher adopts a purposive sample of a homogeneous group of experts who are considered senior practitioners, professors and administrators in the field of sustainability related to housing investments from different sectors, namely industry, academia, and government.

Identifying the necessary number of experts in the focus group is another important issue. The focus group, as Cooper (2011, p.719) states, is a "simultaneous involvement of a small number of research participants who interact at the direction of a moderator". However, the literature has no consensus on the number of participants in a focus group. According to Seidman (2016), the focus group usually involves two to four members while the optimal size to promote discussion in a focus group is 5-12 participants according to Bryman (2015). Given that there is no standard for the size of the focus group interview, and number of responses on the researcher's calls, the focus group was held with five subjects who demonstrated the required expertise and knowledge as well as all of whom were responsible for delivering aspects of sustainable development through their organisations. In fact, the current state of Libya (post conflict) as well as limited time and funds available are little conditions that have overweighed this sample size (see Section 6.2.1, p136 for a detailed discussion of procedure).

5.8.1.2 Questionnaire Technique

The questionnaire survey is a technique linked to the deductive approach, described as a set of proforma questions which is distributed to identified subjects in order to generate the desired data (Saunders *et al*., 2016). This type of survey helps researchers to collect a large amount of data from a wide research sample (Cohen *et al*., 2013). It is recommended that to gain wide and reliable evidence, the questionnaire should be designed in a proper manner using a suitable sampling strategy to ensure a rigorous questionnaire is established that can satisfy the investigation of the phenomenon in question.

Intent and Justification

This stage of the questionnaire aims to verify the results obtained from the previous stage of the focus group, which are related to the customisation of the most applicable categories and criteria for assessing sustainability in Libyan home investments. The questionnaire is considered one of the most common approaches to data collection (Saunders *et al*., 2016; Cohen *et al*, 2013; Creswell & Clark, 2011) in which researchers devise a set of written questions before distributing them to the target group. Data collected by using a survey technique can provide several possible explanations for the phenomenon of interest (Creswell & Clark, 2011) and it also has a number of advantageous aspects. For many, the questionnaire as a data collection tool, is relatively easy to implement with a wider coverage (Cohen *et al.,* 2013). Using questionnaires as reported by Cohen *et al*. (2013) can minimise the participants' pressure compared to interviews, which allows subjects to freely express their views and perceptions. Otherwise, there are potential disadvantages for using questionnaires including, the low response rate or the incompleteness and the difficulties of checking the truthfulness of respondents' answers (Creswell & Clark, 2011). However, these obstacles can be overcome or alleviated if the researcher designs their research well and follows a rigorous procedure of rules in relation to research tracking (Saunders *et al*., 2016). Therefore, the primary objective for the use of the questionnaire at this stage is to engage with as many experts from industry, academia, and government sectors which are related to sustainability in the Libyan housing projects with the aim of obtaining the perceived importance and drawing up the ultimate balance of sustainability needed in the housing investments.

Design and Data Collection

Researchers have several options to design the questions of the questionnaire. Saunders *et al*. (2016) report that the choices among different questionnaire types can be influenced by several aspects such as the research objectives, respondents' characteristics, sample size, and the number and types of questions. In this way, scholars (e.g. Bryman, 2015; Gray, 2014; Creswell & Clark, 2011) distinguish between three types of questionnaire, namely structured, semi-structured and unstructured. Structured questionnaires ask closed-ended questions and are mainly used with the quantitative perspective. By contrast, unstructured questionnaires are completely open, whilst semi-structured questionnaires use both close and open-ended questions. According to Gray (2014), questionnaires can be divided into two further nodes, descriptive and analytical. Descriptive questionnaires are designed to investigate the characteristics of a certain sample with the aim of identifying the variability in a phenomenon. Otherwise, analytical questionnaires seek to test a theory and to explore the interrelationship between the study variables. For the purpose of this study, the set of desired data from the questionnaire primarily concerns the collection of normative evidence, as opposed to opinion-based data (e.g. gathering perceptions or understanding meaning), which according to Field (2013), would advocate the use of structured, analytical questions.

The questionnaire content was mainly informed by the results obtained from the focus group conducted within the previous stage, covering the 43 criteria split up into the seven categories of the sustainable homes assessment model, namely: Management and Process; Materials and Recourses; Energy Efficiency; Water Efficiency; Waste and Pollution; Health and Wellbeing; and Location Quality. The participants were asked to indicate the importance of each criterion and define further criteria that are considered critical for the evaluation of housing projects regarding sustainability in the Libyan context (see Section 6.3.1, p.153 for a detailed discussion of design and procedure). The questionnaire developed in the study was initially divided into three parts:

i. Part one included the list of forty-three criteria identified from the earlier investigation. These criteria were classified into seven categories;
ii. Part two included a list of the seven categories where respondents were required to signal the level of their importance; and,
iii. Part three was related to general information of the respondent's field, discipline, qualification, experience, region and gender.

From another perspective, Saunders *et al*. (2016) classified the questionnaire in terms of its distribution into two types, interviewer-administered and self-administered. Interviewer-administered questionnaires are held when the subjects directly respond to questions either face-to-face or via the telephone. While self-administered questionnaires are completed by the subjects themselves through either the delivery by hand, postal questionnaire, and web-based questionnaire. In this respect, according to Carter and Fortune (2004), the web-based questionnaire has been increasingly in use since 1995, providing a new medium by which research data can be collected more quickly, at a lower cost with a higher rate of return. Not only do web-based questionnaires reduce travel and time costs, they also allow a wider sample of participants to be reached and for time to be saved for experts whose available time is very limited (Couper, 2000). As reported by Carter & Fortune (2004), one of the most important features of web-based surveys is that the data is generated instantly in electronic format. This allows the researcher to have data available earlier and it can be more easily transferred electronically into the analytical tools. The weaknesses linked to online-based questionnaires seem to be common to the other forms of survey (e.g. coverage and sampling, non-response, measurement, etc.). According to Couper (2000), one prominent issue associated with this type of questionnaire is sample selection. The potential participants in a web-based questionnaire require access to internet which is not always available to some subjects. As such, this may lead to a low response rate non-response bias (Couper, 2000). However, a non-random sample like 'convenience sample', as adopted in this research, is flexible with a pre-recruited list sample which allows the researcher to ensure higher response rates. There are ethical matters to consider with the use of online-based research. In its guidance 'ethical decision-making and internet research', the Association of Internet Researchers (AOIR, 2012) emphasises a range of important aspects relevant to the field of Internet Studies and the ethical perspective. As AOIR (2012) stress, the privacy issue is one matter that emerges with the use of internet research. Since web-based research is likely to be conducted across different countries with various ethical standards, Carter and Fortune (2004) suggest researchers should recognise these issues in their studies. In this respect, the researcher obtained ethics approval from the Research Ethics Guides issued by the University of Salford and confidentiality and anonymity were maintained in all stages of the research. A web-based questionnaire mode was adopted to distribute the questionnaire to the targeted sample. The questionnaire was issued in electronic format via a commercially available online survey application. Indeed, the development of communication technology and the spread of the internet have allowed for expanded sampling of research to be conducted more easily and reaching a wider spectrum of views on the subject area being researched.

As recommended by Field (2013), a pilot survey is vital to evaluate the clarity and comprehensiveness of the questionnaire, as well as the feasibility of the survey as a whole. The proposed questionnaire was initially tested by particular participants to test the context and consent of its design and to investigate the precision of questions being asked and to establish suitable questions to provide the required information and establish the final questionnaire. The questionnaire was piloted, recruiting 45 participants to gain their feedback and thus, devise the final version of the questionnaire. Piloting the study allows the reliability of the instrument to be tested through employing Cronbach's Alpha. Given that no significant matter emerged from this stage, as suggested by Field (2013), the collected data from the pilot study has been included in the main study data set. (see Section 6.3.1, p.153 for a detailed discussion of procedure).

Sampling Quality and Size

Since the first step in the selection of an appropriate sample is the determination of the population of the study, it is necessary to clarify the extent to which the total population actually is representative (Bryman, 2015). The population can be identified by those who are engaging within the phenomenon of interest (Bryman, 2015). As mentioned earlier, this study aims to define the most applicable categories and criteria for assessing sustainability in home projects in Libya. Various groups of specialists involved in the house building process will be consulted, including: Architect, Quantity Surveyor, Structural Engineer, Civil Engineer, and Construction Manager, all of whom have traditionally been the major specifiers (Emmitt & Yeomans, 2008). Bearing in mind that the analysis unit in this research is the Libyan public house projects, it can be argued that the population of the study encompasses all local and international professionals, contractors, consultants, academics, etc. who are involved in activities related to the implementation of sustainability within the Libyan home projects. Based on this understanding, it is quite difficult to pinpoint or speculate the size of the research population because it has the probability to merge a very wide variety of subjects. In this case of an infinite size of population, consequently a known portion of the population was excluded so that non-random sampling strategies were adopted in this research. It might be argued here that selecting a research sample randomly would be beneficial for this study, however, Sapsford (2007) advocates that representativeness, which is the ultimate target for any sampling strategy, may also not be achieved even with the use of random sampling.

Both Bryman (2015) and Creswell (2013) suggest that researchers should always aim to narrow the population's scope and purpose; it is essential that the research sample should be designed carefully to represent the entire population and, as such, it must sufficiently reflect the population's characteristics. One of the most common types relevant to the non-random sampling strategy is “convenience sampling”. This strategy was adopted not because such sampling strategy is necessarily easy to recruit, but because it is often used with whichever individuals are available rather than selecting them from the entire population. Furthermore, limited time, funds and data available as well as the current state of Libya (post conflict) and the risk associated with collection of data to some extent, have made it necessary to adopt this sampling strategy. To reinforce the choice of convenience sampling and its representativeness, the research sample was designed to thoroughly match the national distribution of public housing projects as closely as possible. In this regard, the researcher first used the database of the Libyan Institute of Architects (LIA), the database of the housing projects from the Organisation for Development of Administrative Centres (ODAC) and the database of the academics in the Libyan universities. Whilst the convenience sampling strategy adopted in this research may have increased the possibility of bias arising within the sample, as noted by Sapsford (2007), the adopted strategy prevented the construction of an unrepresentative sample whilst improving homogeneity and accuracy of data, thereby enhancing the validity of the results.

Another critical aspect is the determination of the sample size. As previously demonstrated, an infinite size of population leads the sample size to be influenced by the number of variables given. According to Costello and Osborne (2005), a majority of survey study researchers perform analyses with subject to item ratios of 10:1 to 5:1 as a minimum to be accepted. In this research, once 43 factors were identified for sustainable homes, based on the item ratio method, a minimum sample size of 215 (43×5) was determined. However, in a pessimistic scenario, Field (2013) asserts that the typical response rate will be in the order of 20-30%, yet, when this is compared with the response rates achieved in research seeking to collect data from built environment professionals based in Libya, returns of 30-35% appear typical (Gherbal, 2015). As such, the researcher assumed a return rate of 30% for this survey. To generate the targeted figure, bearing in mind the anticipated 30% return rate, it was determined that a survey sample of 1050 was required. As a result, however, the researcher distributed 1125 web-based questionnaires amongst potential participants in the national housing associations, universities, and housing providers (as determined earlier). Additionally, facilitated by websites for the relevant organisations as well as social media to obtain the contact details, the researcher started sending individual e-mails to the potential participants to invite them to take part in the survey. Ultimately, a total of 315 (7:1) responses, including 45 piloted subjects, were received with no missing responses, as the respondents were electronically pushed to complete all the questions required (see Section 6.3.1, p.153 for a detailed discussion of procedure).

5.8.2 Data Analysis Strategy

Data analysis is considered one of the key milestones in any research study because it illustrates and inspects the evidence collected through the research process so that conclusions can be reached. As explained by Saunders *et al.* (2016), the data analysis process includes a set of actions by which the primary research targets are to be achieved. This encompasses summarising, testing, classifying and reporting or in some cases, recombining the quantitative and qualitative information. As further pointed out by Saunders *et al.* (2016), the research analysis procedure must be consistent with the philosophical assumptions and methodology adopted. In this sense, to reduce potential analytical difficulties, as Yin (2014) stresses, researchers should organise a clear strategy for data analysis to ensure using appropriate analytical tools that serve the ultimate research goals. Nonetheless, key literature (e.g. Saunders *et al.* 2016; Bryman, 2015; Yin, 2014; Field, 2013) reveals that no clear methods or tools have been customised for conducting a specific analysis of the data, even though there are extensive analytical tools relevant to various methods. For this research, as discussed earlier, pragmatic philosophy in line with exploratory sequential mixed methods strategy was chosen as an appropriate method in this study. As a result, the process of analysis commenced firstly with the qualitative data analysis of data generated from the focus group, which later was used to establish the research stage of the quantitative questionnaire. The second analytical phase is analysing quantitative data collected from the questionnaires, then the findings from both qualitative and quantitative results are collectively discussed at the end of these two phases. A detailed discussion of these two analytical techniques are presented in the subsections that follow.

5.8.2.1 Focus Group Data Analysis

Employing the focus group technique generates qualitative data in the form of free-flowing text. For analysing such data, an array of methods has been suggested within the literature pertinent to qualitative analysis. As stated by Mohamed and Ragab (2016, p.6), six prominent tools are typically used in the analysis of qualitative data, including thematic, content, structural, interactional, performative and discourse analysis:

- ***Thematic Analysis;*** this technique seeks to search for various themes that are recognised as being significant for describing a phenomenon. It is useful for combining meanings and finding common patterns across participants' perceptions (Braun & Clarke, 2006). Thematic analysis is a qualitative analytical tool that searches for various themes that are recognise as being significant for describing the phenomenon under investigation (Fereday & Muir-Cochrane, 2006). Therefore, this type of analytical tool can be suitable for the purpose of this study with the aim of aggregating the most applicable sustainability-based interventions in housing projects.
- ***Content Analysis;*** this technique concerns word patterns, repetition, and relationships between subjects. It is usually employed when large volumes of text emerge and provides only quantitative accounts (Vaismoradi *et al*., 2013), so this technique is not preferable for this study, which is designed on the basis of a small-scale focus group.
- ***Structural Analysis;*** this technique focuses on the narratives emerging amongst the subjects through synthesizing the words to construct meaning. It is useful in the case of narrative-based research (Riessman, 2005). In spite of the structural analysis technique being beneficial to build up patterns of perception and understanding, it is not suitable in the case of developing a set of criteria for sustainable homes on the basis of a normative framework where the objectiveness is fundamentally significant.
- ***Interactional Analysis;*** this technique emphasises the interaction between participants where both the speaker and listeners collaborate to develop meaning. Unlike for this study, an interactional analysis approach is suitable for studies of relationships and interactions between subjects (Nielsen, 2009).
- ***Performative Analysis;*** this technique extends the interactional analysis technique, going further to capture both verbally and non-verbally metaphors influencing subjects through the study session. It is preferable in the case of communication-based research (Riessman, 2005). Therefore, performative analysis technique is unjustifiable for this study as its nature is not relevant to sustainable development in construction.
- ***Discourse Analysis;*** this technique reveals the actual words used to deliver meaning. It primely looks at the way concepts are expressed to examine subjects' sociopsychological characteristics rather than the text structure, so that it is suitable

in disciplines like philosophy and linguistics (Alvesson & Karreman, 2011). Again, this technique cannot be justified as this study is in the field of built environment.

It is evident therefore that the most suitable technique is thematic analysis to conduct the qualitative analysis for data generated from the focus group in this study. As mentioned earlier, thematic analysis is a systematic analysis seeking to capture themes and patterns within the text (Borrell, 2008). According to Braun and Clarke (2006), thematic analysis is one of the most common qualitative analysis techniques due to a range of advantageous aspects. One of these advantages, as both Bryman and Bell (2015) and Vaismoradi *et al*. (2013) advocate, thematic analysis is uncomplexity as well as its flexibility which suits analysing complex phenomena, can potentially reflect on rich outcomes from the analysis process. By contrast, thematic analysis as stressed by Vaismoradi *et al*. (2013), is highly dependent on the researcher's expertise so that it is likely to be inconclusive if not applied correctly. Vaismoradi *et al.* (2013) go on to explain that in such cases, the poor results are due to the failure in conducting analysis or the choice of questions that are designed improperly rather than the tool itself.

To ensure an idealistic performance and reduce potential difficulties in the application of thematic analysis, establishing an analytical process strategy is critical, as asserted by Yin (2014). Qualitative data reduction is the key to the analytical strategy in a way that allows summarising and transferring the findings discussion into a meaningful report through a manageable form. In light of this, Braun and Clarke (2006) point out six key steps guiding researchers to perform thematic analysis properly, as shown in Figure 5.5.

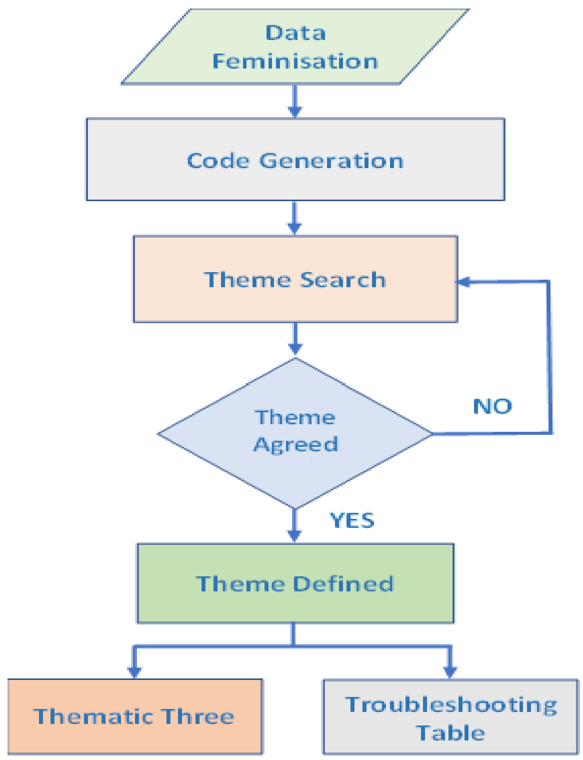


Figure 5.5 The Six Step Process Thematic Analysis. (Adapted from Braun & Clarke, 2006, p.87)

The researcher in this analytical phase found the six-step guidance suggested by Braun and Clarke (2006) helpful. A brief overview is presented as follows:

In the first step all the data collected from the focus group was transcribed from the initial audio form into textual version. The whole transcribed text then was translated from the original language of Arabic into English. The final draft of the script was thoroughly reviewed, and each interviewee was given a unique code to reference the quotations selected properly. Once the textual script became familiar, the researcher in the second step, applied initial coding to distinguish prominent keywords emerging in the qualitative data. An Excel sheet in this step was also used to facilitate the process of thematical analysis and classify the data aggregated, placing all the codes into themes and sub-themes. In the third step, attempts were made to aggregate the similarities into one cluster, which then assisted in the creation of subset nodes. Thematical analysis and the theoretical framework, as suggested by Braun and Clarke (2006, p.8), can "match what the researcher wants to know". In addition, the conceptual model developed through the previous stage significantly facilitated the process of drawing out the clusters and nodes, and the researcher had no intention to reorient these themes, rather he left the coding process to do so. Having identified the initial clusters and nodes in the fifth step, these were revised to make sure that the defined themes and sub-themes were properly established. Finally, all themes and sub-themes along with the quotations were brought together in order to make sense of the analytical process and present the final report of the qualitative analysis. The resulting information of this stage was used to design the following phase of the questionnaire survey.

5.8.2.2 Questionnaire Data Analysis

The questionnaire survey which generated qualitative data has been analysed via various statistical tools in line with the measurement tool adopted within the questionnaire design. The five-Likert scale as a common measurement tool is considered the most commonly used technique for scaling data in questionnaires, providing the respondent with a number of possible options from which to make a selection (Field, 2013). Whilst it must be acknowledged that such an approach to question design restricts the respondent's ability to express their attitude and therefore, limits the polarity of the responses (Yin, 2014), it is more likely to reinforce the reliability of the survey technique (Field, 2013). The questionnaire designed for this stage of study used closed-ended questions, employing five hierarchical levels of agreement, as advocated by Saunders *et al.* (2016) as being more likely to present higher mean scores of responses relative to the highest possible attainable score, as opposed to other methods that adopt measurement tools with 10 levels as an example.

For the purpose of this research, a five-scale hierarchy of "importance" was adopted to capture the degree of importance of the variables examined. This, as stated by Saunders *et al*. (2016), can allow the participants to clearly express their perceptions with an adequate level of agreement with the statements given. Indeed, the choice can be justified on the basis of three reasons. First, it is much easier for the researcher to analyse the data and for the potential participants to stay focused on the statements given and carefully respond to the questions. The second reason is to facilitate a reliable comparison with previous attempts which followed similar techniques, such as Alyami *et al*., (2013), Ali and Al Nsairat, (2009) and Almansuri *et al.,* (2009). Thirdly, the initial purpose of conducting a questionnaire was to consolidate and refine the theoretical model developed through the focus group, which would be followed by the phase of AHP 'Analytical hierarchy Process' in line with the ten-scale measurement tool for ranking the set of criteria raised. Therefore, the five-hierarchy scale (i.e. not important; moderately important; not sure; important; extremely important) is preferable in this stage of the questionnaire.

To calculate the relative weighting of the responses, as suggested by Saunders *et al.* (2016), degree 1 was assigned for option ‘Not Important’, whilst degree 5 was assigned for level ‘Extremely Important’. Table 5.1 portrays the five-Likert scale and its values assigned.

Table 5.1: The Five-Likert Scale and its Values Assigned

Scale	Not Important	Moderately Important	Not Sure	Important	Extremely Important
Value	**1**	**2**	**3**	**4**	**5**

Based on the Likert measurement, the quantitative data generated from the questionnaire has been analysed using the basic descriptive statistics. As defined by Shannon (2000), descriptive statistics is a statistical analysis method for describing attributes in the social sciences. The descriptive analysis encompasses frequency distributions; measures of central tendency, such as means and median; and measures of dispersion like standard deviation (Shannon, 2000). In this respect, nonparametric tests have been employed, because the measurement tool adopted - Likert scale - is an ordinal scale with the aim to examine the level of agreement and disagreement over each subject given. According to Saunders *et al*. (2016), in business research, the three most frequently used tools of statistical measurement are median, mean and Standard Deviation. Therefore, the data collected from the questionnaire survey was analysed employing a variety of statistics, including; Cronbach Alpha, Frequencies, Value of Mean, Standard Deviation, Value of Median and Value of Kendall’s W.

i) Alpha Cronbach

The first process used in the statistical analysis is the Alpha Cronbach test. The scales used in the data collected were checked for reliability through the pilot study, using Cronbach’s Alpha to check for internal consistency and suitability of criteria contained in the questionnaire for analysis. Cronbach's Alpha is widely used in social sciences and it is the most common measure of internal consistency (reliability), particularly used for questionnaires that utilise a Likert scale for question responses (Yin, 2014). Cronbach’s

Alpha ranges from 0 to 1, and the measurement tool is considered to be more rigorous as long as this indicator is closer to 1 (Field, 2013).

ii) Frequencies Distribution

The frequencies of the respondents' characteristics were also calculated, describing and determining the quality of the sample selected. The frequencies were presented in the form of figures and percentages.

iii) Value of Mean

Value of mean indicates the average rating of the importance assigned to each subject. This reflects the significance of each criterion and category. The judgement of agreement among respondents that a certain criterion is either acceptable or not, as Alyami *et al.,* (2013) and Almansuri *et al.* (2009) suggest, can be established based on a value of mean that is equal or above 3 out of 5 on the Likert score. As such, the degree of importance increases as long as the Likert score increases, and vice versa.

iv) Standard Deviation

Standard deviation value indicates the response dispersion or opinion variation, showing the extent to which values differ from the overall mean. Standard deviation takes values from 0 to 1 where a low standard deviation value means that most of the subjects are very close to the average, which reflects a powerful mean value. By contrast, a high standard deviation means that the subjects are spread out, which means a poor mean value.

v) Value of Median

Value of median indicates the scale or pattern that scored the higher rate of responses, or a probability distribution. As such, the median presents the mid-point of the data. To determine the median value in a group of variables, the frequencies must first be arranged in value order from lowest to highest, and the median value is the number that is in the middle, with the same amount of numbers below and above. In this case, the median value can take 1 to 5 in line with the Likert scale adopted.

vi) Value of Kendall's W

Value of Kendall's W reflects if there are statistically significant differences between the various data sources. In this research and aligning with Higham's (2014) suggestion, Kendall's W test was carried out to assess the significant differences between the various participant responses which consist of three different parts, namely professors, professionals and administrators. Kendall's W test sought to compare the means and identified the level of agreement between the respondents. The closer the score is to 1.00, the greater the agreement within the research sample.

The development of data management and statistical analysis tools aligned with the advanced technology allow researchers to easily conduct a variety of statistical analyses, the choice of which should eventually serve the targets of the study, according to Saunders *et al.* (2016). SPSS software application was used to undertake the aforementioned statistical analyses which helps the researcher to deal with complex data and process it in simple steps without being too time consuming.

5.9 Overview of the Methodological Design

Having discussed each element of the methodological design from the underpinning philosophical stances to the research techniques and analysis, which were demonstrated and justified throughout the previous sections, the overall methodological design emerges and was portrayed on the basis of Saunders *et al.*'s (2016) onion. (Figure, 5.6)

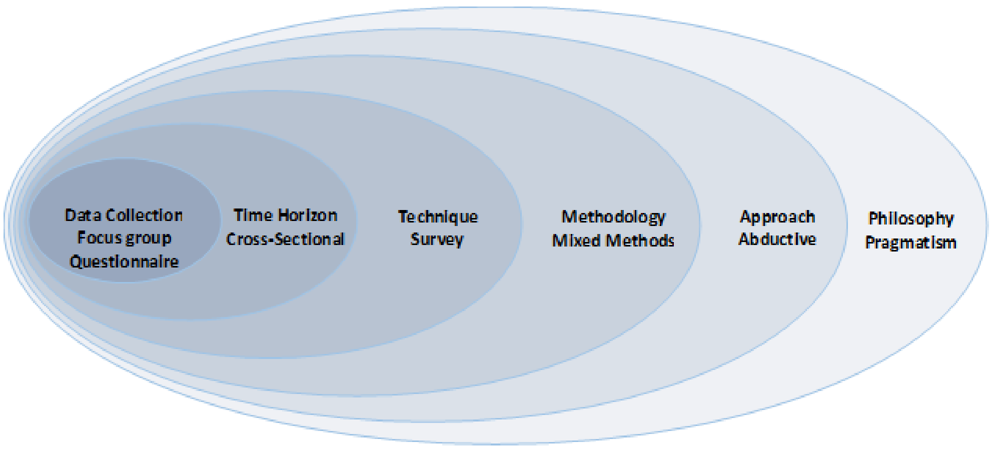


Figure 5.6: The Methodological Design

Research process then becomes clearer after a detailed discussion of the research methodology and design. The research process is a road map, as Marshall and Rossman (1999, p.40) state, "an overall plan for undertaking a systematic exploration". This mainly informs the overall approach to research and includes decisions about research methods and techniques. To this end, along with the methodological considerations and the research objectives throughout this study, the research process has been drawn up to conduct various theoretical and empirical investigations, as shown in Figure 5.7.

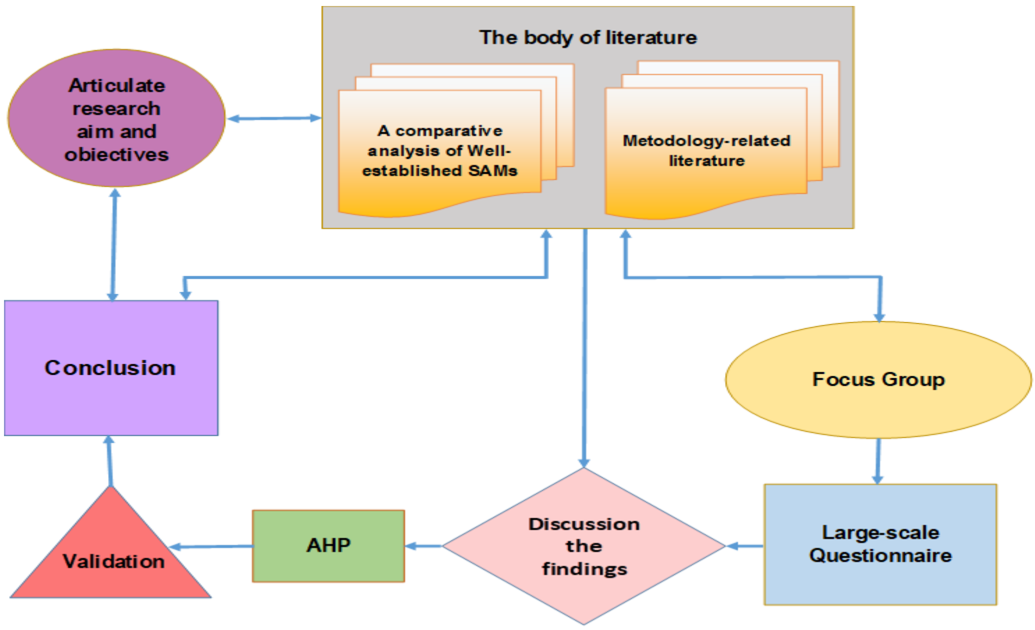


Figure 5.7: Research Process

A brief overview of this development is presented as follows:

Phase One: includes a comprehensive review of the relevant literature to understand the nature of the sustainability assessment's structure in the building field. Reviewing the recent trends in this context is an essential phase of this study. Then, the use of proposed criteria, derived from an integrated analysis of the most reliable building assessment methods, is vital to show areas of convergence through the empirical stage.

Phase Two: uses focus groups through interviews with 5 experts involved in sustainability programs in the Libyan built environment. The focus group is a preferred method to gain meaningful insight into the interesting phenomenon, since it offers narrow but rich qualitative evidence with an adequate number of participants.

Phase three: employs use of questionnaire survey to consult potential participants and collect the desired data that answers the research questions. Questionnaire is widely recommended to gain quantitative evidence, considered to be the most applicable method due to its ability to generate rigorous data and ensuring arrival at a sort of objectivity and generalization.

Phase Four: includes multi-criteria modelling using Analytical Hierarchy Process (AHP) to customise a weighting system for the developing model of building assessment. AHP can play an important role in the development of a potential ranking system, as it has the ability to reflect local needs and prioritise sustainable homes aspects on the basis of the multiple dimensions defined. This method is based on a pairwise comparison technique to prioritise each criterion and category, using MS Excel software to analyse the outcome from the pairwise comparison.

Phase Five: involves testing the model developed through the study to ensure reliability and robustness. For this purpose, a small-scale interview is suggested as a supplementary method, examining all data collection from the literature and empirical research to verify the applicability of LSHAM.

5.10 Chapter Summary

The underpinned philosophy and methodological considerations, a pragmatist stance in line with an abductive approach facilitated by mixed methods methodology were considered to be suitable for the nature of this study seeking to develop a set of sustainability-based interventions relevant to housing projects. In line with this, focus group and questionnaire techniques were considered preferable research instruments to collect the desired quantitative and qualitative evidence required to build a robust assessment model for sustainable homes based on the Libyan context.

6 Data Analysis and Discussion

6.1 Chapter Overview

The aim of this chapter is to identify applicable assessment categories and criteria for Libya's sustainable homes. As explained in the previous chapter, this research employed sequential mixed methods composed of focus group interview and questionnaire survey for collecting data on sustainability practices to discover the most influential factors that ensure successful interventions associated with the concept of sustainable homes. The questions contained in the focus group were informed by the review of the literature and the results obtained from the integrated analysis of the well-established assessment systems (i.e. BREEAM, LEED, GBCA and DGNB), whilst the questionnaire was used to confirm the findings with a large-scale sampling strategy. Detailed information on the design and implementation of both the focus group and questionnaire along with the data analysis and discussion of the findings are addressed and presented in this chapter.

6.2 Findings from Focus Group Interview

The empirical stage was launched with a focus group exercise with an expert group in the field of sustainable homes relevant to the Libyan context. The process and analyses of the data collected will be demonstrated through the sub-sections that follow.

6.2.1 Planning and Managing the Focus Group Interview

The focus group stage has been organised mainly to fulfil four major objectives:

- Reinforce the discussion undertaken through the literature review and investigate the need to develop an applicable sustainability-based assessment schema for home projects in Libya;
- Explore the current practice and level of feasibility applied to the decision making process for the project investments;
- Investigate the main features that have been over-looked or underestimated within the prevalent schemes; and,
- Provide up-to-date criteria that can guide the housing investment decision making processes towards more sustainable homes in Libya.

As discussed earlier in Section 5.8.1.1 (p.115), the focus group interview recruited five panellists, using a purposive sample, as shown in Table 6.1, all of whom were responsible for, inter alia, delivering aspects of the organisation's overall development and quality. The recruited participants have over two decades of experience within the area of environmental development and sustainable assessment systems in construction. The aim of sampling a range of senior professionals and administrators from different organisations was to gain a deeply overarching insight into the phenomenon being researched and to develop a set of sustainability-based indicators for homes in Libya. Participants in the focus group interview were identified through internet searches and a request to take part in the research was sent to each potential participant by email by the middle of February 2018. The invention email was also, attached with an information sheet along with the interview agenda and the consent form. Once each interviewee had confirmed their willingness to take part in this exercise, the interview date, time and location were arranged.

Table 6.1: Profile of the Focus Group Participants

Participant	Organisation	Role	Expertise	Experience (Years)
FG01	Construction firm	Quality and Performance Development Officer	General practice	28
FG02	Housing Association	Housing Services Officer	Housing Advice	25
FG03	Local Authority	Environmental Services Manager	Housing Service	23
FG04	Housing Association	Housing Manager	Housing Service	22
FG05	Construction firm	Project Manager	General practice	21

The focus group interview was held in a hall provided by the University of Tripoli on 5th March 2018, and it took approximately two hours where voices were digitally recorded with the consent of the interviewees. The focus group session commenced with a briefing phase in which the interviewer explained the context of the study and its purpose. At the end of the session, the opportunity was taken to recap on some of the main points covered. The purpose of this debrief, as suggested by Field (2013), was to ensure that the interviewees were comfortable with all the themes covered in the session and were not left feeling tense or anxious. The session was transcribed and then translated from the regional language 'Arabic' into English by the researcher, which provided an opportunity for the researcher to re-familiarise with the data as a first stage in the analysis process.

6.2.2 Analysis of Focus Group Interview

Having transcribed the interview, the qualitative data were analysed using a thematic analysis. In light of this, three main themes alongside sub-themes were extracted from the data. In the following sections, the themes, sub-themes will be presented alongside quotations and texts extracted from the interviewees - the code FG (followed by a Number 1-5) refers to the interviewee from whom the evidence quotations were taken.

6.2.2.1 The Position of Sustainability Assessment in Home Projects

The first strand to be explored sought to establish the understanding of the importance of sustainable homes in the Libyan context. The literature review clearly showed that the there is a lack of reliable data (e.g. research papers, social reports etc.) regarding the assessment methods applied in the home projects in Libya. As expected, the participants unanimously agreed on the fundamental need for a comprehensive scheme guiding the decision-making process in home projects. A clear sign came from the Quality and Performance Development Officer at a construction corporation, who confirmed that the lack of available frameworks would prevent any meaningful sustainability appraisal of projects:

> *"Of course, I believe indicators promoting housing quality or as it's said code for sustainable homes becomes a necessity in order to assess a project in terms of its impact on either environmental, social and economic dimensions for the Libyan context, …" (FG01)*

This was also confirmed by the Housing Services Officer at a Housing Association, who mentioned the need to develop the design of homes to comply with the sustainability requirements:

> *"… raising the quality of life required sort of things that ensure a good place to live in. And one of the most important things now is to give attention to the process of reorientation of the home design". (FG02)*

There was, furthermore, a judgment by the Environmental Services Manager at a local authority that their orientation to renovation has generated some benefits to the community, although these seem to be underestimated.

> *"No one can deny that physical improvement is essential, but there are other interventions that can extremely enhance the quality of people's life, What I meant is . . . the successful plan should give attention to issues such as the surrounding environment whereby ensuring all basic needs are easily reachable". (FG03)*

However, one of the views expressed by the Housing Manager at a Housing Association opined that, although he accepted the importance of sustainability, he felt it was still early to put such a plan and commitment in place:

> *"To be honest, we [Local Authorities] have boundaries. We are unable to make a significant change with the current legislations that impede our efforts to make the change we want. … the commitment to sustainability takes time notably without a clear vision or framework. Our [Local Authorities] priorities in this phase are to face the increasing demand on housing…". (FG04)*

In spite of the interviewees' argument that the lack of usable sustainability scheme remains a key difficulty in appraising projects, interestingly, the Project Manager at a construction firm tempered his comment by suggesting that, whilst sustainability is desirable, the bottom top approach remains a key driver to ensure fully commitment and implementation:

> *"I see that introducing such orientations and embedding them within the firm's culture is not the role of that organisation itself… it's the sort of integration the government level should find a way to communicate with those [firms] to embed the desirable orientations and at the same time it should open doors to develop the traditions that they [government] are willing to embed… here it is not to say that the government should have a rigorous and well-designed system that serves the desirable goals". (FG05)*

6.2.2.2 Current Practice Adopted

This section of the focus group sought to explore the current approaches adopted through investigating the level of feasibility assessment applied to decision making processes for the project investments. The literature review revealed that such an assessment would often depend on a monetary focus, using merely capital cost or in some cases a life cost analysis. The data analysed revealed a significant disparity between the acceptance of eco-social and environmental care given through the industry's practice and the actual need for improving their implementation in practice rather than being rhetorically applied. The participants from the Housing Associations have shown encouraging views upon sustainability application in their business, reflecting their efforts to assimilate the concept of sustainability into their investments:

> *"Housing Corporations work in an integrated manner… we [Housing Corporations] take into consideration multiple dimensions through the process of decision making… I can say, either intentionally or not we [Housing Corporations] have a sense of the concept of sustainability in our business, going back three or four years ago". (FG02)*

> *"… to some extent that's true, currently we [Housing Corporations] devoted ourselves to developing [named] projects in terms of regenerating green spaces and play areas for residents. We're trying to make people more comfortable with their properties as well as*

> *offering environmentally friendly products. However, the level we can achieve depends on the funding we get". (FG04)*

Nevertheless, however, the Project Manager at a large construction corporation rejected the views of the housing associations, commenting that they do not express the commitment to sustainability as much as the monetary-based appraisal:

> *"We are required to undertake a capital cost assessment using the net present value to reflect the revenues through the entire life of a project. This as we know, depends on financial consideration being economically focused. We hardly do rigorous assessments reflecting issues associated with social and environmental dimensions". (FG05)*

Regrettably, as the views of the Environmental Services Manager at a Local Authority expressed, the feasibility assessment conducted which is considered critical to the decision-making process, is fundamentally built upon a comprehensive approach covering multiple dimensions associated with sustainability:

> *"The value assessment along with direct/indirect cost/benefit analysis were conducted for all our projects.... this is supposed to cover all aspects socially, economically and environmentally in order to ensure that we [firm] meet the desirable goals". (FG03)*

The interviewees from the construction corporations opined that the project appraisal lacks a comprehensive norm ensuring best practice in terms of sustainability. This, according to the Quality and Performance Development Officer at a large firm, can be traced back to the fact that the availability of expertise as well as the level of funding are the two main factors preventing undertaking such comprehensive appraisal of projects:

> *"… it was allocated roughly 25,000 D.L for this purpose … no way! with this budget and locally available experience… We [firm] do as much as possible to fulfil our mission in light of our priorities" (FG01)*

This view was also emphasised by a Project Manager at a large construction firm, who was also of the opinion that the lack of funding for renovation towards such desirable targets has held back ambitions:

> *"That's evident, limited budget has significantly affected our plan for implementing any ambitious targets". (FG05)*

The Quality and Performance Development Officer once again expanded his point of view, clarifying the boundary of responsibilities:

> *"… before judging the level of change achieved, we should firstly ask, was I [firm] given the required budget. I'm always saying, stretch your legs according to your coverlet… We are asked to get 100 percent achievement, but with paying zero extra… I can make a significant impact, but you have to pay, as simple as that". (FG01)*

The Environmental Services Manager exemplified further his view through an experienced case study, obviously demonstrating the commitment to a sense of sustainability within public home projects:

> *"… the whole residential area [named project in the city of Sirte] was completely renewed although the decision of demolition would cost less… We took into considerations several aspects generating social, environment and economic benefits for occupants and local community…". (FG03)*

Interestingly, a Project Manager at a large construction firm suggested that enhancing the corporate governance can bridge the gap between the current practice and the expectations, implicitly revealing that the absence of usable frameworks might explain the reasons why multi-dimensional assessments are not given an appropriate place within the development of projects:

> *"...I think we need first to change the organisation culture that raises the financial returns from a project before promoting orientations that serve further dimensions such as eco-social or environmental impacts… this remains a challenge as in reality we value the firms solely based on the monetary side so that the lack of a suitable framework for detailed appraisal or any efforts in this respect are so difficult". (FG05)*

6.2.2.3 Emergent Features of Sustainability in Libya

The final major theme within the focus group sought to confirm the main features of sustainability and explore any additional emerging criteria that are to be applicable for sustainable homes in the context of Libya. The literature review along with the integrated analysis conducted have clearly shown that there are seven major themes (i.e. Management and Process, Materials Efficiency, Energy Efficiency, Water Efficiency, Waste and Pollution, Health and Wellbeing, and Location Quality), split into 44 criteria, as shown in Table 4.3 (p.90). The participants were asked to examine these indicators before being asked to suggest any further indicators that are applicable to the Libyan housing context.

6.2.2.3.1 Existing Features of Sustainability

To facilitate this section of the research, the panellists were provided in advance with an index of the criteria delivered from the previous stage of integrated analysis of the four well-established methods (i.e. BREEAM, LEED, GBCA, and DGNB). Then, the interviewees were asked to give their opinions on the set of categories and criteria suggested through the theoretical model developed through this study to examine the main indicators. Findings from this phase of the analysis show that the number of criteria aggregated within the integrative data analysis scheme are not quite applicable for the Libyan context, resulting in 38 emerging indicators which received consensus amongst the participants. Due to the extensive number of factors identified, the presentation here is confined to only those that were supported by interviewees to be applicable for housing investments in Libya. These features are divided into seven themes, as presented in the subsections that follow.

1) Management and Process Features

In terms of the management and process perspective, the participants highlighted six subset features that were considered important for assessing sustainability within housing investments. The participants unanimously avowed that the need for protecting the ecosystem within the home project processes is fundamental. A clear sign came from the Quality and Performance Development Officer at a construction firm, who confirmed that there is a lack of policy regulating the construction performance and its adverse effects on the environment:

> *"We [construction firm] have no real and clear aspirations to protect the ecosystem from the construction impacts. It's an ethical issue we should recognise" (FG01)*

The participants stressed issues relevant to independent commissioning agents as an important aspect for ensuring successful implementation of sustainability in housing projects. The Housing Services Officer at a Housing Association made a statement, declaring there was a flawed process resulting in the absence of a robust regulation governing the commissioning processes:

> *"The lack of commitment towards independent commissioning agent is a major barrier to the implementation of any genuine regeneration." (FG02)*

A Project Manager at a construction firm was of the view that the potential natural risks must be carefully assessed before establishing a project. He went on to confirm that conducting such an appraisal could allow for mutual benefits:

> *"… this issue is very, very important… we are committed to identifying potential natural risks and rating the severity of each, and in our projects, we [construction firm] fully comply with this requirement to ensure a secure life for residents and to avoid future costs" (FG05)*

The Environmental Management Plan (EMP) was viewed with great interest by all participants. The Environmental Services Manager at the local authority, for example, asserted that EMP has to be collectively designed to cover the entire project:

> *"Yes, of course, the environmental management plan plays a powerful role in construction projects. This should cover all stages including the design, construction, commissioning, and operation and maintenance phases" (FG03)*

FG03 also advocated a comprehensive Life Cycle Cost (LCC) analysis in order to maximise the sustainability benefits:

> *"In general, we work with the aim in mind of maximising life-cycle benefit or in other words, minimising life-cycle cost … If we want to optimise the permeance of our projects this target should be seriously considered at top priority." (FG03)*

Furthermore, the Housing Manager at a Housing Association was one of the proponents of adopting an integrative process in a project, asserting the benefits that can be generated for a project that works together across its activities:

> *"… a comprehensive approach with integrative systems is only one way which gives many advantages, allowing for presenting high levels of performance and raising the competitiveness." (FG04)*

2) Materials Efficiency Features

The second cluster identified by participants revolved around materials efficiency. In this respect, the participants reached a consensus around four key nodes considered applicable for assessing sustainable homes. A prominent claim was calling to adopt environmentally friendly materials, as pointed out by the Quality and Performance Development Officer at a construction firm:

> *"We're committed to building environmentally friendly projects… Look at what we're doing to help mitigate the construction effects in our project in Sirte, we used a wide variety of verified green labelled building production." (FG01)*

FG01 went on to advocate the provision of responsible sourcing of materials as a key to ensuring that these materials are sourced from renewable and sustainable sources:

> *"… regardless, we're voluntarily committed to the responsible sourcing for all building components… but we hope by the way, suppliers to be committed to the same as well" (FG01)*

The participants also stressed materials reuse and recycling as an important aspect for reducing construction waste and its environment related effects. For example, the Environmental Services Manager at a Local Authority encouraged professionals to recognise recycling issues in their designs:

> *"This is at the heart of what we discuss, I think architects and engineers need to put this [materials reuse and recycling] in mind while planning new buildings." (FG03)*

Use of locally available materials has been emphasised by a number of participants, stressing the benefits that can be generated for the national economy. A clear discourse came from FG03 when suggesting the necessity for policy regulating such an issue:

> *"The focus should go towards supporting the local economy through use of available materials for use in development … the priority should be on catalysing local economy by adopting various regulations and legislations." (FG03)*

3) Energy Efficiency Features

Energy efficiency is another important cluster which was discussed by the participants, highlighting seven subset nodes for assessing sustainability-based interventions within housing investments. Most of the participants emphasised the importance of evaluating energy as a primary demand while a clear statement was given by the Housing Services Officer at a Housing Association, who demonstrated the crisis of energy consumption in Libya:

> *"… electricity consumption in Libya has now reached 29 TWH, this means about 5 MWH per capita. It's actually a serious problem and we should all work to mitigate this increasing trend in our energy use." (FG02)*

The use of high-efficiency appliances was acknowledged by interviewees, particularly by the Quality and Performance Development Officer, raising the mutual benefits beyond the adoption of such appliances:

> *"… including sustainable design features with energy efficient equipment compact fluorescent light bulbs in new developments… this makes a huge difference in the lives of residents and offers significant cost savings for the homeowners." (FG01)*

The Project Manager at a construction firm in turn, suggested that the use of daylight access rate can be a possible way to assess energy efficiency:

> *"There is no doubt that windows design and glass are an essential component of house building facades, and it's very good at letting daylight and solar radiation in." (FG05)*

Hot water system use was considered very important by most participants with the aim of minimising the consumption of energy through adopting a proper hot water system, as advocated by the Housing Manager at a Housing Association:

> *"… it's the things we often overlook… being aesthetically pleasing is one thing, but every house needs to be functional to live in and at the same time, it's important to really make sure that a good hot water system and plumbing of your house is settled properly and with verified labelling products." (FG04)*

FG01 stressed another issue of efficient HVAC 'Heating, ventilating and air conditioning' system, which was also considered important by all participants, announcing the commitment towards better practice:

> *"We partner with manufacturers, universities and engineers to take approaches that elevate the efficiency and value of HVAC systems." (FG01)*

Use of thermal insulation was considered one of the main features that should be assessed in the housing projects as unanimously agreed by the participants. The Housing Services Officer at a Housing Association stated the economic benefits can be generated from installing an adequate thermal insulation in housing projects:

> *"With an effective use of thermal insulation, the heat loss can be minimised so that money saving can be achieved, therefore, we could actually make a big difference if we installed a proper thermal insulation in our projects." (FG02)*

Renewable energy is another feature that gained consensus as one of the important aspects for assessing energy efficiency practice in housing projects. The Environmental Services Manager at a local authority regrettably pointed out that:

> *"Renewable energy application can achieve a radical movement towards our ambitions in clean energy… a government scheme was established 15 years ago, but currently unfortunately this project is now locked in the government cabinets." (FG03)*

4) Water Efficiency Features

In terms of water efficiency, the participants emphasised four subset features which were considered important for assessing sustainability within housing investments. Most of the participants agreed that the need for assessing potable water demand in housing projects is critically important. The Environmental Services Manager at a local authority referred to the government efforts made to develop the water infrastructure:

> *"… being committed to sustainable housing, meeting the potable water demand of the people is fundamental… the government has implemented the integrative infrastructure project in many major cities and water supply was achieved through the massive investment in water infrastructure to enhance the existing services for people." (FG03)*

The participants emphasised irrigation-related issues as one of the most important aspects for evaluating water efficiency. As the Quality and Performance Development Officer made it clear, when considering the geographical factors affecting the increase in water use particularly for irrigation purpose:

> *"In the local climate, an automated internal irrigation system that keeps everything perfectly under control is very important if the solutions are to be sustainable in our housing projects." (FG01)*

Greywater systems adopted in housing projects should be assessed, as stressed by a number of participants. The Housing Manager at a Housing Association demonstrated that greywater can be recycled and used for different purposes so as to reduce the freshwater consumption:

> *"Using grey water in a home or garden that doesn't require potable water can help reduce stress on water supplies. This can come out of the drains of showers, baths, sinks, and*

washing machines… however this doesn't include black water flushed down the toilet." (FG04)

Another feature considered important by the interviewees was water appliances efficiency. A clear sign related to this issue was given by the Project Manager at a construction firm, who emphasised the provision of reliable labelling water equipment.

"… designing homes with products such as toilets and appliances must have water efficiency labels, this can make new homes more sustainable." (FG05)

5) Waste and Pollution Features

The fifth cluster identified by participants was waste and pollution considerations. In this respect, the participants reached a consensus regarding four key nodes that were considered applicable for assessing sustainable homes. They called for the need to reduce light and noise pollution, as pointed out by the Quality and Performance Development Officer at a large construction firm:

"… increasing urbanization usually is coupled with noise pollution … because of a number of noise complaints from local residents, we are working with a specialist company to conduct an evaluation of the sound impact and the best available solutions in our projects." (FG01)

FG01 went on to assert that the evaluation of refrigerants rate is very important to reduce the environmental impacts associated with the use of refrigerants:

"… air conditioning is standing beyond many challenges... many questions were brought to mind, some of which have no clear answers. For example, issues related to refrigerant recovery… many companies don't follow any recovery protocol, we will come back to our homes now, but who knows who put what in the refrigerant the last time. When you want to maintain your cooling system, always we have to start from scratch, evacuation, recovery and recharge." (FG01)

The participants stressed also waste treatment and recycling facilities as a critically important aspect for minimising waste generated by the housing construction and operations. The Environmental Services Manager at a Local Authority made a clear statement, emphasising the importance of the provision of adequate waste facilities:

"… but the problems with it [recycling] emerge from a lack of recycling facilities… designing waste treatment planning for housing projects is very important and providing better solution for the billions of tonnes of house waste." (FG03)

Polluted emissions reduction was also emphasised by a number of participants, stressing the adverse effects on the environment and the necessity to evaluate these risks within housing projects, as confirmed by FG03:

"Everything we intend to do to reach performance with zero emissions, this is our vision in our company, we seriously work on that" (FG03)

6) Health and Wellbeing Features

The health and wellbeing cluster is another important aspect which was discussed by the participants, raising nine subset nodes for assessing sustainability-based interventions within housing investments. Most of the participants emphasised the importance of evaluating the natural ventilation level and a clear sign was posed by The Environmental Services Manager at a local authority, who claimed building designers should adopt eco-friendly ventilation devices:

> *"I personally wish that more people could enjoy natural ventilation and be more comfortable in their house… builders typically look at mechanical ventilation, fans, heating and cooling, but often discard eco-friendly devices such as natural ventilation." (FG03)*

The consideration of sound insulation was acknowledged by all participants, in particular by FG03, who confirmed the need for a robust regulation, thereby governing the issues of sound pollution related to housing projects:

> *"Sound transfer between properties is a common problem in housing projects... I hope, a sort of eligibility for sound insulation policy to be authorised by government." (FG03)*

The Quality and Performance Development Officer in turn raised aesthetic-related issues in housing projects:

> *"I think architecture first and foremost is very significance. I think the aesthetics of the house building are one of the issues people make their purchases decision upon such aesthetical features." (FG01)*

Safety protection and fire security were considered very important by most of the participants with the aim of securing residents' lives, as advocated by the Housing Manager at a Housing Association:

> *"… there is nothing more important than being safe in your own house… our projects take this issue into account and we're determined to improve our performance relevant to building safety." (FG04)*

FG04 stressed another issue of cooling and heating comfort, which was in line with all participants who asserted that these aspects are considered critically important for assessing health and wellbeing in housing projects:

> *"Air-conditioning offers comfort to occupants and I notice, people are always asking whether a property is provided with air-conditioning or not before even asking for a viewing." (FG04)*

Illumination quality in turn was raised as one of the key aspects that must be assessed in the housing projects as unanimously declared by the interviewees. The Housing Services

Officer at a Housing Association emphasised the effects related to the level of illumination installed in a house:

> *"It's a good thing we have bright lights in our homes… specialists assert, … the quality and quantity of light are very important for people in terms of productivity and satisfaction and even have adverse health effects." (FG02)*

Internal layout and visual comfort are other features that met with consensus as one of the important aspects for assessing health and wellbeing in housing projects. As stated by the Environmental Services Manager at a local authority:

> *"…the indoor living space is the preferable place all people love to get with a perfect design… Indeed the housing providers claim to provide a visual comfort in interior design." (FG03)*

The participants emphasised cultural and architectural heritage as one of the most important aspects for evaluating health and wellbeing. As FG03 made it clear when calling for issues related to culture and heritage to be taken into account within housing projects:

> *"It's a great demand of preserving traditional and heritage building styles that are part of our culture that seems to be lost… I hope the architectural community can help us to maintain these values in their building design." (FG03)*

Another feature that was considered important by the interviewees was maintainability and flexibility. A clear statement of this issue was made by the Project Manager at a construction firm:

> *"When designing your house, always look for ways to make it as flexible and maintainable as possible… the thought of sustainability code without recognising maintainability would be flawed." (FG05)*

7) Location Quality Features

The last cluster considered by participants was surrounding issues associated with location quality. The participants unanimously selected four subset nodes as the most important features for assessing sustainability within housing investments. One distinguishable call was for considering transportation accessibility, as clearly quoted by The Housing Services Officer at a Housing Association, who implied that the lack of public transportation leads to residents' dissatisfaction:

> *"I live in Kusur [district] where poor public transportation clearly emerges… I am working in the city centre, every single day I ride in my car, struggling with horrible traffic to get to my job… We all need adequate access to housing, transportation, work, social facilities etc." (FG02)*

The participants stressed an issue relevant to pedestrian and cyclist safety as an important aspect for raising the quality of the location in housing projects. The Project Manager at a construction firm announced that the pedestrian and cycling considerations must be inclusively embedded in housing projects:

> *"…there are also plans to provide pedestrian and cycling facilities for residents… We have been lucky as the government understood the development scheme and committed to these needs for people." (FG05)*

Community services availability was considered of importance by most of the participants in that a housing investment should be established in a location where the basic social facilities are in reach. A clear discourse came from the Environmental Services Manager of a local authority when declaring the necessity for linking up housing projects with community services as a top priority:

> *"… we want to establish a community here [district named] and all things have to be inclusive… we are talking 15,000 home units. It's a lot of residents who have to come up with their basic needs." (FG 03)*

Furthermore, the Housing Manager at a Housing Association was one of the proponents of considering car parking capacity in a project, asserting the flexibility in parking spaces in housing projects as critically important:

> *"Car parking is a fundamental issue in housing projects… we've also designed the plot with about 50 car parking spaces in addition to two spaces being provided for each house and one for each flat." (FG04)*

6.2.2.3.2 Innovative Features of Sustainability

As mentioned earlier, the participants were called to suggest further criteria that could help in guiding the housing investment decision making processes towards more sustainable homes in Libya. The interviewees suggested a number of features that were considered important that had been over-looked or underestimated within the prevalent schemes. The results of the expert group discussion showed that there are five further sub-themes associated with sustainability which appear to influence the industry's practice towards more sustainable homes in the context of Libya. This encompasses: (i) Potable Water Quality; (ii) Rainwater Harvesting; (iii) Shading Strategy Uses; (iv) Preventing Sandstorm Strategy; and, (v) Technological Connectivity Consideration.

As this query sounds more normatively focused, the narrative style was compensated by a standing dialogue (Table 6.2) that provides an example of a suppurative quote for each innovative criterion - text highlighted in ***bold*** is to clarify the expressions from which each feature was devised.

Table 6.2: Standing Dialogue for the Emergent Criterions Suggested by Focus Group Panellists

Category	Emergent Criterion	*Example quote*
Energy Efficiency	Shading Strategy Uses	*"Our homes are exposed to high level of bright sunlight during most of the year. This makes me sick notably in the summer... it is not to say, we need to improve our design in relation to **sun control using shading strategies** that ensure reducing the heat gained so that reducing the energy consumption" (GF01)*
Water Efficiency	Potable Water Quality	*"The issue of **fresh** water indeed is really frustrating. It's not acceptable at all, a city such as the Capital [Tripoli], in many districts, people there still struggling with very poor, salty water supply... it's true that the problem isn't linked solely to the providers themselves however we [local authorities] should give priorities to those zones that have already provided with **good water quality** supply. My suggestion, for example, the **potable water should be verified** by third part such as the water utilities to ensure the minimum level of water quality" (GF02)*
	Rainwater Harvesting & Alternatives	*"... we need to encourage the providers to give attention to **maximise the benefit from rainfall** as much as we can... why we don't think of a particular design in terms of surface runoff and roof runoff with a proper size of storage... with no renewable water resources in Libya **groundwater also might be an important alternative resource** compensating the lake of potable water provided" (GF03)*
Waste & Pollution	Preventing Sandstorm Strategy	*"... **sandstorms phenomenon**, many regions with heavy sandstorms require recognising the need for **strategies to prevent or alleviate this phenomenon**... we need to make sure that the windows and doors are provided with a barrier to dust... and it cannot forget planting trees in the opened areas surrounded is worthwhile" (GF02)*
Location Quality	Technological connectivity consideration	*"... my daughter who works at a large insurance corporation, one's office is in the bed - laughing - indeed, a tendency nowadays is towards telework which increasingly becomes a phenomenon attracting youths especially who are looking for jobs while they are studying or so on. We know, the contemporary home or 'Smart Home' means the homeowners are to be **fully connected** with their business and the whole world. Confidently, I can say, all homeowners expect that their homes are **well-linked to service technological networks** such as internet, mobile, etc." (GF05)*

6.2.3 Overview of the Focus Group

In light of the results obtained from the data collection within this stage, it must be acknowledged that the applications of the concept of sustainable homes has been taken into consideration by the professionals throughout their decision-making processes, yet, it still falls far short of the sector's expectations. However, from the data analysis of the focus group, one cannot be argued to be robust, but the findings correspond to earlier work evident from the literature (Elgadi *et al.,* 2016; Shebob, 2012; Almansuri *et al*., 2009), indicating the strong desire within the social housing sector to embed the three dimensions associated with sustainability into their practice. More importantly, a model of sustainable homes emerged, comprising 43 criteria, split up into seven broad categories which were deemed to be fundamentally critical if any efforts of targeted sustainability are to be successfully imbedded. Figure 6.1 below encapsulates the clusters and nodes developed through the focus group.

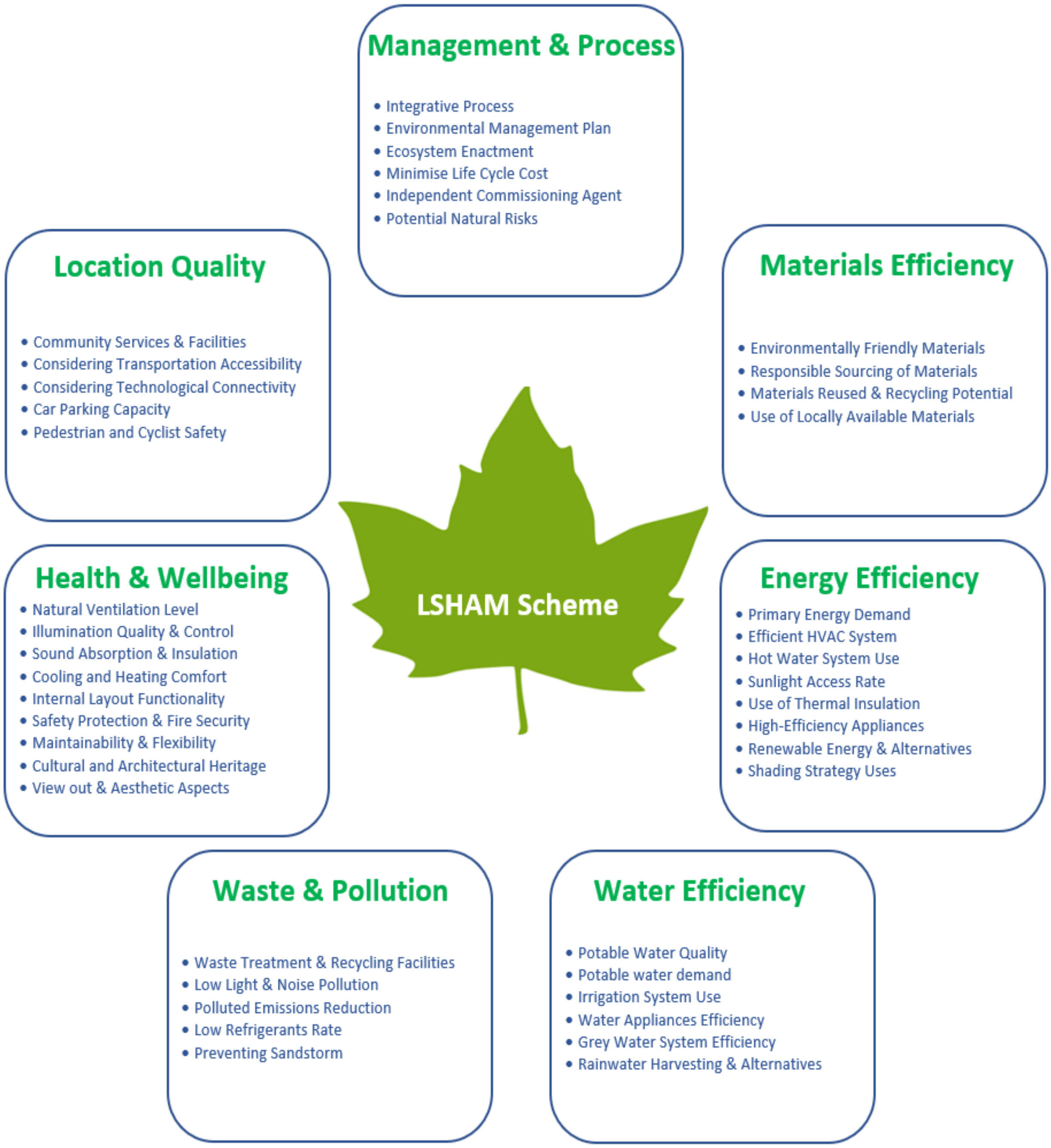


Figure 6.1: A Conceptual Model for Sustainable Homes Developed through the Focus Group

To this extent, attempts to minimise the effects associated with the small sample to build a rigorous sustainability-based index to guide the housing investment decision making processes towards more sustainable homes in Libya were carefully considered. A questionnaire survey analysis was scheduled to take place in the next phase, aiming to reinforce the results achieved with a sense of reliability and validity using a wider questionnaire survey for which a more representative sample was drawn from the population.

6.3 Findings from Questionnaire Survey

The second empirical stage was targeted at conducting a large-scale questionnaire survey covering a wide spectrum of well-qualified practitioners, professors and administrators in the sustainable homes field relevant to the Libyan context. The process and analyses of the data collected will be demonstrated through the sub-sections that follow.

6.3.1 Designing Questionnaire

The main aim of the questionnaire was to engage with as many participants as possible in order to qualify the categories and criteria suggested through the previous stage of the focus group interview. Large-scale views from either industry, academia or government were desirable to obtain the perceived importance and establish the ultimate balance of sustainability needed in the housing investments. To manage this, the questionnaire was split into seven key sections covering the various categories (i.e. Management and Process, Material Efficiency, Energy Efficiency, Water Efficiency, Waste and Pollution, Health and Wellbeing, and Location Quality), besides the section related to the demographic data about participants, encompassing field, discipline, qualification, experience, region and gender.

The questionnaire was primarily concerned with the collection of normative evidence, as opposed to opinion-based data (e.g. gathering perceptions or understanding meaning), as this sort of data would advocate the use of close questions (Field, 2013). A Likert scale was considered the most commonly used measurement scale for this, providing the respondent with a number of possible options from which to make a selection (Field, 2013). Whilst it must be acknowledged that such an approach to question design restricts the respondent's ability to express his or her attitude and therefore, limits the polarity of the responses (Yin, 2014), to some extent, it reinforces the reliability of the survey technique. Adopting a five-point Likert scale, ranging from 'Not Important' to 'Extremely important', the respondents were required to indicate the extent to which they agreed with each identified feature of sustainability based on their perception of its importance for the delivery of sustainable benefits to home projects (see Section 5.8.1.2, p.120 for a detailed discussion).

A copy of the suggested questions was sent to the supervisory team in the middle of March 2018. Based on the comments of the supervisory team, the demographic questions were adjusted. Once the questionnaire was approved, the final version was completed along with an Arabic translation. This stage was very difficult because it required accurate translations for the business and technical terminology bearing in mind that there is no agreement in Arabic literature on most terminology. The questionnaire was issued in electronic format via a commercially available online survey application. It was designed to take approximately ten minutes to complete. This aspect is important because it has been shown that participation in research is influenced heavily by the amount of effort that is required on the part of the participant (Field, 2013). The first page of the questionnaire carried a full explanation of the purpose of the questionnaire. Subsequent pages presented the seven main categories separately with a brief definition, whilst rounded off by the demographic questions. After the draft of the questionnaire was designed, the pilot study was conducted.

6.3.2 Piloting Questionnaire

In order to evaluate the clarity and comprehensiveness of the questionnaire, as well as the feasibility of the survey as a whole, a pilot survey should be conducted (Field, 2013). Therefore, the proposed questionnaire was initially tested by particular participants to test the context and consent of its design and to investigate the precision of questions being asked, and to establish suitable questions to provide the required information and reach the final questionnaire. The questionnaire was piloted by the end of March 2018, recruiting 45 participants to gain their feedback and thus, devise the final version.

As a result of the analysis of the pilot survey, the questionnaire was taken through a process of revision to make it more suitable for the main questionnaire survey. From the feedback provided by respondents, it was evident that the questionnaire as a whole functioned well even though some themes were adjusted on the basis of participants' recommendations in order for the questionnaire to be easier to move from one theme to the next. Some of the terms were also re-worded as the feedback from the respondents seemed to suggest that they found them ambiguous. As expected, the average time taken to complete the questionnaire was approximately 10 minutes. It was therefore considered unnecessary to reduce the overall number of variables included in the questionnaire to make it shorter.

In addition to this, piloting the study allows the chance to test the reliability of the instrument measurement data through employing Cronbach's Alpha (Field, 2013).

Cronbach's Alpha is widely used in social sciences and it is the most common measure of internal consistency 'reliability', that is, how closely related a set of items are as a group and particularly used for questionnaires that utilise a Likert scale for the question responses (Yin, 2014). Cronbach's Alpha ranges from 0 to 1; the measurement tool would be more rigorous as long as this indicator is closer to 1. Cronbach's alpha can be written as a function of the number of test items and the average inter-correlation among the items. Alpha coefficient can be calculated based on the formula below:

$$\alpha = \frac{k \times \bar{c}}{\bar{v} + (k-1)\bar{c}} \qquad \text{.................} (6.1)$$

Where: k *refers to the number of scale items*

$\bar{c}$ *refers to the average of all covariances between items*

$\bar{v}$ *refers to the average variance of each item*

This indicates that if the average inter-item correlation is low, alpha will be low and vice versa. SPSS (Statistical Package for Social Sciences) software was used to establish this analysis, generating Table 6.3 below, which illustrates the different values of Cronbach's Alpha test over the seven categories suggested.

Table 6.3: Reliability Statistics from the Pilot Questionnaire

	Categories	Cronbach's Alpha	No of Items
1	Management and Process	.864	6
2	Material Efficiency	.868	4
3	Energy Efficiency	.867	8
4	Water Efficiency	.881	6
5	Waste and Pollution	.878	5
6	Health and Wellbeing	.877	9
7	Location Quality	.869	5
	Total	.872	43

According to Table 6.3, it can be seen that the value of Cronbach's Alpha coefficient was high for each dimension of the study and ranged between 0.864 - 0.881. The overall Cronbach's Alpha coefficient for the data set is 0.872, which indicated excellent reliability and internal consistency, as Field (2013) pointed out. This confirms the stability of the results and their harmony with the statistical analysis results in terms of objectivity and encourages the acceptance and truthfulness of the outputs targeted.

Having satisfied the requirement to pre-test the questionnaire, and once the ultimate version of the questionnaire had been devised, it was ready for deployment but after the sampling plan had been designed.

6.3.3 Sampling and Distributing Questionnaire

A first step in the selection of an appropriate sample is the determination of the population of the study, which is necessary for clarifying the size of the total population (Bryman, 2015). The population can be identified by those who are engaging within the phenomenon of interest (Bryman, 2015). As mentioned earlier, this study aims to define the most applicable categories and criteria for assessing sustainability in home projects in Libya. This study thus aims at investigating various groups of people involved in the home building process including: Architect, Quantity Surveyor, Structural Engineer, Civil Engineer, and Construction Manager (Emmitt & Yeomans, 2008). Bearing in mind that the analysis unit is the Libyan public home projects, this implies that the population of the study could compose all local and international professionals, contractors, consultants, academicians, etc. who are involved in activities related to the implementation of sustainability within the Libyan home projects. The consequence is that a known portion of the population is excluded (see Section 5.8.1.2, p.120 for a detailed discussion of justification).

Both Bryman (2015) and Creswell (2013) suggest that researchers should always aim to narrow the population's scope and purpose; it is essential that the sample should be designed carefully to represent the entire population and, as such, it must sufficiently reflect the populations' characteristics. In this case, convenience sampling was adopted, not because such samples are necessarily easy to recruit, but because it often uses the individuals who are available rather than selecting them from the entire population. In fact, due to the infinite size of population and limited time, funds and data available as well as the current nature of Libya (post conflict) and the risks associated with collection of data to some extent, the adoption of this sampling strategy in particular was necessary. To ensure that the sample matches the national distribution of public housing projects as closely as possible, the researcher first used the database of the Libyan Institute of Architects (LIA). The database of the housing projects was from the Organisation for Development of Administrative Centres (ODAC). Finally, the sample was constructed from the database of the academics in the Libyan universities. Whilst this approach may have increased the possibility of bias arising within the sample, the technique prevented the construction of an unrepresentative sample whilst improving homogeneity and accuracy of data, thereby enhancing the validity of the results.

Another critical aspect is the determination of the sample size. As previously demonstrated, an infinite size of population leads the sample size to be influenced by the number of variables given. According to Costello and Osborne (2005), the majority of survey study researchers perform analyses with subject to item ratios of 10:1 to 5:1 as a minimum that is acceptable. In this research, therefore, once 43 factors were identified for sustainable homes, based to the item ratio method, a minimum sample return size of 215 (5:1) was determined. However, as a pessimistic scenario, Field (2013) asserts that the typical response rate will be in the order of 20-30%, yet, when this is compared with the response rates achieved in research seeking to collect data from built environment professionals based in Libya, returns of 30-35% appear typical (Gherbal, 2015). As such, the researcher assumed a return rate of 30% for this survey. To generate the targeted figure, bearing in mind the anticipated 30% return rate, it was determined that a survey sample of 1050 was required. Against this, however, a total of 1125 computer-assisted questionnaires were distributed among potential participants in the national housing associations, universities, and housing providers. Then, facilitated by websites for the relevant organisations as well as social media to obtain the contact details, the researcher at the beginning of April 2018 started sending individual e-mails to the potential participants to invite them to take place in the survey.

To encourage a good response, three steps were followed in administering the survey as recommended in Creswell (2003). The potential participants were firstly invited through an invitation e-mail which included information about the research aim; the structure and the criteria for selecting the participants; and the approximate time taken for answering the full questionnaire. The second step was a follow-up email of the actual questionnaire. This was undertaken about one week after the advance-notice email. The final step involved an email of another set of questionnaires to all non-respondents. This was also undertaken about three weeks after the second step. Ultimately, a total of 315 (7:1) responses were received from the participants, with no missing responses - as the respondents were electronically pushed to complete all the questions required (Table 6.4).

Table 6.4: Questionnaire Responses

Questionnaires	Academia	Industry	Government	Total
Distributed	390	380	355	1125
Respondents	126	115	74	315
%	32%	30%	20%	28%

As shown in Table 6.4, the level of return responses was deemed acceptable, as it lay above the range of 5:1 (n=215) of the total number of variables examined within this survey. Unsurprisingly, the greatest response rate was among academics (32%), followed by practitioners (30%), whilst respondents from the governmental sector recorded the lowest response rate (20%). The overall response rate was 28%, which was close to the expected average of 30% and above the norm for CM research of 20% (Field, 2013).

Having collected the targeted qualitative evidence, the data analysis was established to statistically reflect the agreement drawn upon the criteria given which represent the most applicable norms for sustainable homes in the Libyan context.

6.3.4 Questionnaire Data Analysis

As mentioned earlier, the main aim of the research was to develop holistic sustainable assessment criteria to assist a decision support system to promote sustainable development in the residential building sector. The likelihood of sustainable homes was established from the questionnaire survey along with the willingness to both meet the expectations of the occupations and maintain the environmental and eco-social features. Data collected from the questionnaire survey which aggregates quantitative data was statistically analysed and presented. This major section was allocated to statistically present and discuss the results of the responses to every question utilised in this questionnaire. In this manner, the data analysis reported first the background of the respondents followed by the reliability test, and finally, the measures of central tendency along with Kendall’s W test of the various categories and criteria. All these techniques are discussed in the subsequent sections.

6.3.4.1 The Characters of the Respondents

The first part of the questionnaire analysis established the quality of the questionnaire sample through analysing basic factual data relating to the respondents personally. This includes field, region, qualification, discipline, experience, and gender. The results are aggregated and summarised in Table 6.5, showing both the size and percentage of the responses across various features.

Table 6.5: Summary of Demographic Data of Questionnaire Respondents

Features	Variable	Frequency	%
Field	Education	126	40.0
	Industry	115	36.5
	Government	72	22.9
	Other	2	0.6
Discipline	Quantity Surveyor	76	24.1
	Construction Manager	68	21.6
	Architect	63	20.0
	Structural Engineer	55	17.5
	Civil Engineer	51	16.2
	Other	2	0.6
Qualifications	Postgraduate	235	74.6
	Graduate	79	25.1
	Undergraduate	1	0.3
Experience	-5	41	13.0
	5 - 10	146	46.3
	+10	128	40.6
Region	North	171	54.3
	South	78	24.8
	Middle	66	21.0
	Other	1	0.3
Gender	Male	215	68.3
	Female	90	28.6
	Missing Data	10	3.2

6.3.4.1.1 Analysis of the Characteristics

As shown in Table 6.5 above, the data analysis showed that the majority of the participants were involved in the educational sector. As expected, the data revealed that of the 315 respondents, 40% of the respondents defined themselves as academics, followed by the respondents from industry with 36.5%, whilst the lowest percentage was recorded for the governmental departments at 23%. This result implies that, since responses from both the educational and industrial fields predominated, the perspective provided in this questionnaire would reflect more the perception and understandings of academics and professionals who are commonly in regular interaction with sustainability issues, and they are the ones who are responsible for implementing any relevant initiatives or programmes.

More importantly, the data analysis of the returned questionnaire interestingly revealed that 24% came from quantity survey background, while roughly 21% were construction managers and 20% came from an architectural background. Respondents who were structural engineers and civil engineers constituted approximately 17% and 16% respectively, whilst two other respondents were undefined. This clearly indicated that a great number of the responses to the research questions emanated from those who had practical understanding of the focus area of this study. The results also revealed that roughly 74% of the respondents had high education levels and 25% had a graduate degree, whilst only one participant in the survey was not a graduate. In essence, the majority of respondents were well educated and very well suited to answering the questionnaire items which gave robustness to the study's findings. Accordingly, the results also showed that 40% of the respondents had more than 10 years of experience, and 46% had experienced 5 to 10 years, whereas only 13% had less than 5 years in the profession. Once again, the point here is that the majority of the respondents had reasonable experience in the field being researched which further shows that respondents were sufficiently experienced enough to provide data which are credible, thereby offering an element of robustness to the findings.

Geographically, the distribution of participants showed that the sample represents various Libyan cities, since roughly 54% of the participants said they were from the Northern region; 24% from South and the remaining 21% from the middle of Libya, with one respondent undefined. As expected, this result to some extent mirrors the actual distribution of the population in Libya, as the majority of Libyans live in the coastal cities in the North. In terms of their gender diversity, analysis of the returned questionnaire showed that the survey participants were predominantly male, making up 70% of the sample recruited, while less than 30% were female. This may also reflect the fact that the Libyan men dominate most practical-based fields such as construction.

6.3.4.1.2 Overview of Respondent Characteristics

The primary focus of this section was on developing a demographic profile of the respondents. It is clear that a great part of the responses to the research questions emanated from those who are sufficiently experienced and are well educated to answer the questionnaire items which gives robustness to the study's findings. The demographic data collected revealed that the majority of the survey respondents belong to both educational and industrial fields relating to the construction field. Whilst the survey participants were predominantly by male, it covers a wide variety of Libyan cites which strengthens the reliability of the expected findings.

6.3.4.2 Analysis of Categories and Criteria

Since the principle aim of the study is to establish the most applicable categories and criteria for assessing sustainable homes in Libya, many exclusive criteria and major categories have been developed through a large-scale questionnaire survey. Within this stage, the aim was to investigate the respondents' perception of the levels of significance of features that help to embed sustainability in the design and construction process of home projects. Through a set of closed ended questions, facilitated with a five-point Likert scale, ranging from 'Not Important to 'Extremely Important', the respondents were asked to indicate the extent to which they agreed with each identified feature of sustainability based on their perception of its importance for the delivery of sustainable benefits to home projects. The data collection from this part of the questionnaire survey was analysed by employing a variety of statistical procedures. Firstly, the scales used in the data collected were checked for reliability to ascertain the reliability of the data collected and thus, Cronbach's Alpha was used to check for the internal consistency and suitability of criteria contained in the questionnaire for analysis. As long as the data was found reliable, the basic descriptive statistics would have been carried out, encompassing measures of central tendency such as means and median; and measures of dispersion such as the standard deviation. In addition to this, Kendall's W test was carried out to assess the significant differences between the various data sources, namely professors, professionals and administrators. Given that it was not the aim of the study to examine the significance of the differences between the responses and between the variables, the analysis procedures did not seek to carry on into the structure of interrelationships or correlations that require measurement instruments such as factor analysis test. In this section therefore, after carrying out the reliability test, the measures of means, median, standard deviation and Kendall's W test of each category and criteria are analysed and presented individually.

6.3.4.2.1 Reliability Test for the Set of Categories

To ensure that the five-scale rating adopted for measuring the criteria yields the same results over time, a reliability analysis using the internal consistency method was first examined. This is an important recommendation for researchers in order to assess the degree to calculate testing the internal consistency reliability of the generated scale (Yin, 2014; Field, 2013). Cronbach's Alpha, as aforementioned (see Section 6.3.2, p154), ranges from 0 to1. The closer alpha is to 1 the greater the internal consistency reliability of the criteria in the scale. To establish this analysis, the collected data were fed into SPSS (Statistical Package for Social Sciences) software, and using formula (6.1, p155) Cronbach's Alpha values for the set of categories are summarised in Table 6.6.

Table 6.6: Cronbach's Alpha test for Reliability

Cronbach's Alpha	No of Items
.870	43

As shown in Table 6.6, the Alpha Cronbach coefficient to a large extent corresponded with the results obtained from the pilot study analysis, scoring 0.870 as a total of all the categories. This, as suggested by Field (2013), confirms excellent reliability and internal consistency, and the respondents provided responses based on clear and common understanding of the questions in the questionnaire and thus making the results of the research findings more reliable.

6.3.4.2.2 Agreement Measurement of Criteria

To establish the most applicable categories and criteria for assessing sustainable homes in Libya, many exclusive criteria and major categories have been developed through a large-scale questionnaire survey. The following measures were identified and then assigned to each category and criterion:

- Value of mean: indicates the average rating of the importance of the criterion.
- Standard deviation value: indicates the dispersion and shows the extent to which values differ from the mean, or in other words, opinion variation.
- Value of median: indicates the scale or rate that scored the higher half of responses, or a probability distribution.
- Value of Kendall's W: reflects if there are statistically significant differences between the various data sources.

Agreement among respondents that a certain criterion is important or acceptable can be established based on the mean that is equal or above 3 out of 5 in the Likert scale, as suggested by Alyami *et al.,* (2013) and Almansuri *et al.* (2009). Standard deviation measures how spread out the values in a data set are around the mean. More precisely, it is a measure of the average distance between the values of the data in the set and the mean. This indicted that a low standard deviation value (closer to zero) means that most of the subjects are very close to the average, which reflects a powerful mean value. The value of the median indicates the scale that scored the higher rate of responses so that it takes the values between 1 to 5 in line with the Likert scale (i.e. not important; moderately important; not sure; important; extremely important). Kendall's W test sought to compare the means and identified the level of agreement between the respondents. The closer the score is to 1.000, the greater the agreement within the group, as indicated by Saunders *et al*. (2016) (see Chapter 5 for a detailed discussion). Table 6.7 encapsulates the results of the measures of central tendency for the set of categories examined within this phase of the questionnaire.

Table 6.7: The Measures of Central Tendency for the Set of Categories

	Main Categories	Mean			Overall		
		Professionals	Professors	Administrators	Mean	Std.	Median
1	Energy Efficiency	4.55	4.63	4.65	4.61	.491	5
2	Water Efficiency	4.53	4.58	4.69	4.60	.491	5
3	Material Efficiency	4.44	4.55	4.63	4.54	.542	5
4	Health and Wellbeing	4.51	4.52	4.50	4.51	.519	5
5	Waste and Pollution	4.44	4.46	4.51	4.47	.543	4
6	Management and Process	4.38	4.30	4.25	4.31	.558	4
7	Location Quality	4.27	4.34	4.29	4.30	.557	4
Test statistics							
Kendall's W=0.837							

As Table 6.7 shows, the judgement of participants is that 'Energy Efficiency' and 'Water Efficiency' are almost at the same level and they are the top priority. These are compatible with current concerns in relation to the Libyan built environment regarding water use challenges and renewable energy potentials, specifically solar energy (MWR and CEDARE, 2014). The next most important priorities include 'Materials Efficiency', 'Health and Wellbeing' and 'Waste and Pollution'. These categories are closely linked. For example, the criterion of 'Waste Treatment and Recycling' from the 'Waste and Pollution' category can also affect the user comfort of 'Health and wellbeing' criterion. The categories of 'Management and Process' and 'Location Quality' achieved almost the same level of importance but at the bottom of the list. However, all these categories, as agreed by the participants, are essential for the establishment of a coherent and comprehensive scheme to evaluate the requirements of Libyan housing projects in relation to sustainability. The categories showed rigorous standard deviation rates from 0.491 to 0.557, which means a lower level of variance. The Kendall's W test coefficient of concordance value was 0.837, which was significant at 95% confidence level. There is thus a significant degree of agreement between the various participants indicating these categories are in harmony and valid for assessing the home projects.

To this end, each criterion involved in these categories is individually analysed and presented in the sub-sections that follow.

1) An Agreed Set of the Management and Process Criteria

Somewhat surprisingly, the results showed that this category 'Management and Process' was rated sixth out of the seven categories, as its mean scored 4.31 with a median of 4 'important'. The category of 'Management and Process' encompasses six criteria. This set of criteria was analysed, and the results are presented in Table 6.8.

Table 6.8: The Measures of Central Tendency for Management & Process Criteria

Main Criteria		Mean			Overall		
		Professionals	Professors	Administrators	Mean	Std.	Median
1	Minimise Life Cycle Cost	4.66	4.53	4.49	4.54	.506	5
2	Environmental Management Plan	4.39	4.47	4.52	4.46	.546	4
3	Ecosystem Enactment	4.45	4.48	4.45	4.46	.536	4
4	Potential Natural Risks	4.41	4.48	4.43	4.44	.534	4
5	Independent Commissioning Agent	3.73	3.76	3.82	3.77	.599	4
6	Integrative Process	3.72	3.76	3.77	3.75	.617	4
Test statistics							
Kendall's W=0.831							

From the analysis of the descriptive statistics presented in Table 6.8, however, the respondents generally reflect the principal goal of the sustainability-based managerial considerations within the home projects, including the minimising of life cycle costs and the reduction of the potential impacts of construction activities on site development and the ecosystem. Although there was not a significant difference between variables, it is clear that the highest scored feature was the criterion of 'Minimising Life Cycle Cost', with a mean of 4.54 and a median of 5 'Extremely Important'. Following this, the respondents' considerations were in favour of the issues of 'Environmental Management Plan', 'Ecosystem Enactment', and 'Potential Natural Risks'. These criteria received mean values of 4.46 - 4.46 and 4.44 respectively. Meanwhile, the least significant managemental issues were the criteria related to 'Independent Commissioning Agent (scored 3.77) and 'Integrative Process' (scored 3.75). Encouragingly, the variables all showed rigorous standard deviation rates from 0.506 to 0.617, which means a lower level of variance. The Kendall's W test coefficient of concordance value obtained was 0.731, which was significant at 95% confidence level. There is thus a significant degree of agreement between the various participants, so these categories are in harmony and valid for assessing the 'Management and Process' features.

2) An Agreed Set of the Material Efficiency Criteria

The data analysis indicated that this category was rated as 'extremely important' with a median of 5 and mean of 4.54 out of five-rate score. The results also showed this category was rated third among the seven categories given. The category of 'Material Efficiency' encompasses four criteria. This set of criteria were analysed, and the results are presented in Table 6.9.

Table 6.9: The Measures of Central Tendency for Material Efficiency Criteria

		Mean			Overall		
	Main Criteria	Professionals	Professors	Administrators	Mean	Std.	Median
1	Environmentally Friendly Materials	4.51	4.56	4.58	4.55	.499	5
2	Materials Reuse & Recycling Potential	4.50	4.50	4.44	4.48	.507	4
3	Responsible Sourcing of Materials	4.42	4.42	4.48	4.44	.517	4
4	Use of Locally Available Materials	4.40	4.34	4.31	4.35	.592	4
Test statistics							
Kendall's W=0.876							

As would be expected, Table 6.9 shows that the highest scored features within the group of Material Efficiency were assigned to the choice of materials with environmentally friendly impacts along with materials reuse and recycling, since they recorded a mean of 4.55 and 4.48 with lower standard deviation rates of 0.499 and 0.507 respectively. The participants also agreed that the use of responsible sourcing of materials is an important issue, which should be considered for the Libyan context, scoring a mean of 4.44 whilst the issue related with the locality of material used came last in this category, achieving 4.35 out of five-rating score. Kendall's W test coefficient of concordance value obtained was 0.876, which was significant at 95% confidence level. This indicates that there is a significant degree of agreement between the various participants and thus, these categories are in harmony and valid for assessing the 'Material Efficiency' features.

3) An Agreed Set of the Energy Efficiency Criteria

As expected, this category 'Energy Efficiency' was one of the top priorities for sustainability in home projects, recording a mean of 4.61 and a median of 5 'extremely important'. The category of Energy Efficiency encompasses eight criteria. This set of criteria was analysed, and the results are presented in Table 6.10 below.

Table 6.10: The Measures of Central Tendency for Energy Efficiency Criteria

Main Criteria	Mean			Overall		
	Professionals	Professors	Administrators	Mean	Std.	Median
1 Renewable Energy & Alternative Strategies	4.54	463	4.54	4.57	.497	5
2 Efficient HVAC Systems	4.51	4.53	4.61	4.55	.498	5
3 Use of Thermal Insulation	4.46	4.55	4.52	4.51	.501	5
4 Primary Energy Demand	446	4.51	4.53	4.50	.520	5
5 Shading Strategy Uses	4.53	4.50	4.44	4.49	.532	4
6 Sunlight Access Rate	4.33	4.34	4.38	4.35	.504	4
7 High-Efficiency Appliances & Monitoring	4.30	4.31	4.38	4.33	.562	4
8 Hot Water System Use	4.32	4.30	4.25	4.29	.533	4
Test statistics						
Kendall's W=0.837						

Renewable energy and alternative strategies, efficient HVAC systems, use of thermal insulation, and primary energy demand, all emerged as the top four issues for the main category of Energy Efficiency, as shown in Table 6.10. These criteria scored a median of 5 'Extremely Important' with mean values of 4.57 - 4.55 - 4.51 and 4.50 respectively. The respondents also recognised the importance of shading strategy uses along with sunlight access in the way of promoting the use of greener energy. Both categories recorded 4.49 and 4.35 respectively, with a median of 4 'Important' while the two lowest degrees of agreement related to the features of appliance efficiency and hot water systems with 4.33 and 4.29 respectively. However, all the variables in this category also showed rigorous standard deviation rates where the highest figure recorded was 0.562, which means they had a lower level of variance. Kendall's W test coefficient of concordance value obtained was 0.837, which was significant at 95% confidence level. There is thus a significant degree of agreement between the various participants, so these categories are in harmony and valid for assessing the 'Energy Efficiency' features.

4) An Agreed Set of the Water Efficiency Criteria

Water issues had a great deal of consideration among the respondents. The results showed that this category 'Water Efficiency' was rated second after the category of Energy Efficiency, with a mean of 4.60 and a median of 5 'extremely important'. Six different issues were suggested to be checked in terms of the extent to which they are important for assessing the features of 'Water Efficiency' in the housing projects. This set of criteria was analysed, and the results are presented in Table 6.11.

Table 6.11: The Measures of Central Tendency for Water Efficiency criteria

Main Criteria	Mean			Overall		
	Professionals	Professors	Administrators	Mean	Std.	Median
1 Potable Water Quality	4.59	4.58	4.54	4.57	.495	5
2 Rain Water Harvesting & Alternatives	4.57	4.55	4.50	4.54	.499	5
3 Potable Water Demand	4.51	4.47	4.40	4.46	.536	4
4 Water Appliances Efficiency	4.30	4.31	4.38	4.33	.570	4
5 Grey Water System Efficiency	4.23	4.28	4.36	4.29	.555	4
6 Irrigation System Use	4.37	4.23	4.27	4.29	.549	4
Test statistics						
Kendall's W=0.889						

The results of the 'Water Efficiency' category, shown in Table 6.11, indicated that issues related to potable water quality and rainwater harvesting received the highest degrees of agreement amongst the respondents. They recorded respectively 4.57 and 4.54 as mean values whilst both scored a median of 5 'Extremely Important'. It was not surprising to know that the features associated with potable water demand and water appliances efficiency were also considered viable ways of reducing the overall water consumption, achieving 4.46 and 4.33 with a degree of 5 as a median. Interestingly, although they recorded the lowest and similar values of mean at 4.29, the greywater system efficiency criterion seemed to have slightly less variance than the criterion of irrigation system use, with standard deviation rates at 0.555 and 0.549 respectively. The Kendall's W test coefficient of concordance value obtained was 0.889, which was significant at 95% confidence level. There is thus a significant degree of agreement between the various participants, so these categories are in harmony and valid for assessing the 'Water Efficiency' features.

5) An Agreed Set of the Waste and Pollution Criteria

The results showed that this category 'Waste and Pollution' was rated fifth among the set of categories, with a mean of 4.47 and a median of 4 'important'. The category of Waste and Pollution encompasses five criteria. This set of criteria was analysed, and the results are presented in Table 6.12. below

Table 6.12: The Measures of Central Tendency for Waste & Pollution Criteria

Main Criteria	Mean			Overall		
	Professionals	Professors	Administrators	Mean	Std.	Median
1 Waste Treatment & Recycling Facilities	4.52	4.54	4.59	4.55	.498	5
2 Preventing Sandstorms	4.33	4.42	4.36	4.37	.557	4
3 Polluted Emissions Reduction	4.23	4.45	4.40	4.36	.538	4
4 Low Refrigerants Rate	4.30	4.39	4.33	4.34	.543	4
5 Low Light & Noise Pollution	4.25	4.33	4.23	4.27	.569	4
Test statistics						
Kendall's W=0.854						

According to Table 6.12, the most common features of waste and pollution that appear important among participants were the issues related to the waste treatment and recycling facilities. This criterion recorded 4.55 and a median at 5 'Extremely Important'. Interestingly, the participants agreed that the protection from sandstorms is a unique criterion, particularly relevant for the built environment in the Libyan context. It scored 4.37 and with a median range of 4 'Important'. Similarly, the rest of the criteria (i.e. Polluted Emissions Reduction, Low Refrigerants Rate, and Low Light and Noise Pollution) revealed a closer degree of agreement at 4.36 - 4.34 - 4.27 respectively. All the variables in this category showed rigorous standard deviation rates as they were less than 0.569, which means they had a lower level of variance. The Kendall's W test coefficient of concordance value obtained was 0.354, which was significant at 95% confidence level. This is indicated that there is a significant degree of agreement between the various participants and thus, these categories are in harmony and valid for assessing the 'Waste and Pollution' features.

6) An Agreed Set of the Health and Wellbeing Criteria

This category represents a strong social bias within the benefit evaluation of sustainable homes, as the results showed that the category of 'Health and Wellbeing' was not given high priority among the set of categories. Nonetheless, the category was rated fourth, with a mean recorded of 4.51 and a degree of median of 5 'extremely important'. The category of 'Health and Wellbeing' encompasses nine criteria. This set of criteria was analysed, and the results are presented in Table 6.13 below.

Table 6.13: The Measures of Central Tendency for Health & Wellbeing Criteria

Main Criteria	Mean			Overall		
	Professionals	Professors	Administrators	Mean	Std.	Median
1 Cooling and Heating Comfort & Control	4.51	4.50	4.58	4.53	.500	5
2 Natural Ventilation Level	4.52	4.48	4.56	4.52	.510	5
3 Safety Protection & Fire Security	4.56	4.53	4.47	4.52	.507	5
4 Illumination Quality & Control	4.37	4.38	4.42	4.39	.502	4
5 Internal Layout Functionality & Visual Comfort	4.27	4.31	4.32	4.30	.547	4
6 Cultural and Architectural Heritage	4.22	4.27	4.38	4.29	.572	4
7 Sound Absorption & Insulation	4.25	4.21	4.26	4.24	.570	4
8 Maintainability & Flexibility	3.78	3.71	3.85	3.78	.637	4
9 View out & Aesthetic Aspects	4.06	3.76	3.49	3.77	.632	4
Test statistics						
Kendall's W=0.881						

As Table 6.13 shows, the three highest significant features of sustainability identified reflect both the significance of such measures to deal with the harshness of the Libyan climate that makes the operation of cooling systems necessary, and the needs for home developments where people feel safe and secure. This was clear through the mean scores recorded for the criteria of 'Cooling and Heating Comfort and Control', 'Natural Ventilation Level' and 'Safety Protection and Fire Security', which were 4.53 - 4.52 - 4.52 respectively. Furthermore, the issues related to 'Illumination Quality', 'Internal Layout Functionality', 'Cultural and Architectural Heritage Considerations', and 'Sound Absorption and Insulation' were all deemed to be more important than other features such as 'Maintainability and Flexibility' or 'View Out and Aesthetic Aspects', as the average mean of the former group was roughly 4.30 whilst for the others it was 3.78, while all scored a median of 4 'Important'. Encouragingly, however, the standard deviation rates for all variables indicate that the variance level was very low, being less than 0.632 in all cases given. The Kendall's W test coefficient of concordance value obtained was 0.881, which was significant at 95% confidence level. There is thus a significant degree of agreement between the various participants, so these categories are in harmony and valid for assessing the 'Health and Wellbeing' features.

7) An Agreed Set of the Location Quality Criteria

Very surprisingly, the results showed that this category 'Location Quality' was rated last among the set of categories, yet, its mean scored 4.30 with a median of 4 'important'. In this cluster, five issues were suggested to be examined in terms of the extent to which they are important for assessing the features of 'Location Quality' in the housing projects. This set of criteria was analysed, and the results are presented in Table 6.14.

Table 6.14: The Measures of Central Tendency for Location Quality Criteria

Main Criteria	Mean			Overall		
	Professionals	Professors	Administrators	Mean	Std.	Median
1 Community Services & Facilities	4.50	4.53	4.59	4.54	.499	5
2 Considering Technological Connectivity	4.49	4.50	4.54	4.51	.501	5
3 Considering Transportation Accessibility	4.22	4.24	4.29	4.25	.556	4
4 Car Parking Capacity	4.28	4.25	4.22	4.25	.546	4
5 Pedestrian and Cyclist Safety	4.12	4.15	4.21	4.16	.658	4
Test statistics						
Kendall's W=0.856						

As Table 6.14 shows, it is not surprising that the issues prioritised within the Location Quality features highlighted the importance of aspects associated with community services and those enhancing the technological connectivity in relation to the concept of 'Smart Homes'. These criteria recorded 4.54 and 4.51 respectively, with a median of 5 'Extremely Important'. Following this, the consideration of transportation and car parking capacity were significantly targeted within the sustainability agenda to improve the accessibility for homeowners, as both scored 4.25 with a median of 4 'Important'. However unsurprisingly, the issue of pedestrian and cyclist safety did not receive as much agreement by the respondents as the rest of the Location Quality group, even though their mean scored 4.16 with a median of 4 'Important'. Again, all the variables in this category also showed rigorous standard deviation rates as they were less than 0.658, which means they had a lower level of variance. Kendall's W test coefficient of concordance value was 0.856, which was significant at 95% confidence level. Again, this indicates that there is a significant degree of agreement between the various participants and thus, these categories are in harmony and valid for assessing the 'Waste and Pollution' features.

6.3.4.3 Overview of the Findings from Questionnaires

Determining a set of principal sustainable development criteria that guides a decision support system to promote sustainability within the residential building sector was the key objective of this stage of the research. A large-scale questionnaire survey recruiting a wide variety of participants relevant to sustainability in housing projects, was carried out to meet the desired goal. The questionnaire consolidated the findings from the integrated analysis of the four-well-established systems (BREEAM, LEED, GBCA, and DGNB) and the focus group interview, thus enhancing the reliability of the data whilst also providing a comprehensive model of sustainability for housing projects. An interesting finding is that none of the criteria fall under the mean of 3 nor the medium of 4 'Important'. This clearly approves the significance and validity of the identified criteria to shape sustainability-based interventions within the housing investments. The sustainability assessment model for housing projects, hence, has been developed throughout this research, which encompasses a set of 43 principal sustainable development criteria grouped into seven broad categories (i.e. Management and Process, Materials Efficiency, Energy Efficiency, Water Efficiency, Waste and Pollution, Health & Wellbeing, and Location Quality). Table 6.15 shows the categories and criteria defined through the questionnaire survey.

Table 6.15: Categories and Criteria Defined through the Questionnaire Survey

Category	Criteria	
Management & Process	Integrative Process	1
	Environmental Management Plan	2
	Ecosystem Enactment	3
	Minimise Life Cycle Cost	4
	Independent Commissioning Agent	5
	Potential Natural Risks	6
Materials Efficiency	Environmentally Friendly Materials	7
	Responsible Sourcing of Materials	8
	Materials Reuse & Recycling Potential	9
	Use of Locally Available Materials	10
Energy Efficiency	Primary Energy Demand	11
	Efficient HVAC System	12
	Hot Water System Use	13
	Sunlight Access Rate	14
	Use of Thermal Insulation	15
	High-Efficiency Appliances & Monitoring	16
	Renewable Energy & Alternative Strategies	17
	Shading Strategy Uses	18

Water Efficiency	Potable Water Quality	19
	Potable water demand	20
	Irrigation System Use	21
	Water Appliances Efficiency	22
	Grey Water System Efficiency	23
	Rain Water Harvesting & Alternatives	24
Waste & Pollution	Waste Treatment & Recycling Facilities	25
	Low Light & Noise Pollution	26
	Polluted Emissions Reduction	27
	Low Refrigerants Rate	28
	Preventing Sandstorm	29
Health & Wellbeing	Natural Ventilation Level	30
	Illumination Quality & Control	3
	Sound Absorption & Insulation	32
	Cooling and Heating Comfort & Control	33
	Internal Layout Functionality & Visual Comfort	34
	Safety Protection & Fire Security	35
	Maintainability & Flexibility	36
	Cultural and Architectural Heritage	37
	View out & Aesthetic Aspects	38
Location Quality	Community Services & Facilities	39
	Considering Transportation Accessibility	40
	Considering Technological Connectivity	41
	Car Parking Capacity	42
	Pedestrian and Cyclist Safety	43

The next section presents an extensive discussion of the features that have been identified through this research as the most important criteria for assessing and shaping sustainable homes in the context of Libya.

6.4 Discussion the Findings and Reflections

This section provides an in-depth insight into the findings from the research. This study sought to develop a Composite Index for assessing sustainable homes in the context of Libya. To achieve this aim, the researcher needed to rationally identify a set of criteria to facilitate the delivery of sustainable housing projects. Therefore, this section will discuss the main findings obtained from this study through triangulating the results obtained from literature review, the integrated analyses of the well-known SAMs, the focus group interviews and the large-scale survey. This will confirm the main objectives, contribution, features and possible orientations for each criterion. Taken together, the comprehensive conception has provided a clear insight for understanding the proposed model built throughout this study.

6.4.1 The First Category: Management and Process

The issue concerning management and process is considered important among the major themes with respect to sustainable homes. Crucial elements have been identified throughout this research, which cover the Management and Process category, namely: the Integrative Process; Environmental Management Plan; Ecosystem Enhancement; Minimise Life Cycle Costs; Independent Commissioning Agents; and Potential Natural Risks.

Integrative Process

The integrative process has been considered one of key components amongst the management features. It mainly promotes the adoption of an integrated, system-oriented approach to sustainable project design and development in order to ensure durability and a high level of performance. Process efficiency, as a concept, is the process of doing more with less by using fewer resources to accomplish the same goals (Cole, 1998). The requirements of sustainable homes with regard to 'Integrative Process', allow the sustainable homes requirements to be fulfilled consistently throughout the entire house's building life. These objectives have been emphasised by Alyami *et al*. (2013), who considered the adoption of an integrative process as one of the most important aspects for ensuring sustainable homes. Furthermore, SAMs embedded these objectives in different ways, as discussed earlier (Section 4.5.6, p.91), However, neither BREEAM nor GBCA pay much consideration to this aspect; the term adopted for this criterion 'Integrative Process' has corroborated LEED terminology. Meanwhile, DGNB slightly covers this enquiry within the Planning with BIM criterion. To ensure that the quality of the project management and process is optimal, several indicators, as suggested by USGBC (2013b), can be used to evaluate the extent to which the relevant general conditions have been established early in the project. For example, this includes; evaluating the extent to which requirements planning has been undertaken; measures implemented to inform the public; conducting the durability risk evaluation; putting a quality management process in place; adopting a BIM approach; promoting the adoption of Lean construction techniques; and the integration of a detailed description of sustainability requirements within the specifications. Among the benefits of adopting an integrative process, as reported by Alyami *et al*. (2013), are maximising opportunities for the integrated, cost-effective adoption of construction design and strategies, and ensuring that the quality of the home building is as high as possible by means of an optimised, transparent planning process and by defining the relevant general conditions early in the design stage.

Environmental Management Plan

The Environmental Management Plan (EMP) represents one of the essential components through the sustainability assessment. The principle purpose of this criterion is to recognise and encourage housing sites that are managed in a manner that mitigates environmental impact. The environmental management plan should provide procedures and commitments for reducing waste and maintaining the environment on site in accordance with the best practice and the defined waste groups. Yet, these objectives (as discussed earlier in Section 4.5.6, p.91), are not much recognised within the literature. Moreover, the term adopted for this criterion 'Environmental Management Plan' corroborated GBCA terminology, whilst DGNB to some extent, covers this enquiry within the 'Image and site value appreciation' criterion. Thus, according to Addis and Talbot (2011), the development undertaken by the construction industry in general, generates millions of tonnes of waste and pollution that can adversely affect health, quality of life and the environment. The major potential sources of pollution from construction processes, as DETR (2000) demonstrated, include; waste materials; emissions from vehicles; noise; and the release of contaminants into the ground, water, and atmosphere. Recovery activities typically begin at the job site, with separation into different bins or disposal areas. In some areas, regional recycling facilities accept commingled waste and separate the recyclable materials from those that should go to landfill. These facilities, according to USGBC (2013b), can achieve waste diversion rates of approximately 80%. Likewise, minimising the disturbed area of a site can be achieved by leaving an adequately undisturbed area and developing a tree or plant preservation plan determined 'no-disturbance' that should also be protected from parked construction vehicles and building material storage. Consideration and plans should also be developed for ground and water contaminants, which are the main means by which pollutants are dispersed from a contamination event. In this respect, several measures have been recommended in USGBC (2013b) to reduce the impacts of construction activities. For example, this includes; providing an environmental management plan based on the life cycle assessment; introducing waste reduction targets by putting construction waste to a positive use; considering the reuse and recycle of construction materials; considering the minimising of emissions from vehicles; and adopting improved logistics strategies. According to Addis and Talbot (2011), among the benefits of conducting an EMP that adopts a life cycle approach, are helping commissioners and designers to make environmentally friendly decisions based on comprehensive information. This also, helps to identify solutions that are optimised both in terms of various relevant environmental issues and in terms of various locations and times of environmental impact. This includes the reduction of construction waste and alleviating emissions-related impacts on the environment as well as ensuring the consumption of non-renewable resources is minimal across all stages in the life of a house building.

Ecosystem Enhancement

The ecosystem features lie at the core of the sustainability concept as it focuses on the impact of current patterns of development on biological diversity and ecological value. As Ben-Eli (2015) clarified, seeking ecosystem enhancement demonstrates the linkages between the different dimensions of sustainability and implies that the significant environmental, social, and economic costs of current construction are not passed on to future generations. This criterion was noted within the two highest features of sustainability within the Management and Process cluster. It was corroborated by the most well-known assessment tools, such as BREEM and LEED, and by some authors (e.g. Tupenaite *et al*., 2017; Alyami *et al.,* 2013) who emphasised the ecological value of a site as one of the most important criteria for assessing the environmental features of sustainability. Although the focus of sustainable homes is typically based on built structures, the design of the site and its natural elements can have significant environmental consequences. How a building is incorporated into the site can benefit or harm local and regional ecosystems, and reduce or increase the demand for water, chemicals, and pesticides for site management. Plants in and around the home and respect for the local fauna create a positive image of the building as it increases the value of the property. As Sourani (2008) argued, ideal decisions, made early in the design process, can result in attractive, easy-to-maintain landscaping that protects native plant and animal species and contributes to the health of local and regional habitats. According to USGBC (2013b), possibilities to improve ecological value can be achieved through paying precise consideration to the careful selection of plant species and habitats in addition to the existing and neighbouring features. As USGBC (2013b) demonstrated, paying attention to site design can help in safe-guarding biodiversity. For example, this might include: the recognition of construction elements that can encourage bird populations; and the recognition of road verges, which can be rich areas for wildlife and amount to significant areas of land with the potential for improving habitats. Biodiversity can also be preserved and enhanced indirectly through the actions that housing providers can take to reduce pollution, reduce energy consumption and use renewable resources. All these should contribute to tackling global warming. Complying with such methods and orientations can help to ensure that a home is implemented through an efficient manner and satisfies sustainability targets.

Minimise Life Cycle Costs

Minimising Life Cycle Costs (LCC) has long been considered a key element amongst the management features. This criterion featured at the top of the Management and Process list, in accordance with the most well-known assessment tools, such as BREEM and LEED. This also corresponds with Sourani (2008), who emphasised whole life cycle costing as one of the most important criteria for assessing the economic features of sustainability. The LCC analysis is useful in ensuring that future costs are considered and that the impact on future generations is assessed, using discounting techniques that transfer all future costs and benefits to the present values (Addis & Talbot, 2011). The life cycle costs of a built asset facility include: the acquisition costs, including consultancy, design, construction and equipment; the operating costs, including utilities, renovation, and repairs and maintenance through to disposal; and internal resources and overheads, including risk allowances, predicted alterations for known changes in business requirements, refurbishment costs and the costs associated with sustainability and health and safety aspects (Goh & Yang, 2009). There is an increasing acknowledgment that the decision making process in relation to the selection of contractors should move away from the consideration of the lowest bid to a broader direction that emphasises the value obtained over the asset life cycle. Traditionally, as Goh and Yang (2009) observed, there has been an imbalance between sustainability requirements and project budgets. They found that the decisions related to the design and construction of building projects are mainly taken based on the first-cost mentality approach. As Higham (2014) argued, decisions based solely on an initial cost may not turn out to be the best selection in the long term and this method cannot be effectively utilized to realize the benefits of the long-term cost implications of sustainable development in housing projects. Nevertheless, sustainability innovators often ultimately push for sustainable homes with less concern for the cost required or the sustainability commitment. However, this encourages the adaptation of emerging global issues of sustainability while continuing to return profit as the concept of sustainable development per se; this promotes the utmost efficiency and the reduction of financial costs (Goh & Yang, 2009). To ensure best practice in this context, it is of vital importance to deliver: a rigorous elemental life cycle cost; a component level life cycle cost; and capital cost reporting. The USGBC (2013b) guidance provided a number of recommendations with respect to the compliance with the minimisation of life cycle costs. For example, this includes: drawing up the life cycle costs system in the early planning phase; determining the life cycle costs at regular intervals during the planning process; determining the effects of significant alternative decisions on the expected life cycle costs; determining the effects of significant decisions on the expected life cycle costs; assessing and comparing the building-related life cycle costs; and optimising the life cycle cost during the planning process. The benefits of conducting LCC, as reported by Goh and Yang, (2009), are encouraging the sensible and conscious use of economic resources throughout the entire life cycle of a home building. LCC analysis makes it possible for decision makers to evaluate competing initiatives and identify the most sustainable growth path for the common building project (Goh & Yang, 2009). Carrying out the life cycle cost calculations earlier in the planning process increases the likelihood of achieving solutions optimised for cost-efficiency in the long term, on which the economic viability of a project is mainly determined (Ding, 2008). He also asserted that recognising and encouraging the use of life cycle costing and the sharing of data can truly raise awareness and understand the economic and social viabilities of a project.

Independent Commissioning

The independent commissioning agent reflects the organisation's strong compliance with a properly planned handover that meets the needs of the home's occupants as initially designed. Higher reliability and credibility can be granted when a formalised management system is certified by a third-party organisation. A third-party certifier should be statutorily recognised or a member of relevant international accreditation organisation. The need for independent commissioning has been well established and reflected in Tupenaite *et al.*'s (2017) study, which also, addresses the most well-known assessment tools, such as GBCA and DGNB, that emphasised the adoption of independent commissioning as one of the most important criteria for assessing the managerial features of sustainability. As Tupenaite *et al*. (2017) asserted, seeking independent commissioning encourages home-buyers to identify sustainability-based issues more strongly and is a relevant component of efficient performance. This, as Higham (2014) demonstrated, would minimise risks and can also play a key role in increasing the acceptance of decisions, devising a more balanced solution, improving decision-making, and reducing conflicts. Mathur *et al.* (2008) considered the importance of recognising the stakeholders' consultation, which is a cornerstone that should be considered, especially, within the design stage. They emphasised that the involvement of stakeholders is of particular importance, allowing for the management of conflicts and risks, avoiding unnecessary disputes and delays, improving management decision making, building consensus among widely different views, creating stakeholder buy-in to the outcomes of the project's activities, and inspiring innovation in decision making through considering the different perspectives. Several measures have been recommended in USGBC (2013b), aiming to ensure best practice associated with this respect, including: commissioning and testing schedule and responsibilities; commissioning building services, testing and inspecting building fabrics, and handover; consulting with stakeholders covering project delivery and relevant third parties; monitoring and reporting site related energy, water and transport impacts; inspecting, testing, identifying and rectifying defects via an appropriate method and, after an initial operating phase, readjusting the technical components (e.g. heating system, ventilation, room air conditioning, cooling technology, building automation, lighting, hot water supply, façade shutters, etc.).

Potential Natural Risks

Resilient homes that are tailored to their environment need to be sustainable. A natural risk is a natural disaster, such as an earthquake, flood, or hurricane, which negatively affects society, either through damage to the property or through loss of life. The geography of the house's site has its own set of natural hazards. The need to address natural risks and the guidance related to these issues have been reported within the sustainability assessment for a long time. This has been reflected in Alyami *et al*.'s (2013) study, which have emphasised natural risks as major concerns hindering the application of sustainability. As discussed earlier (Section 4.5.6, p.91), these objectives were handled differently by SAMs; however, DGNB has covered this objective through multiple criteria, whilst neither GBCA nor LEED pay much consideration to this subject. Moreover, BREEAM merely allocated the criterion of 'Flood Risk' to fulfil this enquiry. As Abdudayem and Scott (2014) identified, valley and coastal flooding are two of the most frequent natural risks in Libya, resulting of rising rainfall and sea levels. Yet, it is not easy to predict the natural risks in terms of their intensity and frequency; it is of utmost importance to correctly classify the potential natural risks and to take measures to reduce the impact of any adverse effects expected and to maintain sustainability in urban areas. The Meteorological Office predicts a very significant increase in the incidence of flooding over the next century as a result of climate change (Pielke & Downton, 2000). They warned that, if property development continues to increase in high-risk areas, the frequency and intensity of natural catastrophes will inevitably increase too, even if the number of natural events remain constant. Therefore, providing efficient measures and indicators to evaluate natural risks in the local environment is crucial to maintain sustainability in urban areas. According to USGBC (2013b), this could include; flood compensation measures (e.g. a flood protection concept based on required uses, temporary structural measures for flood protection, safe distances of the ground floor above the level of a potential flood, the enlargement of retention areas within the project area, a flood risk analysis with the safety measures proposed, etc.); landslide hazard compensation measures (e.g. analysis and assessments of the soil conditions, structural protection measures such as installation of drainage systems and preventive installations in the endangered subsoil, a landslide risk analysis with the safety measures proposed, etc.); earthquake compensation measures (e.g. early warning system with the measures that should be taken, dedicated earthquake-proof shelters, an earthquake risk analysis with the safety measures proposed, etc.). Among the benefits of considering potential natural risks are; protecting houses and their occupants from the severe impact of negative environmental influences and extreme events, and to improve the resilience of homes against any influences that might be present in the local area. As Ding (2008) stressed, defining the probability of each of these events and aligning this with the potential severity of their consequences earlier in the planning stage would reduce the cost of any retrofitting work that might be necessary.

6.4.2 The Second Category: Material Efficiency

The choice of building materials is important for sustainable homes because of the extraction, processing, and transportation they require. Issues in this section focus on major features, namely: Environmentally friendly materials; the Responsible Sourcing of Materials; Materials' Reuse and Recycling Potential; and the Use of Locally Available Materials.

Environmentally Friendly Materials

Since the production and use of construction materials account for the greater amount of resources and energy, and align with difficulties and safety measurements during the disposal process, it has become necessary to pay more attention to environmental issues in their selection and use. The use of Environmentally Friendly Materials was brought to the top of the 'Material Efficiency' list, which have corroborated most SAMs, such as BREEAM and LEED, and correspond with some authors (e.g. Tupenaite *et al*., 2017; Alyami *et al.,* 2013) who have emphasised material efficiency as one of the most important criterions for assessing sustainability. The main intent is to reduce all dangerous or damaging construction materials that can adversely affect or cause damage to people, and flora and fauna. The use of particularly environmentally friendly materials not only makes an important contribution to the reduction of the contamination risk of a building with regard to pollutants, but also helps to improve indoor environment quality. Products with low emissions, such as volatile organic compounds (VOCs), may improve health and wellbeing for residents. Such products are highly recommended to consolidate sustainability in relation to the materials' efficiency (TCPA & WWF, 2003). Unsustainable building materials and products are not healthy to use and live with; some consume large amounts of energy during manufacturing. They are also often difficult to safely dispose of, causing negative environmental impacts at the site of this disposal (TCPA & WWF, 2003). Minerals, such as sandstone and fossil fuels, are considered non-renewable as they cannot be replenished within a human time scale. Conversely, biomass, including quickly renewable resources (e.g. agricultural crops) and slowly renewable resources (e.g. timber) are renewable within that timescale. However, making use of such resources might be, in some cases, unsustainable, when they are used beyond their rates of recovery or overexploited, resulting in irreversible effects. In this regard, the development undertaken by the Libyan construction industry, as reported by Ahmed *et al.* (2015), extracts about 90% of non-energy minerals for use as aggregates and raw material for construction products. This development accounts for approximately 10% of the Libyan carbon emissions as a result of extraction and transportation of these materials (Ahmed *et al*., 2015). To address these issues, housing providers should be encouraged to adopt products and materials that have low environmental impacts and exclude environmentally damaging materials. It is therefore important that the contracting authorities should set minimum requirements in relation to the percentage of recycled or reused content where possible. Thus, contractors can identify the way through and how they can meet such requirements (Cole, 1998). To ensure best practice associated with this criterion, particular considerations have been raised in the USGBC (2013b) guidance. For example, this includes: the use of renewable resources, such as crop based materials in insulation design (e.g. hemp, flax, wool, etc.); paints (e.g. crop-derived pigments, binders and thinners, solvents and emulsifiers, etc.); and timber (e.g. FSC 'Forest Stewardship Council' - as a well-recognised and independent international standard). Applying such materials can help to ensure that a home is sourced from renewable sources and complies with sustainability targets.

Responsible Sourcing of Materials

The responsible sourcing of materials lies at the heart of efficient material issues, due to the range of concerns across ethical, environmental and societal dimensions that have to be satisfied. More attention is given to obtaining materials from responsible sourcing, and ensuring that these materials are sourced from renewable and sustainable sources. These objectives have corroborated previous studies from Tupenaite *et al*. (2017) and Abdul-Rahman *et al*. (2016), who have emphasised the responsible sourcing of materials as one of the most important aspects for ensuring sustainable homes. SAMs also adopted this objective in different ways, as discussed earlier (Section 4.5.6, p.91). Furthermore, the term adopted for this criterion 'Responsible Sourcing of Materials' corroborated BREEM terminology, whilst LEED covers this enquiry within the 'Certified Tropical Wood' criterion. However, DGNB does not pay much consideration to this subject. As Sourani (2008) demonstrated, responsible sourcing responses to many valuable questions, such as: the sources of materials; the materials extracted and processed in an environmentally sensitive manner; the fair treatment of the workforce involved in their extraction and production; the effective consultation of stakeholders in the supply chain; and the adequate consideration of communities local to the extraction and manufacture area. In this context, supply chain management and material stewardship, as Ding (2008) asserted, are considered essential elements of responsible sourcing. Certification by independent, licensed competent bodies should be attained to confirm compliance with the required standards and an effective assessment should be applied. This ensures that the consequences and impacts of using a particular material have been considered from the point at which they are mined or harvested in their raw state, through manufacture and processing, then use, reuse and recycling, until their final disposal as waste. Therefore, recognising the importance of these issues would be the main target if responsible sourcing is to be assessed within home projects.

Materials Reuse and Recycling Potential

Materials Reuse and Recycling are of great importance for sustainable homes. Reuse materials comprise waste that is used again in its original form, whilst recycled material refers to waste that has been turned into a new product. Therefore, the main difference between recycled and reuse is whether material is used for its original purpose. Both reused and recycled materials are considered sustainable because they decrease landfill waste, reduce the need for raw materials, lower environmental impacts and energy use, and reduce air and water pollution from incineration and landfills. This criterion was brought with the two highest features of sustainability within the list of Materials and Resources, which have corroborated most SAMs, such as BREEM and LEED, and corresponded with some authors (e.g. Tupenaite *et al.,* 2017; Alyami *et al.,* 2013) who have emphasised the reuse and recycling of materials as one of the most important aspects for ensuring sustainable homes. An efficient sustainability-based assessment can therefore ensure that the material applied is considered and its potential for reuse or recycling taken into account. The USGBC guide has provided efficient measures and indicators in order to ensure best practice associated with the reuse and recycling issues. For example, this includes; the use of reused components or structural elements; solutions that use the current recycling paths of construction materials; the use of reused and reusable building components; the selection of easy-to-recycle construction materials; evaluation methods for easier recovery and recycling are used in the early planning phases to optimise resource efficiency (USGBC, 2013b). Among the benefits of reusing materials and recycling is the reduction in construction waste or disposal components, which enables house providers to reduce the consumption of natural resources to a minimum and ensure that, once resources have been used for their current purposes, they will continue to be available to future generations to the highest extent possible. Reclaimed materials can, in turn, be substituted for new materials, saving costs and reducing resource use. Thus, housing investors who implement reductions in the use of materials, can benefit from reduced costs whilst occupants, in turn, enjoy positive effects in their homes, such as lower costs for maintenance, repair and conversion measures.

Use of Locally Available Materials

The use of local resources is an important aspect, which raises awareness of its impacts, and are often thought to be shown upon employability. Although the focus group interview suggested that issues, such as the use of Locally Available Materials, are considered in evaluating the sustainability of a housing project, the least important aspect was the estate's appearance. This can be traced to the fact that, through the decision-making process for selection materials, the quality and performance of materials is more critical than the locality or the economic benefits. Tupenaite *et al.* (2017) and Akadiri (2011) have stated that a consideration of locally available materials is an area of sustainability, which has corroborated the findings in this study. As discussed earlier (Section 4.5.6, p.91), these objectives are not well-recognised by BREEAM, DGNB and GBCA, whilst LEED has allocated the criterion of 'Regional Priority' to partially fulfil this enquiry. Among the benefits of using locally available materials are reinforcing the national economy as this increases demand for environmentally preferable products, and products or building components that are extracted, processed, and manufactured within the region (Cole, 1998). Housing projects can reinforce a successful local economy through creating jobs, training local people, increasing demand for local materials, sourcing local suppliers, encouraging new businesses, improving access to services and attracting people to live and work in the local area (Cole, 1998). In parallel, using locally available materials avoids the harmful effects of long-distance transport. A substantial amount of energy is used to transport materials from product manufacturing plants to home construction sites. Choosing local products, as Akadiri (2011) demonstrated, will reduce the use of embedded transportation energy associated with construction, as an extensive amount of energy is often used to transport materials from product manufacturing plants to home construction sites. With such use, transportation would be minimised and as a result, smaller amounts of emissions would be produced, and less congestion would be encountered. To ensure the use of locally available materials, Sourani (2008) suggested the encouragement of investors within procurement activities, to support social and community enterprises and to recycle funding in the local economy. Local authorities can enforce suppliers to utilise local labour, local sourcing or local subcontracting. This should be integrated into their contracts and specifications requirements relating to the community benefits delivered in a locality.

6.4.3 The Third Category: Energy Efficiency

Energy efficiency is the utilisation of less energy to provide the same service. The need to better use energy in a more sustainable way becomes of paramount importance, and housing projects have a leading role in meeting such a need. Crucial elements have been identified through this research, which cover the 'Energy Efficiency' section, namely: Peak Energy Demand; Efficient HVAC System; Hot Water System Use; Daylight Access and Light Systems; Use of Thermal Insulation; High-Efficiency Appliances and Monitoring; Renewable Energy and Alternative Strategies; and Shading Strategy Uses.

Peak Energy Demand

Peak Energy Demand refers to the maximum amount of energy consumed by an electrical system at any point in time and represents the accumulated demand of many electrical supply points across a system. Furthermore, a network's peak demand is the accumulated peak demand of all buildings and infrastructure on a supply network. The main purpose of this node is to optimise the energy performance for homes by which saving energy is to be achieved. These objectives have corroborated a previous study from Chang *et al*. (2007), which have emphasised the adoption of energy efficiency as one of the most important aspects for ensuring sustainable homes. SAMs also adopted this objective in different ways, as discussed earlier (Section 4.5.6, p.91). Meanwhile, this criterion is not much recognised by BREEAM, DGNB and GBCA; LEED has, to some extent, covered this enquiry within the criterion of 'Annual energy use' and 'Minimum Energy Performance'. According to IEA (2018), the relevant indicators are dated 2016 which is the most recent year for which comparable data are available. At this time, Libya was ranked 99th globally in relation to electricity consumption, using 28.48 billion kWh which means 4,680 kWh per capita. The average Libyan consumes roughly two times more electricity than the average Indian person, although this is still about fourth average in the UK. Likewise, in relation to gas consumption, Libya in the same year, was ranked 60th globally in relation to natural gas consumption, consuming 4.49 billion m^3 which means 704.36 m^3 per capita. The average Libyan consumes roughly two times more natural gas than the average Indian person, though still about 70% of the average in the UK (IEA, 2018). Optimising home design can help to achieve better energy performance. This could involve, for example, the consideration of passive systems that use natural light, air movement and thermal mass as well as producing energy from renewable resources. The criterion, 'Peak Energy Demand', can be assessed on the provision of efficient measures by calculating its annual peak demand ratio and comparing these results to a pre-defined benchmark. The energy requirements can be estimated on the standard occupancy assumptions of a home rather than the actual energy use. In addition, Akadiri (2011) suggested that, after the lack of awareness, occupants' behaviour is one of the significant factors that controls the energy consumption in homes; technical advances should be accompanied by a greater ecological commitment from households in order to achieve energy savings. Among the benefits of assessing these features are promoting operational practices that reduce peak demand on electricity supply infrastructure, pushing the home's peak demand performance to meet the network's peak demand ratio benchmark.

Efficient HVAC System

Heating, ventilation and air conditioning (HVAC) systems are the largest consumers of energy in the house, particularly in harsh climates. Libya has a hot climate, containing both arid and humid areas, and this aggressive climate requires extra energy for air conditioning to cool the property to a satisfactory level for human thermal comfort. According to Almansuri *et al.* (2009), air conditioning consumes about 80% of the energy used in Libyan homes. An HVAC System is likely to be critical to homeowners, and the need to adopt Efficient Systems have been well established and reflected in many publications (e.g. Tupenaite *et al*., 2017; Abdul-Rahman *et al*., 2016; Akadiri, 2011), which have corroborated the current finding. SAMs also, adopted this objective in different ways, as discussed earlier (Section 4.5.6, p.91). Moreover, DGNB has covered this objective through multiple criteria, whilst BREEM does not pay much consideration to this subject. Likewise, LEED allocates it between the 'HVAC Start-Up Credentialing' and 'Heating and Cooling Distribution Systems' criteria, whilst GBCA covers this query within the 'Ventilation and Air-Conditioning' criterion. The USGBC guide provided efficient measures and indicators to ensure best practice associated with the efficiency of HVAC systems. For example, this includes; assessing that processes are in place to monitor, measure and maintain indoor temperatures; the control of relative humidity within acceptable best practice ranges; designing the HVAC system with flow control valves on every radiator; air leakage rates

(USGBC, 2013b). Among the benefits of using sufficient HVAC Systems are the minimising of energy consumption through the recognition of the thermal bridges and leaks in the heating and cooling distribution system.

Hot Water System Use

The issue related to hot water system use is considered important among the major themes within the Respect for Energy efficiency. The adoption of an efficient hot water system has been highlighted as a sustainability area by Alyami *et al*. (2013), which corroborates the research findings. As discussed earlier (Section 4.5.6, p.91), these objectives are handled differently by SAMs. Furthermore, neither BREEAM nor DGNB pay much consideration to this subject, although LEED has covered these objectives through the 'Efficient Hot Water Distribution System' and 'Efficient Domestic Hot Water Equipment' criteria. However, GBCA merely allocated the criterion of 'Domestic Hot Water Systems' to fulfil this enquiry. According to Alyami *et al*. (2013), the importance of the 'Hot Water System Use' criterion is shown through assessing hot water systems adopted within a house in order to encourage the reduction of energy consumption associated with the domestic hot water system, including improvements in the efficiency of both the hot water system design and the layout of the fixtures in the home. Particular attention, suggested by USGBC (2013b), could be divided into two main parts: (i) Design and install an energy-efficient hot water distribution system (e.g. a demand-controlled circulation loop, the total length of the circulation loop, branch lines from the loop to each fixture, a push button control with an automatic pump shut-off etc.); and (ii) Central manifold distribution system (e.g. the length of central manifold trunk, recognise the branch line from the central manifold to any fixtures, etc.).

Daylight Access and Light Systems

Daylight access has long been considered one of key elements for energy efficiency. The main purpose of promoting this feature is to encourage the provision of well-lit spaces that offer appropriate levels of natural daylight for the tasks regularly performed by home occupants. These objectives have corroborated previous studies (e.g. Tupenaite *et al,* 2017; Abdul-Rahman *et al*., 2016; Akadiri, 2011), which have emphasised the adoption of efficient daylight access and light systems as one of the most important aspects for ensuring sustainable homes; thus, suggesting many possibilities for efficient lighting. As discussed earlier (Section 4.5.6, p.91), these objectives are handled differently by SAMs. Whilst BREEAM has covered these objectives through multiple criteria, DGNB covers this enquiry within the 'Availability of daylight for the entire building' criterion. Similarly, GBCA and LEED embed this within the 'Lighting' criteria. According to Wang and Ebrahimi (2016), traditional bulbs waste a lot of their energy and produce more CO_2 emissions, whilst natural light can provide a positive effect on the mental and physical health of humans. Daylight makes an interior look more attractive and interesting, and provides light to work or read, which psychologically helps to enhance occupants' health and wellbeing. In addition, the effective use of daylight provides a great deal of potential energy savings in terms of electric lighting and cooling loads, while winter solar gain can meet some of the heating requirements. Access to views, as Akadiri (2011) reported, can be provided externally or internally, such as via clear lines of sight to a courtyard or atrium. The quality and quantity of natural light in an interior depends both on the design of the interior environment (size and position of the windows, the depth and shape of rooms, the colours of internal surfaces) and the design of the external environment (obstructing buildings and objects). If obstructing buildings are large in relation to their distance from the room, the distribution of light in the room will be affected, as well as the total amount received. To ensure best practice, interiors including kitchens, all living rooms, dining rooms and studies, should achieve a minimum average daylight factor and adequate window spaces. USGBC (2013b) describes good practice in daylight design and presents standards intended to enhance the wellbeing and satisfaction of people in homes. Particular attention, in this regard, includes: the availability of daylight in the entire home; an available direct view to the outside; an evaluation of the sun and glare protection system in place; artificial light conditions; the colour rendering index of the daylight and the duration of exposure to daylight; the use of compact fluorescent light bulbs (CFLs); and motion sensor controls or integrated photovoltaic cells for exterior lighting.

Use of Thermal Insulation

Although the innovative systems used in contemporary homes may reduce energy consumption, it is the use of thermal insulation that can have the most significant long-term effect, as this is unlikely to be radically altered during its life. The main intent of this node is to enhance the energy efficiency of homes by limiting heat losses across the building envelope. It encourages the design and installation of insulation and the application of proper windows to minimise heat transfer and thermal bridging, and to maximize the energy performance of homes. These objectives have corroborated previous studies from Abdul-Rahman *et al.* (2016) and Akadiri (2011) which have emphasised the use of thermal insulation as one of the most important aspects for ensuring sustainable homes. As discussed earlier (Section 4.5.6, p.91), these objectives are handled differently by SAMs. Whilst, GBCA did not pay much consideration to this subject, DGNB covers this enquiry within the 'Summer heat protection' criterion. Likewise, BREEM embeds this within the 'Building Fabric' criterion, whilst LEED uses the 'Envelope Insulation' criterion to fulfil this query. The importance of this criterion, as Akadiri (2011) clarified, is shown through assessing the thermal performance of the home envelope on its own, thereby creating the conditions required to ensure high thermal comfort with the lowest possible energy demand. In this context, the Heat Loss Parameter (HLP) is a statistic, which combines the impact of both the external surface area, the insulation value of construction, and airtightness. A lower value for HLP refers to the increased levels of insulation and airtightness as well as efficiency in the design of homes. A well-planned building envelope is highly recommended in many initiatives, such as The GCCP (2000) guide, that aims to achieve higher energy savings and user comfort. This includes, for example: install walls and insulation systems (e.g. structural insulated panels (SIPs) and insulated concrete forms (ICFs)); install windows and glass doors that have efficient have efficient reflectance; and install skylight glazing, etc. Accordingly, as reported by Akadiri (2011), the concept of 'Passive Design' can have a great impact on reducing energy use in homes by using ambient energy sources, such as daylight, natural ventilation, and solar energy.

Energy Efficiency Appliances and Monitoring

The choice of energy efficiency appliances can play a vital role in terms of reducing energy consumption. The principle purpose of this node is to encourage the provision of energy efficient equipment and monitoring appliances thereby ensuring the optimum performance that achieves energy savings and the reduction of CO_2 emissions from homes. These objectives have corroborated previous studies from Tupenaite *et al*. (2017) and Abdul-Rahman *et al.* (2016), which have emphasised the application of energy efficient equipment as one of the most important aspects for ensuring sustainable homes. As discussed earlier (Section 4.5.6, p.91), these objectives are handled differently by SAMs. Whilst DGNB does not pay much consideration to this subject, GBCA covers this enquiry within the 'IT

Equipment' criterion. Likewise, BREEM embeds this within the 'Energy Labelled White Goods' criterion, whereas LEED uses the criterion of 'High-Efficiency Appliances' to meet this query. According to Almansuri *et al*. (2009), up to 25% per year of the energy consumed can be saved by each household by choosing energy efficient equipment. Compact fluorescent light bulbs (CFLs) use around 60% less electricity than traditional incandescent lights, lasting ten to twelve times as long. Accordingly, emissions from lights and appliances, as Amer (2007) observed, are now higher than both the space and water heating emissions, comprising about 43% of the total CO_2 emissions, whilst space heating accounts for 26%, water heating 22% and cooking 9% of the CO_2 emissions. It is widely acknowledged, as USGBC (2013b) reported, that the provision of energy efficient appliances under the internationally recognised Energy Efficiency Labelling Scheme (e.g. energy efficient white goods, ENERGY STAR, ASHRAE, etc.) can make a huge difference in relation to energy and money saving for homeowners. Particular attention to assessing energy efficiency appliances, for example, includes; install appliances (e.g. refrigerators, ceiling fans dishwashers, clothes washer etc.) that meet the applicable requirements; design and size HVAC equipment properly using a verified method; and install programmable thermostat (USGBC, 2013b).

Renewable Energy and Alternative Strategies

Renewable Energy, which produces zero or low levels of greenhouse emissions, have an increasingly important role in contributing to the achievement of sustainable homes. Renewable energy can be obtained from energy flows that occur naturally and continuously, including solar, wind, waves or tides (Amer, 2007). The participation in this research, strongly acknowledged this feature, showing a broad understanding of the importance of the adoption of renewable energy in the evaluation of sustainable homes. This accords with the international tools, such as BREEM and LEED that ranked renewable energy at the top of the cluster of energy. The use of renewable energy has been also highlighted as a sustainability area by Tupenaite *et al*. (2017) and Abdul-Rahman *et al.* (2016), which corroborated the research finding. As Alyami *et al*. (2013) warned, climate change is now a real threat to the world; it can lead to global problems (e.g. drought, famine, flooding, disease, regional insecurity and population displacements), and can seriously hinder poor countries' efforts to tackle poverty. It could affect every economic sector and every level of governance. Aligned with this, the increasing demand for energy has led to the production of emission levels that are sufficient to affect the climate system. The Libyan energy industry, as Shawesh (2016) observed, is considered the largest single contributor to Libyan's greenhouse gas emissions. The use of fossil fuel, which is a non-renewable resource, produces the bulk of Libyan energy, generating more than one third of Libyan carbon emissions (Shawesh, 2016). Renewable energy sources should be promoted, not only to minimise reliance on the finite and diminishing sources of fossil fuel (e.g. coal, oil, gas, etc.), but also to reduce pollution and tackle climate change. The importance of assessing these features is shown through encouraging the generation of local energy from renewable sources to supply a significant proportion of the energy demand thereby reducing energy consumption and CO_2 emissions. The use of resilient home building technology and renewable energy sources, as reported by Amer (2007), reduces the risk of cost increases and external dependencies and is generally engineered for long-term durability. Housing providers and developers can play a major role in optimising domestic energy needs that rely on renewable energy technologies. Many of the initiatives pursued, such as The GCCP (2000) guide, have provided examples of solutions, such as natural light, natural air movement, thermal mass, solar water heating, wind turbines, biomass and photovoltaics as well as the commitment and the setting of buildings.

Shading Strategy Uses

The use of shading strategy is an important aspect of many energy-efficient home design strategies. Well-designed sun control and shading devices can significantly reduce peak heat gain and cooling requirements in a home, as well as improve the natural lighting quality of home interiors. The main intent of this node is to encourage house providers to use a shading strategy in their designs to reduce energy demands for space cooling. It greatly appreciates the adoption of building facade designs that take into account shading strategies to reduce the sun's heat effects. However, although increasing attention has been paid to the attainment of energy from renewable resources to achieve energy efficiency, little consideration was given to the strategies that benefit from shading devices and solar control through well-known SAMs and relevant literature. There are various reasons to control the amount of sunlight admitted into a home. In warm, sunny climates, excess solar gains may result in high cooling energy consumptions; in cold temperatures, the sun can positively contribute to passive solar heating. Shading devices and solar control can also help to diffuse natural illumination, thereby improving daylighting which can reduce the energy consumption. According to Elgadi *et al*. (2016), depending on the amount and location of fenestration, 5-15% reductions in the annual consumption of cooling energy have been reported. Sun control and shading devices lead to an increase in occupant satisfaction and productivity, as well as improvements in user's visual comfort through controlling glare and reducing contrast ratios. In addition, shading devices offer the opportunity of differentiating one house facade from another, which can provide interest and human scale to an otherwise undistinguished design. The orientations required to ensure best practice with this criterion include; adopting external window shading as, during warm seasons, it is an excellent way to prevent unwanted solar heat gain from entering a conditioned space. Shading can also be provided by natural landscaping or by building elements, such as awnings, overhangs, and trellises. Some shading devices can also function as reflector 'light shelves', which bounce natural light as daylighting deep into home interiors. It is critical, in this regard, to understand the angles of the sun during the year. This should determine various aspects of shading design, including the basic house orientation and the selection of shading devices. In light of this, shading strategies can be assessed based on their ability to provide a system that addresses solar control issues. For example, this could involve a wide range of home components including; landscape features (e.g. mature trees or hedge rows); exterior elements (e.g. overhangs or vertical fins); horizontal reflecting surfaces 'light shelves'; low shading coefficient glass; and interior glare control devices (e.g. venetian blinds or adjustable louvers).

6.4.4 The Fourth Category: Water Efficiency

Water efficiency management has an essential role to play in helping to ensure sufficient water bulk for people, the economy and the environment, for both now and in the future. Crucial elements have been identified through this research, which cover the Water Efficiency category, namely: Potable water demand; Potable Water Quality; Irrigation System Use; Water Appliances Efficiency; Sanitary Fixture Systems; and Rainwater Harvesting and Alternatives.

Potable Water Demand

The Potable Water Demand criterion can play a vital role in advocating the efficient use of water. The principle purpose of this criterion is to encourage less potable water use in the home. It mainly aims to reduce the consumed rate of bulk water per capita and to maximise the exploitation of water resources in a sufficient manner. These objectives have also corroborated previous studies by Alyami *et al.* (2013) and Ali and Al Nsairat (2009), who have assessed water demand as one of the most important aspects for ensuring sustainable homes. SAMs, in turn, adopted this objective in different ways, as discussed earlier (Section 4.5.6, p.91). Whilst GBCA does not pay much consideration to this subject, DGNB covers this enquiry within the 'Potable water demand and wastewater volume' criterion. Similarly, BREEAM embeds this within the 'Internal Water Use' criterion, whilst LEED uses the criterion of 'Indoor Water Use' to meet this query. As MWR and CEDARE (2014) reported, Libya relies almost completely on non-renewable, fossil, groundwater resources. With very limited perennial water resources, namely only ephemeral rivers or wadis, the Libyan government has undertaken a massive project, known as the Great Man-Made River Project (GMMR). GMMR provides approximately 6.5 million m^3 of freshwater per day to supply water for the Northern cities of Libya, which accommodate around 70% of Libya's population (Abdudayem & Scott, 2014). The figures indicated that approximately 5830 million m^3 of fresh water in 2012, which is the most recent year for which data are available, was withdrawn from reservoirs and underground aquifers, for which 20% was used domestically and over 50% of this used for flushing WC's and washing. Groundwater (including fossil groundwater) provides over 95% of the water withdrawn, whilst the remaining amount is divided between surface water, desalinated water and wastewater (Abdudayem & Scott, 2014). The national targets indicated that a sustainable groundwater abstraction should not exceed 3650 million m^3/year, although only 650 million m^3/year comes from renewable groundwater and 3000 million m^3/year comes from fossil water (CEDARE, 2014). Due to the fact that fossil groundwater is not included in the renewable water resources, the current water withdrawal is more than eight times the annual renewable water resources, whilst more than half of the domestic water supplies were from the GMMR (MWR & CEDARE, 2014). Accordingly, people in Libya are not charged for water use, as water supplies are taken for granted. This, as Abdudayem and Scott (2014) asserted, has led to unconscious behaviours towards the consumption of water and the lack of value for this resource, which results in even further waste and less efficient distribution. Thus, potable water demand could be assessed on the predicted average occupant's water consumption and wastewater volume using a recognised code for the home type. This can be determined on the basis of historical water use data from comparable homes. The importance of the 'Potable Water Demand' criterion is shown through providing a measurement and comparison method, which allows home occupants to set out goals and improve their performance against water use targets over time thereby reducing costs and the use of local resources (wells, rainwater) as well as encouraging recycling waste water that helps achieve independence and maintain water resources.

Potable Water Quality

The issue of water quality is among the major themes that assess sustainability in public housing. The criterion of Potable Water Quality was moved to the top of the water efficiency list, through emphasis amongst interviewees within the focus group, who encouraged the provision of higher water quality with water suppliers' alternatives for housing projects. The principal purpose of this node is to encourage the use of higher water quality and promote potable water suppliers' alternatives that maximise the water resource quality in a sufficient manner. It mainly aims to minimise the risk of water contamination in home facilities and ensure the provision of clean, fresh sources of water for home users. It is widely acknowledged that water resources are under increasing pressure from population growth, climate change and the need to protect the environment. Many homes use thousands of litres of potable water each day. These include cooking; cleaning works; washing (e.g. bodies, clothes, cooking utensils); recreation and occupant amenity (e.g. swimming pools); and irrigation. As MWR and CEDARE (2014) reported, the state of Libya is relying largely on groundwater to satisfy its water demand whilst it is struggling with a situation of severe drought that has put a great strain on its water supply, especially in relation of the quality of water required to meet the bespoke standards. Water consumption is likely to become an increasing national problem as water demand exceeds the volume licensed for abstraction, with the shortfall met from ground water (MWR & CEDARE, 2014). As mentioned previously, 20% of Libya's water is used domestically with half of this used for flushing WC's and washing (Abdudayem & Scott, 2014). Therefore, the development of practical ways to reduce water demand has become a top priority. To ensure best practice in this context, the USGBC (2013b) guide suggested that particular consideration for the design and assessment of housing projects in terms of the 'Water Quality' criterion could be implemented. This could be achieved through conducting water quality analyses that demonstrate satisfaction with the verified requirements in order to minimise the risk of water contamination in home facilities and ensure the provision of clean, fresh sources of water for home occupants. This information is considered crucial as it helps the project team to take appropriate action, where necessary, to mitigate negative impacts and promote sustainable homes.

Irrigation System Use

Water is one of the most important substances on earth. All humans, animals and plants must have water to survive. Irrigation issues, in this context, are placing increasing pressure on finite freshwater resources, especially in countries where water extraction is often unregulated, unpriced and even subsidised. The principle purpose of this criterion is to encourage the adoption of water-efficient irrigation systems within housing investments. It mainly aims to minimize outdoor demand for water, thereby reducing the rate of the bulk water per capita. The need to address irrigation system has been long reported within sustainability assessments. This was reflected in Alyami *et al.*'s (2013) study, which emphasised efficient irrigation systems as a major element to assist in the application of water efficiency. As discussed earlier (Section 4.5.6, p.91), these objectives are handled differently by SAMs. Whilst GBCA did not pay much consideration to this subject, LEED covers this enquiry within the 'Outdoor Water Use' criterion. Similarly, DGNB embeds this within the 'External works' criterion, whilst BREEM uses the criterion of 'External Water Use' to fulfil this query. According to Alyami *et al.* (2013), a substantial improvement in water use efficiency is required in order to shift to a more sustainable use of water in irrigation without harming the fauna and flora. Innovative irrigation practices can enhance water efficiency, helping developers to adapt and implement viable solutions, and thus gain more benefits from irrigation technologies, while also providing an economic advantage and reducing environmental burdens. To ensure best practice in this context, the USGBC (2013b) guide suggested paying particular attention to substantial improvements in irrigation. For example, this includes the adoption of drip and sprinkler irrigation systems, which deliver water directly to a plant's roots, reducing the evaporation that happens with spray watering systems. Timers can also be used to schedule watering during the cooler days which further reduces water loss.

Water Appliances Efficiency

The choice of water appliances and their efficiencies can play a vital role in terms of raising the concept of sustainability in housing projects. The principal purposes of this criterion is to encourage the provision of water-efficient fixtures and fittings, and to design homes for water efficiency that helps to reduce out and indoor demand and achieve water savings. The need to address the efficiency of water appliances has long been reported within sustainability assessments. This has been reflected in Alyami et al.'s (2013) study, which has emphasised water fixture as a major element assisting in the application of water efficiency. As discussed earlier (Section 4.5.6, p.91), these objectives are not much recognised by BREEAM, LEED and DGNB, whereas, GBCA has allocated the criterion of 'Domestic Appliances Efficiency' to partially meet this enquiry. It is widely acknowledged that the provision of water efficient appliances under the internationally recognised water efficiency labelling scheme can make a substantial difference to energy and money savings for owners. According to Abdudayem and Scott (2014), up to 20% of water consumed per year can be saved by each household by choosing water efficient equipment. The guide USGBC (2013b) stated that particular attention should be paid to the design and assessment of features for water appliance efficiencies. This includes installing; high-efficiency (low-flow) fixtures or fittings (e.g. lavatory faucet, toilet, etc.); compensating shower valves; energy-efficient water heating equipment; restricting water flow for showerheads; dual-flush in toilets. The benefits of improving the performance of home water distribution systems can not only be shown through achieving water savings, but also by reducing the energy demand that results from minimising the demand for hot water (e.g. low-flow showerheads, faucets, etc.), thereby gaining money savings.

Greywater System Efficiency

The design of an efficient sanitary system can play a vital role in terms of ensuring a sustainable home. This seeks to encourage the design and application of efficient sanitary fixture systems in homes. It mainly aims to capture and control the reuse of greywater to offset the central water supply through using municipal recycled water. The need to address the sanitary system has long been reported within the sustainability assessment. This has been reflected in Yuce's (2012) study, which has emphasised the adoption of an efficient sanitary system as a major element to assist in the application of water efficiency. SAMs adopted this objective in different ways, as discussed earlier (Section 4.5.6, p.91). Whilst, neither BREEAM nor LEED pay much consideration to this subject, GBCA embeds this within the 'Sanitary Fixture Efficiency' criterion. Likewise, this objective partially appeared within the 'Integration into the district infrastructure' criterion in DGNB. It is widely acknowledged that the provision of high quality, sanitary efficient appliances can minimise life cycle costs and maintain the environment's surrounding (Yuce, 2012). As USGBC (2013b) suggested, to ensure best practice in relation to this section, greywater should be collected from various sources (e.g. clothes washer, showers, some combination of faucets, etc.), and from this the following should be considered; install a greywater reuse system for landscape irrigation use, including a tank or dosing basin; the recycled water quality should meet local standards and consult manufacturers' recommendations to determine the compatibility of plumbing fixtures with greywater. Among the benefits of improving greywater systems include the reduction of adverse effects resulting in sewage in the home site.

Rainwater Harvesting and Alternatives

Water conservation is considered one of the most concerning issues throughout the world, in terms of it being a finite and invaluable resource. The main purpose of the 'Rainwater Harvesting and Alternatives' criterion is to encourage the design of efficient surface water management to recycle rainwater in home sites. It mainly aims to capture and control the reuse of rainwater to offset the central water supply through using the efficient harvesting of a rainwater system. These issues were emphasized by interviewees within the focus group, who encouraged the provision of higher water quality with water supplier alternatives for housing projects. These objectives have corroborated previous studies by Alyami *et al*. (2013) and Chang *et al*. (2007), which emphasised the adoption of rainwater harvesting strategies as one of the most important aspects for ensuring sustainable homes. As discussed earlier (Section 4.5.6, p.91), these objectives were not much recognised by BREEAM, DGNB nor GBCA, whilst to some extent, it appeared within the criterion of 'Rainwater Management' in LEED. Rainwater, as reported by Chang *et al*. (2007), could be collected to reduce: the amount of water being discharged into drains and watercourses, the risk of localised flooding, overall water bills for householders. To ensure best practice in this context, the guide USGBC (2013b) suggested a range of interventions to enhance the application of water conservation. For example, this includes designing and installing: surface runoff and roof runoff; a proper storage system design and size to harvest rainwater, taking into consideration the rate of rainfall; permeable yard designs through vegetative landscape (e.g. grass, trees, shrubs, etc.); permeable paving with a proper base layer and porous above-ground materials (e.g. open pavers, engineered products, etc.); impermeable surfaces to direct water runoff toward an appropriate permanent infiltration feature (e.g. vegetated swale, on-site rain garden, rainwater cistern, etc.); appropriate permanent erosion control measures (e.g. native groundcover, shrubs, trees, terracing, retaining walls, etc.) to reduce long-term runoff effects; vegetated roofs covering an appropriate area. Among the benefits of assessing these features and adopting efficient rainwater harvesting strategies are the minimisation of adverse effects resulting in erosion and runoff in the home site, which may lead to a reduced amount of potable water, particularly for external water uses, as well as the minimisation of life cycle costs, and maintaining the environmental surroundings.

6.4.5 The Fifth Category: Waste and Pollution

Waste reduction in a housing project is important from the perspective of efficiency; however, concern has been growing in recent years about the adverse effects of waste on the environment. The Waste and Pollution cluster includes five criteria, which have been identified through this research, namely: Waste Treatment and Recycling Facilities; Low Light and Noise Pollution; Polluted Emissions Reduction; Low Refrigerants Rate; and Preventing Sandstorm Strategy.

Waste Treatment and Recycling Facilities

Waste treatment and recycling can play a vital role in terms of ensuring a sustainable home. Improving the performance with efficient waste recycling systems in home projects can not only achieve waste reduction, but also reduce the hazardous pollutants resulting from mismanaged waste homes. The Waste Treatment and Recycling Facilities criterion emerged as the top issue when evaluating the Waste and Pollution category. This appears to validate the view expressed by Alyami *et al*. (2013), who emphasised that the provision of efficient waste recycling systems is essential to assess environmental sustainability. SAMs also adopted this objective in different ways, as discussed earlier (Section 4.5.6, p.91). Whilst, DGNB covered these objectives through multiple criteria, BREEM embeds this within the 'Construction Waste Management' criterion. Likewise, these objectives are assessed within the criterion of 'Low-waste construction site' in DGNB, whilst LEED assesses this through the 'Construction Waste Management' and 'Construction Activity Pollution Prevention' criteria. As Ahmed *et al*. (2015) demonstrated, it is difficult to recycle housing waste due to high levels of contamination and a large degree of heterogeneity; furthermore, there is often insufficient space for its disposal in large cities. In Libya, the

Ecological Protection Agency (EPA) stated that the landfill situation is now critical, with local authorities having to resort to transporting waste further afield or to burn it and thus release pollution into the air (Jain, 2013). She further stressed the consequences of the high levels of waste, both in reducing the future availability of resources along with the creation of unnecessary demands on the transportation system. According to Elgadi *et al*., (2016), approximately 28 Million tons of municipal waste was generated in Libya in 2016, and a total of 15 Million tons of this was collected from households, which is more than half a tonne of household waste per person. Through regular waste collections or recycling schemes, local authorities generally collected waste from Libyan homes. Accordingly, the Libyan local authorities, as Ahmed *et al*. (2015) reported, lack waste recycling management, and adequate storage should be provided for waste in order to facilitate appropriate waste management. The size, type and number of containers should be also set out by the waste collection authority to ensure best practices in this respect. Directions as to what constitutes a sustainable system for waste treatment have been suggested (DGNB, 2018; USGBC, 2013b). Particular attention has been paid to: increasing waste diversion; reducing non-recyclable household waste to a level below the recognised norm; providing an external storage space for household recyclable materials; and providing an appropriate combination of adequate internal space for the storage of recyclable materials. Among the benefits of avoiding and managing waste strategies are the generation of cost savings, and conservation of resources, the prevention of pollution and emissions, a reduction in costs for waste disposal, and less time spent on dealing with waste. As stressed by Jain (2013), the consideration of waste efficiency within housing projects not only reduces the environmental impacts but also raises awareness and generates behaviour change across homeowners.

Low Light and Noise Pollution

Preventing light and noise pollution can play a vital role in terms of raising a sustainable home. The principle purpose of this criterion is to encourage the provision of efficient external and internal lighting and the minimising of noise pollution and avoidance of excessive energy use. It mainly aims to prevent negative impacts on people and nature through mitigating noise and light disruption to the immediate surroundings of the home. Tupenaite *et al.* (2017) and Alyami *et al*. (2013) have highlighted the reduction of noise and light pollution as a sustainability area; moreover, the findings from this study whose research corroborate their research. As discussed earlier (Section 4.5.6, p.91), whilst these objectives are not much recognised by BREEAM or LEED, this objective is assessed within various criteria in DGNB, including: 'Noise Emissions', 'Outdoor noise', 'Low-noise construction site' and Light pollution'. Similarly, GBCA satisfies these objectives through the criteria: 'Internal Noise Levels', 'Light Pollution to Night Sky' and 'Light Pollution to Neighbouring Bodies'. Light pollution disrupts global wildlife and the ecological balance and has been linked to negative human health outcomes. According to the International Dark Sky Association (IDA, 2018), light pollution is defined as a harmful effect resulting from the use of artificial lighting (e.g. sky glow, glare, light trespass or light clutter). Accordingly, traditional bulbs produce more CO_2 emissions and waste a lot of their energy. Light pollution wastes energy lighting, and accounts for around 10% to 15% of an electricity bill (Almansuri *et al.*, 2009). To ensure best practice with this criterion, particular consideration has been given to the USGBC guide, which, for example, includes: automatic turn off all internal and external lighting; limit the impact of external light pollution during the performance period; use lights with an external impact that are designed to prevent upwards and lateral light scattering; reduce distracting glare effects; draw up floor plans that incorporate noise protection; and apply reduction factors to air traffic noise based on relevant noise maps for this purpose (USGBC, 2013b). Moreover, applying appropriate measures to reduce noise emissions and adverse light conditions have a positive impact on the health and well-being of home occupants and the surrounding environment. As such, improving the performance with efficient measures that recognise low light and noise pollution can not only achieve a reduction in pollution, but also reduce energy consumption and thereby support the stability of an ecosystem by reducing the subsequent social costs incurred as a result of a such damage.

Polluted Emissions Reduction

Reducing polluted emissions can play a vital role in raising a sustainable home. It is probably the criterion on which most, if not all, publications on sustainability (e.g. Tupenaite *et al*., 2017; Alyami *et al*., 2013; Ali & Al Nsairat, 2009) have agreed; namely, that the reduction of emissions is a key environmental sustainability criterion, which corroborates the research finding. As discussed earlier (Section 4.5.6, p.91). Whilst LEED does not much consider these objectives, BREEM has assessed these objectives through multiple criteria, and DGNB only embeds this objective within the 'Volatile organic compounds (VOCs)' criterion. Likewise, this objective is satisfied within the criterion of 'Nontoxic Pest Control' in LEED. The principle purpose of this criterion is to encourage home providers to include low-CO_2 or NO_2 fittings or systems in their schemes. SAMs also adopted this objective in different ways. Among the benefits of adopting this criterion is the minimising of greenhouse gas emissions into the atmosphere that arise through the construction phase and home use, thereby reducing global warming. CO_2 is emitted from the burning of fossil fuels, whilst NO_2 formation, which is highly temperature dependent, arises when combusting natural gas. They greatly contribute to both acid rain and global warming in the upper atmosphere. As IPCC's (2018) report states, estimated anthropogenic global warming recently rises at approximately 0.2°c per decade due to ongoing emissions. Scientists, accordingly, predict that emissions of CO_2 or NO_2 and other greenhouse gases from human activities will raise global temperatures by 2.5º to 11.5ºF (1.4º to 6.4ºC) this Century (Florides & Christodoulides, 2009). The national figures also show that a significant amount of carbon emissions is produced as a result of the energy consumed during the operation of facilities in Libya. In 2016, which is the most recent year for which data are available, Libya was ranked 58th globally in relation to its CO_2 emissions, which were calculated at 43 Million tons equating to 6,88 emissions per capita (IEA, 2018). The average Libyan consumes two times more energy than the average global citizen, four times more than the average Brazilian person, although is still half of the average in the US. In this respect, particular attention should be paid to the percentage improvement in the 'Dwelling Emission Rate' (DER) which refers to the rate of estimated polluted emissions in kg per m^2 per annum arising from energy use for heating, hot water and lighting for an actual home, over the 'Target Emission Rate' (TER). The TER represents the maximum emission rate permitted by verified standards. This information is considered crucial as it helps the project team to take appropriate action where necessary in order to mitigate the negative impacts and promote sustainable homes.

Low Refrigerants Rate

Refrigerant leakage can cause significant damage to the environment through global warming. The main purpose of this criterion is to address the environmental impacts associated with the use of refrigerants, their selection and leakage. This criterion encourages housing providers to identify upgrade paths for their refrigeration equipment thereby minimising contributions to the ozone depletion and global warming. The need to address refrigerant leakage has long been reported within the sustainability assessment.

This has been reflected in Alyami *et al.*'s (2013) study, which emphasised that refrigerants are one of the most important aspects for ensuring sustainable homes. To ensure best practice, several indicators suggested by USGBC (2013b) can be used to evaluate the extent to which the relevant general conditions have been established on the project. For example, this includes; providing proof of the proper refrigerant charge test of the air-conditioning; installing an HVAC system with a refrigerant that complies with verified standards; and identifying the GWP factor of refrigerants in refrigeration systems. It is important to assess the use of automated leak detection systems to ensure that the most appropriate actions can be taken when the leak detection system's alarm is activated. A legionella risk management plan is also, an essential aspect that should take place to prevent the growth and dissemination of Legionella and thereby mitigate the risk of other types of bacterial and microbial contamination. Among the benefits of adopting such this criterion are the minimising of potential negative impacts on human health by reducing the greenhouse gas emissions into the atmosphere that arise from the operation of a home and its facilities.

Preventing Sandstorms

The term sandstorm is used most often in the context of desert sandstorms, and refers to a high amount of wind, where the wind speed is able to lift the top layer of sand from the ground and push it in every imaginable direction. Sandstorm has become a severe social-environmental phenomenon in many countries, notably across the Sahara region – the Sahara or 'the Great Desert' is the largest hot desert in the world (Worlddata, 2018), forming a large area of north Africa, including Libya. The principle purpose of this criterion is to address the environmental impacts associated with the sandstorm risk. It mainly aims to encourage housing providers to undertake a sandstorm risk assessment to minimize the adverse effects of this phenomenon. Yet, as discussed earlier (Section 4.5.6, p.91), these objectives are not much recognised by BREEAM, LEED, DGNB nor GBCA. A unique Saudi study from Alyami *et al*. (2013) has emphasised that the prevention of sandstorm is one of the most important aspects for ensuring sustainable homes. Sandstorms in Libya have increased due to extreme weather patterns brought about by drought, besides the encroachment of increasing development on areas prone to sandstorm (Shawesh, 2016). Sandstorm, as Abdegalieva and Zaykova (2006) reported, causes considerable hardship and loss of income. It disrupts communications and presents serious public health problems. In extreme cases, it causes death, the extensive destruction of livestock and crops, and leaves a damaged ecosystem. Particular attention to ensuring best practice over sandstorm risk includes, for example: providing a system to address dust emissions; conducting a sandstorm risk assessment to accompany a planning application thereby demonstrating the satisfaction of local requirements and that the development has a low risk of sandstorm or is appropriately sandstorm resilient; the management of any residual risk; the use of temporary mechanical methods (e.g. concrete barrier, mulching, tree buffer etc.) to reduce localised small-scale dust emissions due to human induced activities; an increase in vegetation cover as this helps in stabilizing the soil, sand dunes and forms windbreaks; the use of native plants and trees as a buffer to reduce wind velocity and sand drifts and, at the same time, increase the soil moisture; the design of sandstorm control measures (e.g. native groundcover, shrubs, terracing, retaining walls, etc.); and the conduct of air infiltration testing during home commissioning.

6.4.6 The Sixth Category: Health and Wellbeing

The Health and Wellbeing of homes plays a significant role concerning indoor quality and performance so that it is recognised as a key aspect of sustainable homes. It mainly revolves around enhancing safety and comfort queries, thereby increasing occupant satisfaction. Crucial elements have been identified through this research which encompass the 'Energy Efficiency' section, namely: Natural Ventilation Levels; Illumination Quality and Control; Sound Absorption and Insulation; Cooling and Heating Comfort and Control; Internal Layout Functionality and Visual Comfort; Maintainability and Flexibility; View out and Aesthetic Aspects; Safety Protection and Fire Security; and Cultural and Architectural Heritage Considerations.

Natural Ventilation Level

Ventilation quality has been considered one of key components amongst the health and wellbeing cluster. It mainly promotes improvements in the overall quality of a home's indoor environment by installing an approved bundle of air quality measures. The principle intent behind this criterion is to ensure that indoor air is of sufficient quality so as not to adversely affect occupants' health and well-being. This is advised through reductions in moisture and exposure to indoor pollutants in kitchens and bathrooms through ventilation with outdoor air and the control of indoor moisture levels. It is probably the criterion on which most, if not all, publications about sustainability (e.g. Tupenaite *et al*., 2017; Alyami *et al*., 2013; Ali & Al Nsairat, 2009) have agreed, namely that natural ventilation is a key sustainability criterion; this corroborates the research finding. Improving indoor natural ventilation levels can not only lead to improvements in health conditions and the reduced risk of building-related health impacts (e.g. asthma, allergic reactions and chemical hypersensitivity), but also to achieve higher levels of comfort and greater satisfaction. Figures show that people typically spend a significant time within homes, where pollutant levels may run two to five times higher than outdoors (Addis & Talbot, 2011). The World Health Organization (W.H.O) in turn, reported that most of an individual's exposure to many air pollutants comes through the inhalation of indoor air (W.H.O, 2010). Hazardous household pollutants include carbon monoxide, radon, formaldehyde, mould, dirt and dust, pet dander, and residue from tobacco smoke and candles (Iesa *et al*, 2017). According to Iesa *et al*., Many of these pollutants can cause health reactions in the estimated 17.8% of Libyan people who suffer from asthma and the approximate 30% who have allergies. This, in turn, contributes to a high absence rate from school and work. Housing providers can help to create a healthy, non-toxic environment by having appropriate procedures in place to identify and manage any risks that can negatively affect the creation of a healthy environment and the attainment of an appropriate indoor air quality. Numerous measures have been recommended in several publications (e.g. DGNB, 2018; USGBC, 2013b), and these aims to ensure best practice. This includes: air exchange rates; airspeed within the permitted value; the installation of verified dehumidification equipment to maintain relative humidity at safe levels; the measurement of volatile organic compounds (VOCs); the design of passive ventilation systems approved by a licensed HVAC engineer; the installation of a whole home active ventilation system that complies with a verified Standard; and the installation of local exhaust systems in all bathrooms and the kitchen.

Illumination Quality and Control

Providing high-quality light has a positive impact on the health and well-being of home occupants. The principle purpose of this node is to encourage the provision of efficient and comfort lighting systems. The quality of illumination has been highlighted as a sustainability area by Tupenaite *et al*. (2017) and Chang *et al*. (2007), whose research are corroborated by this study's finding. As discussed earlier (Section 4.56, p.91), these objectives are handled differently by SAMs. Whilst LEED does not pay much consideration to this subject, GBCA covers this enquiry within multiple criteria, including: 'Daylight'; 'Surface Illuminance'; 'General Illuminance and Glare Reduction'; 'Localised Lighting Control'; 'Glare Reduction'; and 'Minimum Lighting Comfort'. Likewise, DGNB embeds this within the 'Daylight colour rendering' and 'Exposure to daylight' criteria, meanwhile BREEM merely uses the 'Daylighting' criterion to fulfil this query. Measures to reduce adverse light conditions can also reduce the subsequent social costs incurred as a result of damage. According to Tupenaite *et al.* (2017), flickering lights, lights that poorly render colour, and discomfort from glare can result in a number of negative health impacts for home occupants, such as headaches, general fatigue and eye strain. It is important to consider that different spaces and activities require different amounts of light, for which design teams should ensure that appropriate lighting levels are maintained in accordance with the space use. In this respect, the USGBC guide suggests that particular attention should be paid to: checks that processes and strategies are in place to ensure that all lights are flicker-free, and render colour accurately, and where discomfort glare is minimised; the assessment of processes to measure, monitor and manage lighting levels and ensure optimal lighting levels within a home's regularly occupied spaces; and the minimum requirements for artificial light (USGBC, 2013b). Among the benefits of adopting higher quality illumination systems are the prevention of negative impacts on occupants and nature and improvements to the indoor quality as well as reducing the energy consumption and CO_2 emissions from a home.

Sound Observation and Insulation

Applying measures to improve sound observation not only increases the occupier's quality of life, but also represent an important requirement for reinforcing stability and productivity, and reducing the subsequent social costs incurred as a result of damage. The principle purpose of this criterion is to encourage housing providers to ensure the provision of improved sound insulation to reduce the likelihood of noise complaints from neighbours and between entire home's rooms. It mainly aims to achieve acoustic conditions in a room by installing higher standards of sound insulation to ensure appropriate user comfort. As discussed earlier (Section 4.5.6, p.91), these objectives are handled differently by SAMs. Meanwhile this criterion is not much recognised by LEED, whilst GBCA has allocated this to the criterion of 'Acoustic Separation' Likewise, these objectives are assessed within the criterion of 'Sound Insulation' in BREEAM, whilst DGNB satisfies this criterion through the criterion ‘Sound insulation in residential buildings’. These objectives also have corroborated previous studies from Tupenaite *et al.* (2017) and Alyami *et al*. (2013), which have emphasised that sound observation is one of the most important aspects for ensuring sustainable homes, and provided guidelines to address and assess these effects. As Tupenaite *et al*. (2017) reported, sound pollution from the surrounding environment results in negative impacts on a home’s occupants. They warned that excessive noise from home systems and outside sources can cause stress and impede an occupier’s comfort. Moreover, one of the most common causes for disputes amongst neighbours is noise. The USGBC (2013b) guide provided a range of suggestions to minimise disruption from noise in homes. For example, this includes: designing services away from bedrooms in houses and flats; designing stairs, lifts and circulation areas away from sensitive rooms (e.g. bedrooms); corridors in apartment buildings have acoustically absorbent ceilings to reduce disturbance from footsteps; isolating pipework and ductwork from the building structure to avoid the transmission of vibration, and sealing all service penetrations; separating walls between bathrooms and sensitive areas to minimize acoustic transmission; ensuring resistance to the passage of sound between a home’s rooms; and considering air-line distances.

Cooling and Heating Comfort and Control

‘Cooling and heating comfort’ is often one of the most significant features for homeowners as this allows occupants to exert the greatest possible influence on the indoor climate to increase their individual well-being and satisfaction. This node was brought to the top of the Health and Wellbeing cluster. This also appears compatible with previous studies from Tupenaite *et al*. (2017) and Ali and Al Nsairat (2009), which emphasized the importance of thermal comfort as one of the most important aspects for ensuring sustainable homes. As discussed earlier (Section 4.5.6, p.91), these objectives are handled differently by SAMs. Whilst LEED has satisfied these objectives through multiple criteria, this criterion is not much recognised by BREEAM. Likewise, GBCA embeds this within the criterion ‘Balancing of Heating and Cooling Distribution Systems’, whilst DGNB uses the criteria ‘Thermal Comfort’ and ‘Advanced Thermal Comfort’ to fulfil this query. The principle purpose of this criterion is to encourage housing providers to ensure the appropriate distribution of space heating and cooling in the home. It mainly aims to promote the ‘Smart Home’ concept that guarantees thermal comfort throughout winter and summer with the greatest possible control thereby providing a high level of user satisfaction in the indoor areas of the home.

Installing Smart Home systems not only allows home occupants to be remotely controlled and monitored, but they can also achieve money, energy and time savings and it gives home occupants a better lifestyle quality. As such, today's homebuyers expect the integration of sustainability-focused measures and Smart Home technology into any newly constructed home, whilst occupants' satisfaction depends on their ability to adjust ventilation, sun and anti-glare protection, temperatures and lighting to their individual preferences (Archibald *et al*., 2013). The consideration of the scheduling and automatic operation of heating, lighting, electrical, HVAC, and security systems are all critical in relation to the design of Smart Homes. Advanced technology, as Archibald, *et al.* (2013) demonstrated, allows these smart systems to be controlled remotely from anywhere in the world via an Internet connected device. While many facilities only control thermal comfort in terms of temperature, an ideal balance should be struck between temperature, relative humidity and air speed. This is particularly vital in hot and humid climates, where applying effective dehumidification can significantly reduce cooling loads. The significance of such measures becomes clearer when one takes into consideration the harshness of the Libyan climate that makes the operation of cooling systems necessary. Home providers and developers, therefore, should familiarize themselves with the integration of sustainable design through Smart Home technologies to ensure that their projects stand out in the competitive market. To ensure that the quality of cooling and heating systems are optimal, several indicators, as suggested by USGBC (2013b), can be used to evaluate the extent to which the relevant general conditions have been established on the project. For example, this includes: assessing that processes are in place to monitor, measure and maintain indoor temperatures; ensuring measures to increase user control of the ventilation, and the temperature during and outside the heating/cooling period, alongside the shading and glare protection; controlling the room air quality whereby relative humidity and air speed fall within an acceptable best practice range; ensuring the compliance of interior surface temperatures with verified standards; designing the HVAC system with flow control valves on every radiator; installing no ducted HVAC system with multiple zones and independent thermostat controls.

Internal Layout Functionality and Visual Comfort

Visual comfort forms the basis of general well-being and satisfaction, whilst the issues related to internal layouts are deemed essential to promote social interaction and boost the health and happiness of occupants. The principle purpose of this criterion is to encourage the provision of high-quality indoor and outdoor spaces that are accessible to everybody and where the layout can easily be adapted to meet the needs of future occupants and increase the comfort of all occupants for a long time to come. The need for an internal layout and visual comfort has been well established and reflected in existing research (e.g. Higham *et al*. 2016; Alyami *et al.,* 2013), which is also established amongst most well-known assessment tools, such as BREEM, LEED and DGNB. These emphasise that the adoption of internal comfort is one of the most important criteria for assessing the internal quality of a home environment. As Akadiri (2011) argued, good design decisions, particularly in the structural framing of homes, can significantly reduce the demand for construction materials, embedded energy and the associated waste. Moreover, Alyami *et al*. (2013) also stated that visual comfort has a significant value that should be considered, with a view to ensuring that it is not sacrificed for the greater productive capacity. In accordance with the USGBC (2013b), particular attention should be paid to the: visual contact with the outside; colour rendering index; indoor spaces to enhance wellbeing and communication; children's play areas; senior citizens' recreation and games areas (e.g. areas for playing parlour games); quality of the interior access and circulation areas; doorways opening onto external spaces (e.g. balconies, roof terraces, atria, etc.); usable floor areas; space efficiencies; ceiling heights; building depth; and vertical access.

Safety Protection and Fire Security

It is often said that a poor-quality built environment leads to a poor public perception that results in low occupancy levels and ultimately, raises the level of vandalism in the community. The need for safety protection has been well established and reflected in the studies of Tupenaite *et al*. (2017) and Higham and Stephenson (2014), who emphasised the adoption of safety protection as one of the most important criteria for assessing the internal quality of a home environment. The principle intent of this node is to encourage the highly efficient design of home developments. It mainly aims to devise a design concept that prevent dangerous situations in a home and provides a high sense of security which makes a vital contribution to occupiers' comfort. As discussed earlier (Section 4.5.6, p.91), these objectives are not much recognised by LEED and GBCA, whilst this objective appears within the 'Sound Insulation' criterion in BREEAM, and through the 'Sound insulation in residential buildings' criterion in DGNB. Research and practice (e.g. Higham & Stephenson, 2014; Ali & Al Nsairat, 2009) have demonstrated the benefit of safety considerations in homes, including the reduction of disorder or the fear of crime, and an increased quality of life or community cohesion. Crime levels are higher, and people feel less safe in areas where the sense of security is poor (BRE, 2016). TCPA and WWF (2013) show that crime and dereliction have caused the deterioration of many urban environments and this has led to the degeneration of these communities. Higham (2014) argued that the avoidance of this is deemed a key issue that should be tackled when considering sustainable homes. USGBC (2013b) suggested that safety measures are required to increase the occupant's sense of security and to prevent dangerous situations in a home. This could include; technical safety equipment (e.g. emergency telephones, CCTV, voice alarm systems, etc.); preventive safety measures (e.g. roller shutters on the lower storeys, alarm system, RC protection class, etc.); the provision of domestic security lighting to deter intruders; and checks that fire protection systems are in place. Surprisingly, sensors to alert home occupants to deadly carbon monoxide concentrations are frequently not required by SAMs. This should be included in all new homes, as letting occupants fully and effectively control their thermal environment can reduce hot-cold complaint calls and generally raise satisfaction levels.

Maintainability and Flexibility

The Maintainability and Flexibility criterion represents one of the essential components to enhance a home's viability. The major intent of this node is to make the home's design as flexible as possible and create the greatest possible potential for extension. It mainly aims to promote solutions that enable maintenance and development works to be made with a minimum of loss. As discussed earlier (Section 4.5.6, p.91), these objectives are not much recognised by LEED and BREEM, whilst they are assessed within the criterion of 'Services and Maintainability Review' in GBCA, and through the 'Development and maintenance care' and 'Concept for ensuring ease of cleaning' criteria in DGNB. The need to address issues related to maintainability and flexibility has long been reported within the sustainability assessment. This has particularly been reflected by Chang *et al.*'s (2007) study, which emphasised that maintainability and flexibility are major elements enhancing the application of sustainability. As some homes might need to be improved or extended, attention should be paid to how these homes can be regulated without incurring significant costs. The notion beyond this conception, as reported by Addis and Talbot (2001), is to meet the occupants' requirements within the value for money definition. The ease with which a homeowner can implement maintenance and change a rooms' functionality, according to Chang *et al*. (2007), helps to raise the satisfaction of homeowners, increase the home's viability and reduce its life cycle costs. They further explained that flexibility involves not only ensuring that the home achieves its functional objectives and meets the satisfaction of its current occupiers, but also ensures that consideration is given to its long-term adaptability. In light of this, housing providers should aim to produce specifications that promote future flexibility and adaptability and articulate such objectives in the home design. The USGBC (2013b) guide provided a range of suggestions to ensure best practice in this respect; for example, this includes recognising the flexibility of structural design; ensuring that technical home systems are highly adaptable; and recognising flexibility in aspects of the floor plan.

View Out and Aesthetic Aspects

The view out and aesthetic criterion is deemed one of the most important aspects for enhancing sustainable homes. The principle goal of this node is to encourage the provision of best design and the improvement of landscape features that create social interactions and boost the health and satisfaction of their occupants. As discussed earlier (Section 4.5.6, p.91), these objectives are not widely recognised by LEED or BREEAM, whilst they are assessed, to some extent, within the 'Visual contact with the outside' criterion in DGNB, and through the 'Views' criterion in GBCA. These objectives have corroborated previous studies from Higham (2014) and Alyami *et al.* (2013), who have emphasised the consideration of view out and aesthetic aspects as key to ensuring good practice in sustainability. Home aesthetics, as stated by Higham (2014), is a further value to bear in mind, stressing that the style of homes constructed should be in harmony with the local architectural styles and landscaping consistency in order to preserve the value of the area and to minimise any negative visual impact. Whilst Tupenaite *et al.* (2017) asserted that a home needs to be designed with the recognition of natural landscape, including mountains and plants, and provide a sense of shapeliness. As USGBC (2013b) suggested, particular attention should be paid to ensure best practice in this respect, which includes: the integration of the design concept with the ideal use of materials, lighting, navigation, greening and the necessary technical installations; the façade (e.g. balconies, loggias or conservatories, façade greening, etc.); roof surfaces that the home occupants can use; vegetated roofs to reduce both space heating and cooling loads; connection with a view to create social spaces and a sense of community; auxiliary facilities are integrated into the design (e.g. waste disposal sites, bicycle storage facilities, underground garage ventilation, etc.); the installation of light-coloured, high-albedo materials for sidewalks, patios, and driveways; the installation of vegetation within open pavers; green spaces and parks within easy reach; the location of trees, shrubs or other plantings; the location of appropriate fences; access routes to entrances and the associated circulation; protection from the summer sun (e.g. trees, fixed, rigid or movable shading systems. etc.); communal outdoor seating areas or terraces, atria or inner courtyards with proper spaces; fixed and movable seating and loungers; weatherproof outdoor furniture for lunch breaks including shelter from rainfall with tables and chairs; playgrounds with high-quality equipment; and fixed fitness and exercise equipment.

Cultural and Architectural Heritage Considerations

Issues related to the consideration of architectural heritage are vital to minimise negative visual impacts, retain a house's harmony with the surrounding environment, and ensure consistency with the local culture and heritage. The principle goal of this criterion is to encourage housing providers to preserve and enhance existing cultural areas and heritage. As discussed earlier (Section 4.5.6, p.91), these objectives are not widely recognised by DGNB nor BREEAM, whilst they are assessed within the 'Base Building Cultural Heritage Significance' criterion in GBCA, and through the 'Regional Priority' criterion in LEED. The cultural and architectural heritage considerations have been highlighted as a sustainability area by Tupenaite *et al*. (2017) and Alyami *et al.* (2013). Alyami *et al.* (2013) stated that culture and heritage value is a major issue to bear in mind. They stressed that, where a project is established on a historical site, this needs to be consistent with the local culture and heritage. As Addis and Talbot (2011) stress, archaeological-remains are more unique and irreplaceable than other aspects of the environment. Furthermore, attention should be also paid to consistency in its natural appearance. Several landscape features, such as ponds, hedgerows and grassland, can be protected and improved through careful design (Almansuri *et al*., 2009). This can also contribute to the preservation and enhancement of biodiversity, as discussed earlier. It is recommended that the requirements related to the protection and enhancement of architectural heritage and sensitive landscapes should be addressed as early as possible through the project design stage (Al AKadiri, 2011). To assess these objectives, evidence should be provided to prove that recognition has been given to the local cultural and architectural heritage within the home structural design.

6.4.7 The Seventh Category: Location Quality

The issue of location quality is considered important among the major themes with respect to sustainable homes. This, section assesses five criteria, namely: Community Services and Facilities; Considering Transportation Accessibility; Considering Technological Connectivity; Car Parking Capacity; and Pedestrian and Cyclist Safety.

Community Services and Facilities

The Community Services criterion has long been considered a key element amongst the location quality. ensuring that there are facilities nearby that cater for their day-to-day requirements can increase home occupiers' satisfaction with their homes. The principle purpose of this criterion is to encourage housing providers to establish projects within existing communities and in developments that are served by, or near existing, infrastructure. It manly aims to optimally cater for the day-to-day needs of home occupants through the provision of nearby, easily accessible social and commercial infrastructure, thereby achieving social acceptance for the housing. As discussed earlier (Section 4.5.6, p.91), these objectives are handled differently by SAMs. Whilst this criterion is not much recognised by BREEAM nor GBCA, DGNB has assessed these objectives through multiple criteria, including: 'Social infrastructure' and 'Commercial infrastructure'. Likewise, LEED divides it between 'Compact Development' and 'Community Resources'. The criterion of Community Services and Facilities was included at the top of the list of Location Quality, which accords with the studies of Higham & Stephenson (2014) and Alyami *et al.* (2013), who emphasised the choice of community services as one of the most important criteria for assessing the social features of sustainability. Amer (2007) stated that social capital is closely allied with social cohesion and civic engagement and is an important factor for community development. He defined that social capital involves the structures that help to maintain and develop human capital in partnership, such as families, communities, businesses, trade unions, schools and voluntary organisations. As the World Health Organization (W.H.O, 2010) stressed, higher levels of social capital bring higher rates of economic growth, lower crime, better health and better government. One way in which housing providers can contribute to the increase in social capital is by selecting high quality locations for their projects, which do not only provide good infrastructure but also make all human services reachable. The USGBC (2013b) guide provided a number of recommendations in respect of location quality. This includes the recognition of: (a) Public infrastructure, such as electricity, gas, sewers, and water supply; (b) Social infrastructure within the surrounding area, such as medical services (e.g. hospital, general practitioner, outpatient clinics, dispensary, specialists, pharmacy, dental clinics, etc.), education services (e.g. kindergarten, School, higher education, etc.), leisure services (e.g. cinema, theatre, galleries, library, district centre, community centre, youth centre, senior citizens' centre, fitness studio near to the workplace, etc.), and fitness services (e.g. gymnasium, playgrounds, sports hall, outdoor sports ground sports facilities, swimming pool, etc.); (c) Commercial infrastructure within the surrounding area, such as retail outlets (supermarket, bakery, butcher, drug store, laundry, etc.); convenience store and local supply (every goods); food and catering (e.g. restaurant, café, bakery, etc.); and (d) Other services (e.g. bank, post office, hairdresser, fitness studio, wellness facilities, fire station police station, place of worship etc.).

Considering Transportation Accessibility

As accessible homes are vital to meet home occupants' satisfaction, an important point to note is that transportation accessibility issues should be considered not only in relation to the surrounding amenities, but also in relation to their setting. It can be assumed that if a wide variety of mobility provisions are offered, the home occupants' satisfaction and productivity will increase, and more people will be encouraged to take up public transportation thereby creating less pollution and traffic. Despite the suggestion that issues related to transportation accessibility is usually dominant when considering sustainability in home projects, the least important issues were estate appearance amongst the literature. This appears contrary to the body of literature (e.g. Alyami *et al*., 2013; Ali & Al Nsaira, 2009), which often shows these issues as critical to the design of new housing developments. The principle purpose of this criterion is to promote sustainable mobility in various forms for the home's users and ensures that sustainable traffic infrastructure is provided. It mainly aims to reduce traffic-related emissions into the air, water and soil and to strengthen the opportunities for efficient, affordable mobility thereby increasing user comfort and saving natural resources. As discussed earlier (Section 4.5.6, p.91), these objectives are handled differently by SAMs. Surprisingly, whilst DGNB has covered these objectives through multiple criteria, including: 'Barrier-free design of stops'; and 'Public transport', this criterion is not generally recognised by BREEAM. Likewise, GBCA embeds this within the 'Active Transport Facilities' and 'Access by Public Transport' criteria, while LEED uses the criterion of 'Access to Transit' to fulfil this query. According to The World Health Organization (W.H.O) statistics, almost 1.25 million people are killed worldwide in road traffic accidents each year (90% of deaths occur in developing countries) and an additional 50 million people are estimated injured, half of which are seriously injured or disabled (W.H.O, 2018). Traffic accidents in Libya are an economic and social problem, a burden and loss to the country, making Libya one of the worst affected countries in the world where the road traffic related death rate is 6.5 people daily (Yahia & Ismail, 2013). For such these reasons, it is important when designing a home project, to take into account the relative locations of different facilities (e.g. workplaces, shops schools, and health centres) as this helps in making a proper plan that serves the goals associated with home accessibility. Consideration should also be extended to how residents could travel to and access these facilities. This includes a consideration of the points of access to the site for vehicles and public transportation. Aligning with this, the provision of the accessibility index, a dedicated bus service, access to bus stops, access to the railway station, the proximity to amenities, alternative modes of transport, can all indicate best practice in terms of home accessibility (DGNB, 2018; USGBC, 2013b).

Considering Technological Connectivity

Given society's growing reliance on telecommunication systems, homes should enable their residents to make the most of the benefits that a 'Connected Home' can bring. A Connected Home or Smart Home can play a vital role in increasing time, energy and money savings as well as better lifestyles. The intent of this criterion is to encourage housing providers to design homes that are technologically well linked with the advanced technology of networks and the Internet. However, increasing attention was paid to technological connectivity by the research participants, and a little of this was found within the literature. As discussed earlier (Section 4.5.6, p.91), the concept of a Smart Home was not much recognised by BREEAM, LEED, LEED and GBCA, whilst this objective was assessed within the criterion of 'Accessibility of the building technology' in DGNB. As defined by Archibald, *et al*. (2013), technological connectivity considers the measures that enable occupants to work more flexibly through the principles of 'Smart' or 'Connected' homes that reduce the need to commute to work and offers opportunities to telework. This can range from enabling more flexible patterns of working, remotely accessing home systems, such as central heating and renewable energy storage, and helping an elderly relative to live independently in their own home for longer. For the DGNB (2018), user communication paid particular attention to the design and assessment of housing projects in order to promote the development of Connected Homes. For example, it involves: a home network; a high quality broadband connection; devices that can communicate across that network to support the needs of users; good wireless coverage within homes; and the provision of wired connections (e.g. cables for incoming, a wiring hub where incoming services meet, cables from the wiring hub to distribute services around the home; a telephone point, a wired network point and tv outlets within each room.

Car Parking Capacity

Car Parking Capacity is a huge issue in many areas and is a key component of the 'Location Quality' category. With the high percentage of vehicles in use, parking has become a conflicting and confusing situation for many people. This quite often hurts home occupants and decreases their quality of life. The principle goal of this criterion is to encourage better access to a sustainable means of parking for home occupants. It mainly aims to ensure the provision of convenient parking areas that allow residents' vehicles to be easily loaded and unloaded. As discussed earlier (Section 4.5.6, p.91), these objectives are not much recognised by LEED or BREEAM, whilst these objectives are assessed within the criterions of 'Parking space situation' and 'Motorised private transportation' in DGNB, and through the 'Low Emission Vehicle Infrastructure' criterion in GBCA. The consideration of car parking capacity has been highlighted as a sustainability area by Higham and Stephenson (2014) and Alyami *et al*. (2013), who corroborated the research finding. The increased number of vehicles on the roads are a phenomenon that has been observed in parallel with economic growth, particularly in recent years. According to Yahia and Ismail (2013), the number of private cars in Libya has increased four times in a decade, increasing from 675,000 in 2000 to 2,200,000 in 2010. This level of vehicle ownership has led to increased levels of congestion and pollution, particularly in the more densely populated areas. To ensure best practice in this context, the USGBC (2013b) guide suggested a range of interventions to enhance the application of the car parking issue. For example, this includes: the provision of parking areas including a number of designated parking spaces for families, with dimensions to accommodate the additional needs of families that allow the vehicle to be easily loaded and unloaded, access to a trunk road; access to the motorway; access to a main road; consideration for visitors; the bidirectional charging and discharging of electric vehicles.

Pedestrian and Cyclist Safety

The issue related to pedestrians and cyclists has been considered one of key components amongst the health and wellbeing cluster. It mainly promotes the wider use of bicycles as transport by providing adequate and secure cycle storage facilities, thus reducing the need for short car journeys. Yet, they have not been much recognised within literature; these objectives are discussed earlier in Section 4.5.6 (p.91), and assessed within the criteria of 'Cyclists', 'Pedestrian traffic' and 'Bicycle infrastructure' in DGNB, and to some extent through the 'Walkable Neighbourhoods' criterion in GBCA. As stated by Yahia and Ismail (2013), population congestion and the increasing number of cars is accompanied by consequent traffic accidents and should encourage the development patterns to promote walking or biking as viable alternatives. This will not only reduce air/noise pollution and provide more space on the streets, but also improve the health and fitness of the cyclist and make districts livelier in enabling the use of pavements and cycle paths. In order to make cycling a practical alternative, people need somewhere convenient and safe to store their bicycles when they are at home. To ensure best practice in this context, the USGBC (2013b) guide suggested a range of interventions to enhance the application of the pedestrian and cyclist issue. For example, this includes the provision of; adequately sized, safe, secure, convenient and weather-proof residential cycle parking and pedestrians areas; for example, this includes: designing footpaths and cycle paths along 'desire lines' to key destinations both in the vicinity of the area and in the wider community; locating cycle parking for the maximum convenience of access; ensuring cycle parking is safe and secure; ensuring paths are safe and appropriately lit while minimising light pollution, with natural surveillance from adjacent buildings; minimising the disruption of pedestrian and cycle routes from the road network and car parking layout; incorporating traffic calming measures; ensuring that there are good walking and cycling routes to and from key bus routes and that sufficient cycle parking is provided at bus stops; consideration should be given to the need for high quality cycle parking from the outset of the design process so that provision can be fully integrated into the development. Complying with such standards is considered crucial to ensure that a home is designed in an efficient manner and satisfied with sustainability requirements.

6.5 The LSHAM Scheme

The sustainability requirements conceived in a housing project are to a greater or lesser extent interrelated. The challenge for new sustainable schemes is to bring together the different sustainability requirements in innovative ways. The emergent model has been built upon the conception raised throughout both the theoretical and empirical stages of research, with the core aim of promoting sustainable development in the housing sector. This model includes a set of 43 applicable criteria for assessing sustainable homes in the context of the Libyan built environment, split into seven key categories. Figure 6.2 below, visualises the emergent model of the Libyan Sustainable Housing Assessment Model (LSHAM), which would form the background for developing a system to evaluate sustainability interventions in public housing projects.

Figure 6.2: LSHAM Scheme

To this extent, it can be argued the LSHAM scheme has established the Libyan public housing projects' commitment to sustainability by which the desired shift from a solely monetary based to a multiple dimensions approach is to be facilitated.

6.4 Chapter Summary

Collectively, the theoretical and emergent insights harvested within the empirical stage helps to meaningfully synthesise a comprehensive view upon which the phenomena of sustainability, through the delivery of a set of principal sustainable development criteria for a decision support system for housing projects, has been developed. Using a triangulation method, the analysis of both the qualitative data and quantitative data generated from the integrative comparison of well-established models along with a focus group interview and questionnaire, has identified significant gaps in the perception of the principles of sustainable development along with the absence of a rigorous multiple dimension led approach to guide the decision-making process towards embedding sustainability in housing projects. The model of sustainability for assessing home projects has emerged by investigating a wide range of professional and academic views from different sectors including housing providers, local authorities and academia, encompassing a set of 43 principal sustainable development criteria grouped into seven broad categories (i.e. Management & Process, Materials Efficiency, Energy Efficiency, Water Efficiency, Waste & Pollution, Health & Wellbeing, and Location Quality). The findings have established the Libyan public housing projects' commitment to sustainability by which the desired shift from solely a monetary based to a multiple dimensions approach is to be facilitated. To this end, it is evident throughout the existing body of literature that none of the existing frameworks are applicable to assess sustainability features in home projects within the context of Libya. This raised calls from academia for a paradigm shift to adopt a comprehensive insight that allows for the delivery of housing investments based on multiple merits rather than only on a monetary attribute. Against this, the developed model has established the theoretical basis of a sustainability-based assessment model for Libyan sustainable homes. Therefore, it can be argued that the proposed model aims to meaningfully synthesise the understanding of sustainability approaches at the international and local level to devise and facilitate the delivery of the principles of sustainability within the design and processes of housing projects in Libya.

7 Establishing a Weighting System for the Composite Index

7.1 Chapter Overview

The results of the survey in Chapter 6 analysed and discussed the 43 criteria identified as important components of sustainable homes. These criteria have also been included in seven categories of the sustainability index, namely:

1. Management and Process
2. Material Efficiency
3. Energy Efficiency
4. Water Efficiency
5. Waste and Pollution
6. Health and Wellbeing
7. Location Quality

These seven groups are combined to develop a system of sustainability index to help decision-making processes. Taking these seven dimensions into account in sustainable homes will ensure sustainable development in the design and construction of buildings. A weighting system is one of the best options and a viable strategy to prioritise multiple dimensions (Chang *et al*., 2007; Ding, 2008; Chew & Das, 2008). It is argued that the weighting system of well-known methods (e.g. BREEAM; LEED) was not originally designed to suit different countries, and the literature review revealed that these weighting systems are not fully applicable to the built environment in Libya. With the aim of customising an applicable weighting system that prioritises the identified parameters, this chapter, presents the main methodological approach adopted for this task which involves the use of the process of Analytical Hierarchy Process (AHP). A brief overview of AHP technique is highlighted before justifying the adoption of AHP in this study. This is followed by the establishment of a hierarchy framework and pairwise comparisons. The sampling strategy of AHP technique was addressed before the various stages involved in the development of the emergent LSHAM weighting system, which includes weighting of each criterion and category, the credit allocation strategy and LSHAMs benchmarking expression are discussed. This presentation concludes with a discussion of the approved weighting system for the Libyan context, its distinctive aspects of the LSHAM against the well-established methods along with the added value of the practice.

7.2 The Development of Composite Sustainability Index

Recently, increasing attention has been given in favour of a comprehensive assessment approach adopting multiple dimensional techniques. Multi-Criteria Analysis (MCA) from this perspective is a widely accepted technique for supporting decision-making in construction projects (Capolongo et al., 2014; Lombera & Cuadrado, 2010; Ding, 2008; Kibert, 2008; Cole, 1998). As asserted by many authors (e.g. Zhang *et al.,* 2011; Rees, 2009; Ding, 2008; Cole, 2006; 2005), developing Sustainability Assessment Models (SAMs) on the bases of MCA is one of the effective solutions that helps to promote a more sustainable built environment. The development of a sustainability index reflects the integral concept of sustainable development, which includes critical features capable of assessing sustainability performance through housing projects, with a single value that represents the extent to which sustainability has been incorporated into a project. In light of this, therefore, the proposed index in this study would provide a means of aggregating information into a single relative performance model besides its ability to be used as a comparative assessment tool between available alternatives, since acceptable interventions can be selected by screening out unsustainable options. The principle purpose of the sustainability index can be understood through its ability to efficiently embed various sustainability interventions, which were reflected upon seven clusters, and fairly assign relative weights in order to ensure that key environmental, economic and social aspects are fully incorporated into a project.

In line with this understanding, the Composite Index for this study includes 43 criteria split into seven clusters, namely management and processes, materials efficiency, energy efficiency, water efficiency, waste and pollution, health and well-being, and location quality. All these clusters are combined through using Multi-Criteria Analysis (MCA) approach in a form of Analytical Hierarchy Process (AHP), in order to rank the various sustainability attributes that are included in a model. The total index score is to be provided as the main output of this system. The higher the index, the longer the result is sustainable. Figure 7.1 visualises the mechanism of developing the Sustainability Composite Index.

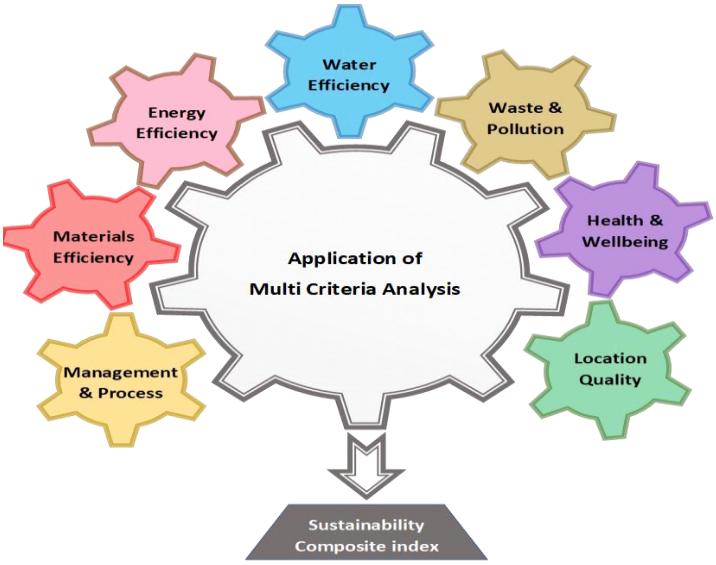


Figure 7.1 The Mechanism of Developing the Sustainability Composite Index

The development of the Composite Sustainability Index is thus established by defining the technique for analysing the multi-criteria model identified in this research which is intended to be presented through the next subsections.

7.2.1 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a well-known MCA technique for providing reliable weighting systems, determining an efficient weighting system for building an assessment method in various nations. Presley (2006) describes AHP model as a decision-making framework that assumes a hierarchical unidirectional relationship between decision levels. A brief overview of the AHP technique is to be presented before justification takes place in the sub-sections that follow.

7.2.1.1 Overview of AHP Technique

AHP was originally developed by Thomas Saaty in the 1970s. AHP offers a logical and representative way to structure the problem of decisions and to derive priorities. AHP technique is a multi-stage analytical judgment process that allows for synthesising a complex arrangement into a systematic hierarchical structure (Singh *et al*., 2007). AHP as described by Saaty (2008) is able to shift the subjectivity of the research problem to a mathematical form, analysing the relative importance of the parameters which then set in a range of priorities and overall weights. AHP approach enables users to convert a complex issue into manageable elements through hierarchical levels (e.g. goal, category, and criteria or alternatives). AHP compares pairs of decision factors and assigns weights to their relative importance (Saaty, 2007). The top element of the hierarchy is the overall goal for the decision model. The basic rationality of the method is to divide the data set into smaller component elements and then elicit pairs comparisons (e.g. how important is indicator i in relation to indicator j), using a wider scale (typically 1-9) to determine their specific priorities.

Yet, the hierarchical structure of the AHP method as pointed out by Singh *et al.* (2007), facilitates analysis by making a complex assessment into smaller, more manageable sub-evaluations, and it is the ability of the method to measure and synthesise a multitude of factors within the developed hierarchy that really distinguishes this technique. The hierarchical approach enables AHP to investigate the interrelationship between criteria for sustainability. This is important because different aspects and criteria related to sustainability are often linked (Singh *et al.,* 2007). Therefore, since interrelationships can be deciphered, the AHP method allows different criteria to be overlapped or strongly interrelated, which while having possible double-counting limitations, is both more suitable for the assessment of the holistic nature of the concept of sustainable development and does not require a very strong assumption of mutual independence.

Against this understanding, the decision process of AHP, according to Saaty (1990), involves four stages to generate priorities and make an organised decision (Figure 7.2).

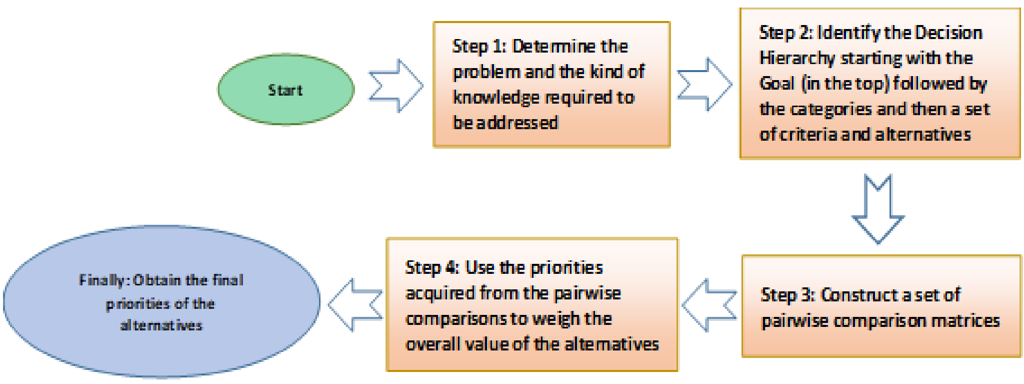


Figure 7.2: The Flow Chart of the AHP Process

As shown in Figure 7.2, the decision process of AHP begins first by determining the problem and identifying the types of required knowledge. Then, it is fundamental to build the decision hierarchy starting from the target of the decision at the top (goal). The objectives or purposes of the decision should be clarified from a broad perspective through the in-between levels which are composed of parameters or criteria on which subsequent elements depend to the lowest level which includes a range of sub-nodes. The third phase is to design a set of pairwise comparison matrixes. Each parameter in a higher level is used to compare the parameters in the level immediately below with respect to it. Through the final phase, the priorities gained from the comparisons are used to weigh the priorities in the level immediately below, then the weighted values for each parameter are added to obtain its overall priority (Saaty, 2008). According to Saaty (2008), following this process is crucial to provide an overarching vision of the complex relationship related to the phenomenon, helping decision makers to evaluate the alternative actions associated with the order of the issues at the same level on the basis of their importance.

AHP system adopts the use of a scale of absolute numbers between 1 to 9 that has been proven to reflect excellent output as compared to other scales such as 1-3 or 1-5 (Saaty, 1980). Table 7.1 shows the AHP measurement of nine scales.

Table 7.1: The Fundamental Scale of Absolute Numbers

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
3	Moderately Importance	Experience and judgment slightly favour one activity over another
5	Strong Importance	Experience and judgment strongly favour one activity over another
7	Very Strong Importance	An activity is strongly favoured, and its dominance demonstrated in practice
9	Extreme Importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	

(Adapted from Saaty, 1980)

It is worth mentioning that other scales have been further strengthened to fuzzy numbers, offering an alternative for users to express their uncertain judgements in fuzzy numbers. In this respect, fuzzy logic is an approach that deals with uncertain data and imprecise knowledge (Singh *et al.,* 2007). As such, it can be understood that fuzzy AHP is more likely used when users need to make a decision in uncertain circumstances, which is not the case in this research as the focal aim was to rate defined attributes related to sustainable homes in Libya. Additionally, the fuzzy scale was opposed by Saaty (2008), who insists that the AHP scale already has the ability to reflect such uncertain judgments and making it fuzzier could worsen the results in some extent.

7.2.1.2 Justification for Adopting AHP Technique

In the development of the sustainability index, the researcher is acutely aware that stakeholders may have different views on the relative importance of the attributes related to sustainability in housing projects, therefore, it was essential to use a verified weighting system to determine the merited credit of each criterion suggested in the proposed model. To do so, Analytic Hierarchy Process (AHP) technique was adopted in order to measure and rank the attributes identified. AHP as an analytical approach has been accepted by practitioners and academics as a leading multi-attribute decision model (Ding, 2008; Saaty, 2007; Presley, 2006). Singh *et al*. (2007) went on to advocate that AHP is a theoretically sound and feasible approach to the selection, weighting, standardization and aggregation of individual criteria into a Composite Index. AHP is evidently justifiable because of several motivating aspects. A review of the body of literature (e.g. Kang *et al*., 2016; Mardani *et al*., 2016; Burdova & Vilcekova, 2015; Alyami *et al*., 2013) revealed that AHP is a useful system for weighting sustainability parameters, as AHP has: (i) the characteristics of a hierarchical structure, which is aligned with the structures of most assessment sustainability models, making the process easy to comprehend for users; (ii) a consistent verification process; (iii) the flexibility to use both quantitative and qualitative data; and, (iv) the applicability to be easily understood and applied.

In addition to this, AHP technique was proven as efficient, widely employed by many researchers for different sustainability-based assessments (e.g. Abdul-Rahman *et al.,* 2016; Yu *et al*., 2015; Capolongo *et al.,* 2014; Chandratilake & Dias, 2013). An extensive study conducted by Cegan *et al.* (2017) reviewed roughly 3000 research studies on MCA in the environmental field, revealing that AHP is the most frequently mentioned MCA method in the body of literature. Likewise, Mardani *et al.*'s (2016) study investigating the application of MCA approaches in the field of sustainability, found that AHP were ranked in the top 14 out of 54 scientific papers published during 2003 to 2015. With regard to the built environment, many publications (e.g. Isik & Alada, 2017; Wong & Abe, 2014; Alyami *et al.* 2013; Ali & Al Nsairat, 2009; Chew & Das, 2008; Lee & Burnett, 2008, Chang *et al.*, 2007) indicated that AHP is a preferable method to use in the development of an assessment method weighting system, and tracing this back to its hierarchical structure is aligned with the structure of the intended model where its design is constructed hierarchically to meet the desired goal. For instance, a study conducted by Ali and Al Nsairat (2009) was intended to develop an applicable building sustainability assessment, following the recognition of a set of criteria for the Jordanian context, AHP was the tool that facilitated constructing a reliable weighting system. Similarly, Chang *et al.* (2007) comprised the components of GBTool/SBTool models to produce a building assessment approach fitting the Taiwanese context. AHP was adopted as a key instrument resulting in the weighing structure (Chang *et al.*, 2007). An assessment tool for the Saudi building context was developed by Alyami *et al.* (2013) through using AHP technique which was used to rank the main components of the desired model. More recently, Isik and Alada (2017) produced a model for assessing sustainable performance of the construction industry from an urban regeneration perspective. They employed the AHP technique to determine measures and indicators associated with sustainability relevant to urban development. For this combination of evidence, AHP is considered to be suitable for the purpose of the study aiming to develop a ranking system for Libya's assessment homes tool in relation to sustainability.

7.2.1.3 Establishment of a Hierarchy Framework

The development of a hierarchical model for the AHP approach, as stressed by Saaty (1980), is regarded as a key step in simplifying the targeted problem. AHP offers multiple levels of decomposition of the phenomenon into manageable components to help users focus, understand and organise the problem (Saaty, 1980). The hierarchy should be constructed so that elements at the same level are of the same magnitude and must be linked to some or all elements in the next higher level. The sub-nodes are at the bottom in a typical hierarchy; the next higher level would be the nodes. These nodes could be grouped into high-level categories in which the groups would be linked to the top single element, which is the goal or the overall objective. According to Saaty (2008), a hierarchy can be constructed by creative thinking, recollection and using people's perspectives. Saaty further notes that there is no set of procedures for generating the levels to be included in the hierarchy. Zahedi (1986) comments that the structure of the hierarchy depends upon the nature or type of design decision. Also, the number of levels in a hierarchy depends on the complexity of the problem being analysed and the degree of detail of the problem that an analyst is required to solve (Zahedi, 1986).

In light of this, the first level of the hierarchy structure (i.e. objective) is the central issue determining the scope of the subject matter, while lower levels (i.e. categories and criteria) are indicators. Figure 7.3 illustrates a simple AHP framework for this stage of study, which is divided into three levels. The highest level of the hierarchy represents the central aim of the research (i.e. the development of a sustainability assessment index for home projects); the second level is assigned to a set of defined categories; and the third level includes the set of criteria identified.

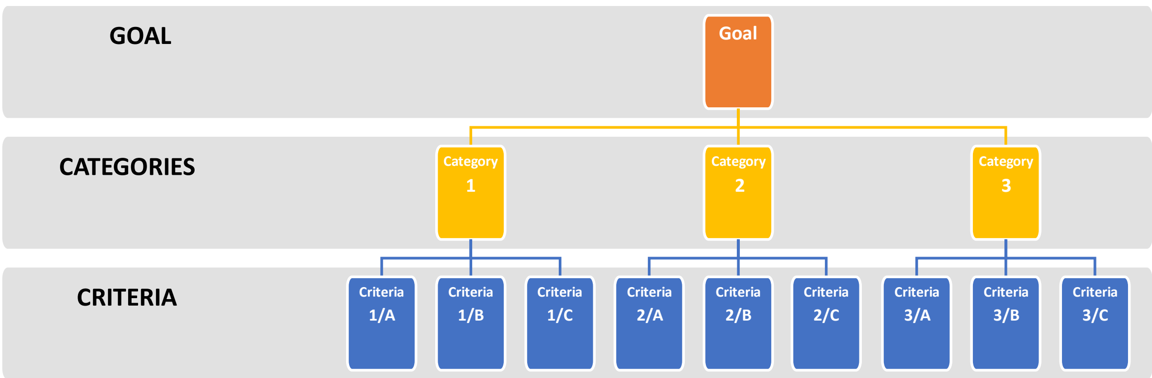


Figure 7.3: A Simple Hierarchy Framework

7.2.1.4 Establishment of Pairwise Comparisons

It is an important feature of AHP to break a complex system into a set of pair comparisons. As Saaty (1986) suggests, after constructing the hierarchy framework, the next step is to use a pair comparison technique to determine the relative importance of each criterion and sub-criteria after arranging the phenomenon in hierarchical terms. Comparisons are made between pairs of elements in each hierarchy level to determine the relative value of one element in relation to the element directly below. For example, a question that may be asked: "How much more important is an ‘integrative process’ than the ‘ecosystem enhancement’ in the assessment of management and processes feature for sustainable homes?" Facilitated by Goepel's Online Software Tool for the Analytical Hierarchy Process (AHP-OS) (Goepel, 2018), the comparison is carried out using a scale of preference from 1 to 9, as mentioned earlier. A number of interviewees were recruited using a purposeful sampling strategy to carry out a reliable AHP for this study as will be discussed in the section that follows.

7.2.2 Selecting Participants for AHP Technique

The objective of this phase is therefore to allocate credit to each category and criterion. Using the AHP technique, the participants were invited to conduct interviews in order to compare criteria and categories based on their knowledge and experience with each pair. The existing literature does not reach a consensus on the appropriate methods of collecting data from AHP panellists, but the number of panellists for AHP recommended by Saaty (2008) is between 5 to 20 experts. However, a highly skilled person with specific, specialist expertise in a subject is considered to be a suitable AHP panellist. In addition, as Maxwell (2008) suggests, a heterogeneous group benefits from the capturing of diverse, unbiased knowledge. With this suggestion (Saaty, 2008), a sample of 12 sustainability experts was drawn from different organisations. All participants were selected on the basis of their experience and seniority, as it was proven that they have an adequate understanding of the broader requirements for sustainability of housing projects (see Table 7.2 below).

Initially, individual invitations were sent to potential participants in order to explain the purpose and aim of the study, to outline the ethical considerations and to confirm their willingness to take place in the AHP exercise. Having returned signed consent forms, all 12 participants received subsequent e-mails determining the date and time of the interview. The interviews with the targeted participants were conducted using telephone in August 2018. Table 7.2 contains a list of experts and their positions in the corresponding companies - in order to respect their anonymity, the names of experts who took part in the interviews are not disclosed.

Table 7.2: List of Experts Involved in the AHP Exercise

	Position	Organization Type	Experience (Years)
1	Principal architect	Architectural/design office	24
2	Director	Home Association	15
3	Professor	Architecture School	33
4	Senior architect	Architectural/design office	20
5	Professor	Architecture School	12
6	Director	Home Association	19
7	Senior associate	Architectural/design office	25
8	Professor	Architecture School	21
9	Associate director	Architectural/design office	22
10	Professor	Architecture School	28
11	Principal architect	Architectural/design office	18
12	Professor	Architecture School	27

To facilitate the practice of AHP, Chua *et al.* (1999) provide a number of suggestions., which were adopted in this study. These proposals include:

a) A brief presentation with regard to the objective and methodology of the AHP was made to every interviewee individually;
b) An illustrative example was provided to explain how the technique is applied;
c) The interviewees were reminded of the importance of observing consistency in their answers; and,
d) The questions were grouped in accordance with different sections based on their aspects, which helps interviewees to focus on one aspect at a time.

Following the collection of priority weights from panellists, the input data for each criterion was calculated and transformed into a usable value.

7.3 The Outputs of AHP

The main tool used in the implementation and analysis of AHP results was AHP-OS software. The results of the AHP exercise were analysed in terms of consistency before extracting the relative weights of each category and criterion of the emergent evaluation model.

7.3.1 Measurement of Consistency

Deviations from both ordinal and cardinal consistency are taken into account and to some extent permitted in AHP techniques. Ordinal consistency implies that for example, if X is greater than Y and Y is greater than Z, then X must be greater than Z (if $X > Y$ and $Y > Z \Rightarrow X > Z$). Cardinal consistency is a stronger requirement stipulating that if X is 2 times higher than Y and Y is 3 times higher than Z, then X must be 6 times higher than Z (if $X > 2Y$ and $Y > 3Z \Rightarrow X > 6Z$).

On the basis of this method, the overall consistency of the judgment resulting from the 12 panellists was measured using a consistency ratio (CR), which determines the degree of contradictions in the input data. An acceptable property of consistency helps to ensure the reliability of participants in determining the priorities of a set of criteria. As identified by Saaty (2000), the acceptable range of CR varies according to the size of the matrix. If CR ≤ 0.05 for a matrix of (3×3), CR ≤ 0.08 for a matrix of (4×4) or CR ≤ 0.10 for all larger matrixes, this implies that the evaluation within the matrix is acceptable or indicates a good degree of consistency in the comparative judgements represented in that matrix. In contrast, if CR is more than an acceptable value, inconsistency of judgments within that matrix has occurred and therefore, the evaluation process should be reviewed, reconsidered and improved. In this exercise, the calculation of CR for the list of categories is presented in Table 7.3 below.

Table 7.3: Consistency Ratio Measured for AHP

	Main Categories	Matrix Size	CR
1	Management and Process	6*6	0.01
2	Material and Resources	4*4	0.02
3	Energy Efficiency	8*8	0.01
4	Water Efficiency	6*6	0.02
5	Waste and Pollution	5*5	0.06
6	Health and Wellbeing	9*9	0.06
7	Location Quality	5*5	0.03

Table 7.3 clearly shows reliable judgments among the panellists involved in the study as the CR values in all categories were less than 0.10, which are considered acceptable and therefore encouraging for carrying out the desired analysis.

7.3.2 Pair-Wise Comparison Synthesis

Using AHP-OS software, the relative values for each criterion and category were calculated on the basis of panellists' judgments. Tables 7.4 - 7.10 encapsulate the results of the HAP exercise in the seven examined categories.

Cluster One: Management and Process

As Table 7.4 shows, the ranking of Management and Process category surprisingly received a relative importance of 0.05, which is the second lowest value amongst the categories given. This reflects to some extent the consideration towards assessing the intangible interventions of sustainability whereby dominating the evaluation of performance in a project. The two highest sustainability characteristics in this category reflect both the enhancement of the ecosystem and the importance of minimising the Life Cycle Cost (LCC) in public housing. This is in line with most well-known assessment tools such as BREEM and LEED and corresponds with the results from Alyami *et al*. (2013), who ranked the feature of the ecological value of a site and the management in the top of the cluster of Management.

By contrast, the least important issue was the independent commissioning agent, which potentially reflects the organisation's strong compliance with a properly planned handover that reflects the initially designed needs of the home occupants. The recognition of potential natural risks and the Environmental Management Plan (EMP) were considered almost similar, with 15.5 percent and 15.3 percent ranked third and fourth.

Table *7.4:* Combined Pair-Wise Comparison Matrix and the Rank of Management and Process Criteria

		Criterions		1	2	3	4	5	6	**Priority**	**Rank**
Management & Process	0.051	Integrative Process	1	1	0.34	0.25	0.32	1.86	0.44	07.3%	5
		Environmental Management Plan	2	2.97	1	0.41	0.56	3.61	0.75	15.5%	4
		Ecosystem Enactment	3	4.05	2.45	1	1.95	4.82	2.39	34.1%	1
		Minimise Life Cycle Cost	4	3.15	1.80	0.51	1	3.79	1.62	22.3%	2
		Independent Commissioning Agent	5	0.54	0.28	0.21	0.26	1	0.38	05.3%	6
		Potential Natural Risks	6	2.29	1.33	0.42	0.62	2.63	1	15.6%	3

Cluster Two: Materials Efficiency

The ranking of Materials and Resources category, shown in Table 7.5, received a relative importance of 0.10, which was the fifth among the categories examined. The recycling related criterion was ranked highest, with an importance of 43.2%, followed by the use of environmentally friendly materials which was scored 33.3%. This appears to correspond with the model developed by Ali and Al Nsairat (2009) that ranked the recycling issues at the top of waste category. Despite the focus group interview suggesting that issues such as the use of locally available materials is to be considered for evaluating sustainability in a housing project, the least important aspect was estate appearance, with only 8.9%. This can be traced back to the fact that the quality and performance of materials is more critical than the locality or the economic benefits through the decision-making process for selection of materials.

Table *7.5: Combined* Pair-Wise Comparison Matrix and the Rank *of Materials Efficiency Criteria*

		Criteria		1	2	3	4	Priority	Rank
Materials Efficiency	0.100	Environmentally Friendly Materials	1	1	2.97	0.65	3.49	33.3%	2
		Responsible Sourcing of Materials	2	0.34	1	0.31	2.29	14.7%	3
		Materials Reuse & Recycling Potential	3	1.55	3.19	1	3.84	43.2%	1
		Use of Locally Available Materials	4	0.29	0.44	0.26	1	8.9%	4

Cluster Three: Energy Efficiency

The ranking of criteria relating to the Energy Efficiency aspect, as shown in Table 7.6 below, is a little surprising. The literature revealed its importance, where Energy Efficiency was ranked second following the category of Water Efficiency, with a value of 0.239. This can be understood in the light of Libya's water crisis. The panellists represent a broad understanding of the importance of renewable energy in the assessment of sustainable homes, which was 27.6 %. This is again in line with the international tools such as BREEAM and LEED that ranked the renewable energy at the top of the cluster of energy. As would be expected, an efficient HVAC system was ranked as the second most important, as this feature is likely to be critical to home occupants, with a degree of importance of 23.7%. Yet, the ranking of sunlight access rate and the use of thermal insulation were unsurprising, as these are unlikely to be considered in harsh weather.

Table 7.6: Combined Pair-Wise Comparison Matrix and the Rank of Energy Efficiency Criteria

		Criteria		1	2	3	4	5	6	7	8	Priority	Rank
Energy Efficiency	0.239	Primary Energy Demand	1	1	0.33	0.46	2.84	2.21	0.61	0.29	2.09	8.9%	5
		Efficient HVAC System	2	3.04	1	2.45	5.30	5.05	2.45	0.65	3.22	23.7%	2
		Hot Water System Use	3	2.16	0.41	1	3.48	2.64	0.86	0.33	1.97	12.2%	3
		Sunlight Access Rate	4	0.35	0.19	0.29	1	0.66	0.32	0.22	0.44	3.8%	8
		Use of Thermal Insulation	5	0.45	0.20	0.38	1.51	1	0.43	0.25	0.48	4.8%	7
		High-Efficiency Appliances	6	1.64	0.41	1.16	3.14	2.34	1	0.39	2.16	12.1%	4
		Renewable Energy	7	3.48	1.55	3.04	4.45	4.03	2.60	1	3.82	27.6%	1
		Shading Strategy Uses	8	0.48	0.31	0.51	2.27	2.07	0.46	0.26	1	6.8%	6

Cluster Four: Water Efficiency

Unsurprisingly, water issues dominated the spectrum of categories given, with a degree of importance of 0.323. This reflects the great demand of water that home developers and providers should pay attention to. In the Jordon rating system for sustainability, Ali and Al Nsaira (2009) have also found that water issues are the top properties with a degree of significance of 27.7%. This was also suggested by MWR and CEDARE (2014) asserting that the situation of severe drought has put a great strain on the water supply, especially in relation to the quality of water required to meet the bespoke standards. As shown in Table 7.7, the ranking of the potable water quality has received the highest degree of agreement amongst the panellists at 33.1%, followed by the rainwater harvesting strategies with a degree of importance 25.9%. These issues were emphasised by interviewees within the focus group, encouraging the provision of a higher water quality with water suppliers' alternatives for housing projects. Irrigation system use and greywater system efficiency criteria were of the lowest importance in this respect, with 6.6% and 6.5% respectively. As such, this potentially does not reflect a broad understanding of the significance of the issues related to the adoption of an efficient irrigation system nor the adverse effects resulting in sewage in the home site that should be sustainably assessed to ensure ideal performance.

Table 7.7: Combined Pair-Wise Comparison Matrix and the Rank of Water Efficiency Criteria

		Criteria		1	2	3	4	5	6	Priority	Rank
Water Efficiency	0.323	Potable Water Quality	1	1	2.90	4.56	2.67	4.33	1.19	33.1%	1
		Potable water demand	2	0.34	1	2.60	1.19	2.43	0.51	14.6%	3
		Irrigation System Use	3	0.22	0.39	1	0.48	0.94	0.28	6.5%	6
		Water Appliances Efficiency	4	0.37	0.84	2.07	1	2.45	0.47	13.2%	4
		Greywater System Efficiency	5	0.23	0.41	1.06	0.41	1	0.29	6.6%	5
		Rain Water Harvesting	6	0.84	1.97	3.53	2.11	3.49	1	25.9%	2

Cluster Five: Waste and Pollution

The category of Waste and Pollution came forth amongst the seven categories at 0,112, as shown in Table 7.8 below. Waste treatment and recycling facilities criteria emerged as the top issue for evaluating this category, with a value of 45.8%. This seems to confirm the view expressed by Alyami et al. (2013), who stressed that the provision of efficient waste recycling systems in home projects not only reduces waste, but also reduces hazardous pollutants resulting from poorly managed waste homes. Interestingly, issues relating to a low refrigerant rate represents the least relevant node within this feature, which scored only 9.5% by the panellists, yet, it was frequently noted amongst the well-known tools such as BREEM and LEED.

Table 7.8: Combined Pair-Wise Comparison Matrix and the Rank of Waste and Pollution Criteria

		Criteria		1	2	3	4	5	Priority	Rank
Waste and Pollution	0.112	Waste Treatment & Recycling Facilities	1	1	3.63	3.27	4.27	2.84	45.8%	1
		Low Light & Noise Pollution	2	0.28	1	0.71	1.66	0.89	13.3%	4
		Polluted Emissions Reduction	3	0.31	1.41	1	1.50	0.79	14.9%	3
		Low Refrigerants Rate	4	0.23	0.60	0.67	1	0.57	9.5%	5
		Preventing Sandstorms	5	0.35	1.12	1.26	1.74	1	16.5%	2

Cluster Six: Health and Wellbeing

The ranking of the category of Health and Wellbeing came third after water and energy aspects, scored at 0.128 as shown in Table 7.9 below. Within this feature, cooling and heating comfort was deemed the most important node, with 28.9%. This also appears compatible with Ali and Al Nsairat's (2009) study which emphasized the importance of the thermal comfort as one of the most important aspects for ensuring sustainable homes. The safety protection criterion was ranked second at 16.3%, which reflects the importance of security issues in the evaluation of the indoor quality and comfort. On the other hand, issues related to the cultural and architectural heritage consideration were not given much attention, even though they were frequently highlighted throughout the focus group interview.

Table 7.9: Combined Pair-Wise Comparison Matrix and the Rank of Health and Wellbeing Criteria

		Criteria		1	2	3	4	5	6	7	8	9	Priority	Rank
Health and Wellbeing	0.128	Natural Ventilation Level	1	1	0.32	1.38	0.20	0.34	0.34	0.39	0.97	0.59	4.7%	8
		Illumination Quality & Control	2	3.09	1	2.21	0.26	0.56	0.54	0.75	1.60	1.07	8.9%	5
		Sound Absorption & Insulation	3	0.72	0.45	1	0.21	0.39	0.35	0.42	1.16	0.56	4.7%	7
		Cooling and Heating Comfort	4	4.97	3.84	4.71	1	3.46	2.04	2.37	5.11	3.95	28.9%	1
		Internal Layout Functionality	5	2.90	1.77	2.53	0.29	1	0.59	0.77	2.21	1.60	11.2%	4
		Safety Protection	6	2.93	1.86	2.84	0.49	1.70	1	1.12	3.86	3.14	16.3%	2
		Maintainability & Flexibility	7	2.53	1.33	2.37	0.42	1.30	0.89	1	3.95	2.06	13.4%	3
		Cultural and Architectural Heritage	8	1.03	0.62	0.86	0.20	0.45	0.26	0.25	1	0.52	4.5%	9
		View out & Aesthetic Aspects	9	1.68	0.93	1.78	0.25	0.62	0.32	0.49	1.91	1	7.3%	6

Cluster Seven: Location Quality

Very surprisingly, the ranking of quality location categories received a low degree of agreement between the panellists at only 0.047, as shown in Table 7.10 below. The community services related criterion was ranked highest as the most important feature for evaluating a sustainable home. However, corresponding with the interviewees in the focus group, the panellists gave technological connectivity the second highest consideration, with 29%. This proves the necessity to ensure homes to be technologically well linked with the advanced technology of networks and internet. Despite the literature suggesting that issues related to 'transportation accessibility' and 'pedestrian and cyclist safety' are usually dominant when considering the sustainability in housing projects, the least important issues were estate appearance, with only 13.6% and 4.9% respectively. This appears to be contrary to the body of literature (e.g. Alyami *et al*., 2013; Ali & Al Nsaira, 2009), which is often critical to the design of regeneration housing.

Table 7.10: Combined Pair-Wise Comparison Matrix and the Rank of Location Quality Criteria

		Criteria		1	2	3	4	5	Priority	Rank
Location Quality	0.047	Community Services & Facilities	1	1	2.78	1.22	3.27	4.80	36.0%	1
		Transportation Accessibility	2	0.36	1	0.44	0.57	4.52	13.6%	4
		Technological Connectivity	3	0.82	2.29	1	2.18	4.98	29.0%	2
		Car Parking Capacity	4	0.31	1.76	0.46	1	4.23	16.5%	3
		Pedestrian and Cyclist Safety	5	0.21	0.22	0.20	0.24	1	4.9%	5

7.4 The Establishment of a Composite Index

The central aim of the research, however, was to customise a model for the evaluation of Libya's public housing projects. The previous phase of AHP was to integrate the sustainability characteristics identified in Chapter 6 together with the relative weightings merited. The weighting system that ideally qualifies sustainability components is an important feature of the Composite Index; this is achieved by aggregating individual credits or points to give a single value. For this to be achieved, two essential steps are to be applied: credits allocation; and Rating benchmarks. As such, the following sub-sections demonstrate the development of the scoring, aggregation and expression of the proposed model.

7.4.1 Credits Allocation

The important weightings as determined in the previous stages have been utilised to allocate the merited value for each cluster and node. Since the values of criteria have been brought with decimals, it would be preferable to use digits without fractures in the application of the weighting system. To facilitate the potential calculation of the weighting system, all values were rounded to the nearest integer. Table 7.11 below shows the values assigned to each category and criteria in the developed index.

Table 7.11: The Weighting System Developed through the AHP Technique

Code	Category	Weighting Coefficient	Code	Criteria	Credits
MP	Management & Process	5%	MP1	Integrative Process	7
			MP2	Environmental Management Plan	16
			MP3	Ecosystem Enactment	34
			MP4	Minimise Life Cycle Cost	22
			MP5	Independent Commissioning Agent	5
			MP6	Potential Natural Risks	16
					100
ME	Materials Efficiency	10%	ME1	Environmentally Friendly Materials	33
			ME2	Responsible Sourcing of Materials	15
			ME3	Materials Reuse & Recycling Potential	43
			ME4	Use of Locally Available Materials	9
					100
EE	Energy Efficiency	24%	EE1	Primary Energy Demand	9
			EE2	Efficient HVAC System	24
			EE3	Hot Water System Use	12
			EE4	Sunlight Access Rate	4
			EE5	Use of Thermal Insulation	5
			EE6	High-Efficiency Appliances & Monitoring	12
			EE7	Renewable Energy & Alternative Strategies	27
			EE8	Shading Strategy Uses	7
					100
WE	Water Efficiency	32%	WE1	Potable Water Quality	33
			WE2	Potable water demand	15
			WE3	Irrigation System Use	6
			WE4	Water Appliances Efficiency	13
			WE5	Grey Water System Efficiency	7
			WE6	Rain Water Harvesting & Alternatives	26
					100
WP	Waste & Pollution	11%	WP1	Waste Treatment & Recycling Facilities	46
			WP2	Low Light & Noise Pollution	13
			WP3	Polluted Emissions Reduction	15
			WP4	Low Refrigerants Rate	10
			WP5	Preventing Sandstorms	16
					100
HW	Health & Wellbeing	13%	HW1	Natural Ventilation Level	5
			HW2	Illumination Quality & Control	9
			HW3	Sound Absorption & Insulation	5
			HW4	Cooling and Heating Comfort & Control	29
			HW5	Internal Layout Functionality & Visual Comfort	11
			HW6	Safety Protection & Fire Security	16
			HW7	Maintainability & Flexibility	13
			HW8	Cultural and Architectural Heritage	5
			HW9	View out & Aesthetic Aspects	7
					100
LQ	Location Quality	5%	LQ1	Community Services & Facilities	36
			LQ2	Considering Transportation Accessibility	14
			LQ3	Considering Technological Connectivity	29
			LQ4	Car Parking Capacity	16
			LQ5	Pedestrian and Cyclist Safety	5
		100%			100

As required within the Composite Index, these individual categories and criteria need to be transformed into single rating score to make it easy to express the ultimate value that reflects the level of sustainability involved in a particular intervention.

7.4.2 Rating Benchmarks

Following the existing evaluation systems such as BREEAM and LEED, the output of the developed index is converted into a single expression of the ranking. LSHAM advocates the use of a percentage-based scale (as shown in Figure 7.4), including 6 different levels of certification. In LSHAM, the targeted project rated below 35 will therefore be considered "UNCLASSIFIED," since this is the starting point for meeting the primary criteria. Homes rating 35 to 45 are considered to be "PASS" (One Star) whilst "BRONZE" (Two Stars) will be considered projects rated between 45 and 55. Homes rated from 55 to 75 are considered "SILVER" (Three Stars); homes rated between 75 and 85 are considered to be "GOLD" (Four Stars). Finally, homes rated above 85 are considered "DIAMOND" (Five Stars), since this is the level of outstanding interventions that meet the majority of LSHAS criteria.

Figure 7.4: LSHAM Rating Benchmark

7.5 How the Composite Sustainability Index Works

The LSHAM Homes Rating System has 43 subject areas grouped into seven sustainability-passed categories, as outlined in Table 7.11, each with a unique purpose or objective. The model rating determination process is shown in Figure 7.5 below.

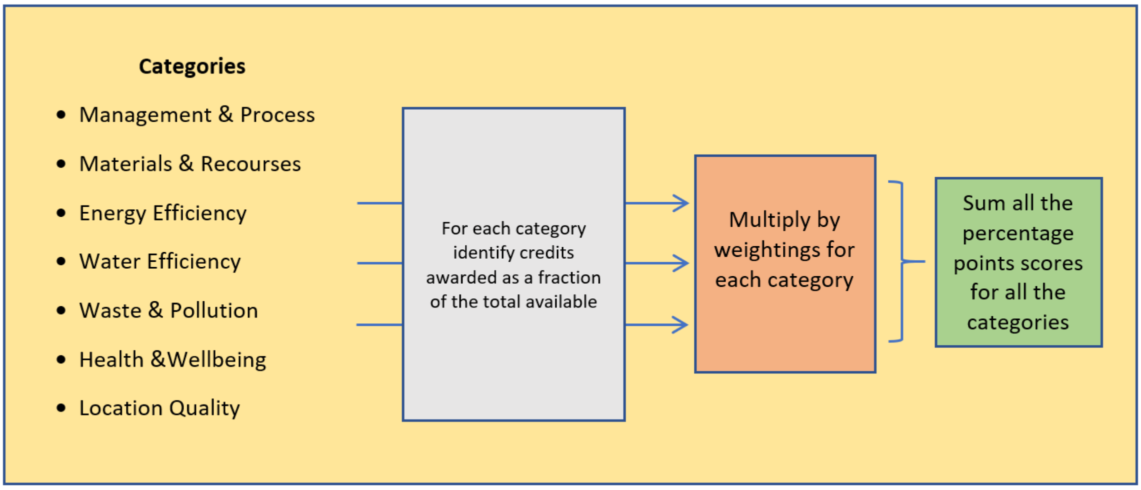


Figure 7.5: The Process of LSHAM

1) ***Step One:*** Evaluating attributes of the criteria. The evaluation of each criteria is one of the important steps in the calculation of individual credits. The evaluators should grant the number of "credits" for all 43 criteria in accordance with the allocations granted. Although this process is likely to be subjective, Ding (2008) believes that guidance should be issued to make it as objective as possible.

2) ***Step Two:*** Section score aggregation. In each section, the "credits" achieved for the criteria are then calculated to obtain the total credits. Mathematical formulae are not necessary to achieve this calculation, instead, a simple aggregation is used to present each section's overall credits. However, for each section, the maximum credits are 100 points.

3) ***Step Three:*** Calculate the percentage of categories. The percentage of "credits" obtained in each section is multiplied by the corresponding weighting coefficient in the section. This gives the overall score for the section.

4) ***Step Four:*** Total score aggregate. The score for each section is then calculated in order to obtain the overall score for the seven categories. It simply adds the seven scores allocated to the various sections. The results should be expressed as 100%.

5) ***Step Five:*** Allocation of the awarded level. Compared to the rating benchmark levels and the relevant rating, the overall score is ultimately achieved.

7.6 LSHAM and the Added Value with the Impact of Existing Knowledge

LSHAM can be shown as a solid foundation for the promotion of a more sustainable built environment. In developing the evaluation scheme for Libya, leading schemes (i.e. BREEM, LEED, GBCA and DGNB) have been widely criticised. Throughout this study, it was clear that leading schemes have not recognised a number of categories and criteria that are considered important to the Libyan context. As such, regional and cultural changes in Libya particularly, have motivated the further development of an appropriate assessment system. The emerging index for sustainable homes can be shown as an assessment tool to promote more sustainable homes based on an extensive set of applicable and reliable criteria with the capability to truly reflect the Libyan built environment as it:

- Identifies a number of problems that have significant impacts on the environment, society and the economy.
- Develops performance measures to help reduce unwanted impacts.
- Evaluates performance in a three-stage process, including stage of design, construction and deconstruction, using objective criteria and verification.

LSHAM thus, can be considered as a step-change in Libya's sustainable home practice. To this end, the relevance of the customised weighting system for the Libyan context and its divergence from the international systems is to be emphasised. This has been also brought in line with the insistent query that ensures the developed index is not confined to assessing merely a monetary-based approach but is used to evaluate environmental and social impacts. Therefore, the subsequent sub-sections are devoted to discussing the main features distinguished in the developed index in light of the multiple diminutions of sustainability (i.e. Environmental, Social and Economic Aspects).

7.6.1 Environmental Perspective

Environmental sustainability has become one of the prominent problems to be addressed through home projects. LSHAM has been embedded in a wide range of distinguishing criteria that maintain many environmental aspects, including recognition of ‘Rainwater Harvesting’, ‘Renewable Energy and Alternative Strategies’, and ‘Preventing Sand-storm’.

The state of Libya is struggling with the situation of severe drought which has put a great strain on its water supply, especially in relation to the quality of water required to meet the bespoke standards (MWR & CEDARE, 2014). Water consumption is likely to be an increasing national problem, as the demand for water exceeds the volume authorised for abstraction from groundwater. Libya relies almost entirely on non-renewable, fossil and groundwater resources with very limited perennial water resources (MWR & CEDARE, 2014). Since there are no permanent rivers in Libya, only ephemeral rivers or wadis, the Libyan government has undertaken a massive project known as the Great Man-Made River Project (GMMR). GMMR provides approximately 6.5 million m^3 of freshwater per day to supply water for the Northern cities of Libya which constitute around 70% of Libya's population (Abdudayem & Scott, 2014). People in Libya are not charged for water use, as water supplies are taken for granted. This has led to unconscious behaviours towards the consumption of water and not valuing this limited resource which results in even further waste and less efficient distribution. The figures show that around 5830 million m^3 of fresh water was drawn from reservoirs and groundwater in 2012, the most recent year for which data are available, where 20 percent was used domestically, with over 50% of this being for washing and washing toilet flushing (Abdudayem & Scott, 2014). Groundwater (including fossil groundwater) accounts for more than 95 percent of the water removed. The rest is divided between surface water, desalinated water and wastewater (Abdudayem & Scott, 2014). The 2008 National Sustainable Development Strategy considered that the abstraction of sustainable groundwater should not exceed 3,650 million m3/year, despite the fact that only 650 million m^3/year comes from renewable groundwater and 3,000 million m^3/year from fossil water (CEDARE, 2014). As fossil groundwater is not included in renewable water resources, the current withdrawal of water is more than 8 times the annual renewable water resources, while more than half of the domestic water supply was from GMMR (MWR & CEDARE, 2014). Therefore, the current study has ranked the water issues as the top priority category (32 credits) with the goal of raising awareness of water scarcity among customers. However, as discussed earlier (Section 4.5.6, p.91), the water issues are not highly recognised by well-known schemes such as BREEAM and LEED (6% and 11% prospectively), which can be understood as they are not applicable to such a context as Libya. LSHAM thus, promotes the use of higher water quality and encourages alternatives for drinking water suppliers to provide home users with clean, fresh water sources. More importantly, the "Rainwater Harvesting and Alternatives" criterion which was assigned with 25.9% among the water issues, can play an important role in increasing the efficient use of water. The adoption of effective rainwater harvesting strategies can minimise the adverse effects of erosion and runoff at the home site, which can reduce the amount of drinking water used especially for external water use, minimising the cost of the life cycle and maintaining the environment.

Another aspect that has been met within the LSHAM index is the adoption of renewable energy and alternative strategies within the area of Energy Efficiency that was allocated second with 24 credits - BREEAM 36% and LEED 35% - with the goal of assessing measures to improve inherent energy efficiency thereby reducing carbon emissions and supporting efficient use throughout the life of the home. In this respect, the use of fossil fuel, which is a non-renewable resource, produces a large proportion of Libyan energy, generating more than a third of Libya's carbon emissions (Shawesh, 2016). Of course, the relevant indicators are concerned and in 2016, which is the most recent year for which comparable data are available, Libya was ranked 99th globally in relation to electricity consumption, using 28.48 billion kWh which means 4,680 kWh per capita. The average Libyan consumes electricity roughly two times more than the average Indian person, though still about 25% the average in the UK (IEA, 2018). Likewise, in relation to gas consumption, Libya in the same year was ranked 60th globally in relation to natural gas consumption, consuming 4.49 billion m^3 which means 704.36 m^3 per capita. The average Libyan consumes natural gas roughly two times more than the average Indian person, though still about 70% of the average in the UK (IEA, 2018). Yet, the lack of awareness of occupants is one of the important factors that controls energy consumption in homes (Akadiri, 2011), and modest investments in energy-saving technologies and other climate-friendly technologies can make homes and communities healthier, more comfortable, more sustainable, more energy-efficient and more environmentally responsible. In recognition of these facts, Renewable Energy criterion is one of the most prominent objectives of the LSHAM scheme - scored 27.6% within Energy Efficiency cluster which was ranked at the top of two priorities in the LSHAM index. It is highly recommended to promote one of the highest potential renewable energy sources, the application of solar energy, together with the use of appropriate thermal insulation and shading strategies.

Such energy sources should be promoted not only for reasons related to minimising reliance on finite and decreasing fossil fuel sources (e.g. coal, oil, gas, etc.), but also for reasons related to pollution reduction and climate change management. The "renewable energy and alternative strategies" criterion is primarily aimed at creating a home concept with the best possible use of passive systems and the inclusion of renewable energy sources. The use of resilient home building technology and renewable energy sources reduces the risk of rising costs and external dependencies and is generally designed for long-term durability (Amer, 2007). However, as discussed earlier (Section 4.5.6, p.91), key issues such as the adoption of solar energy are not given much consideration, and SAMs have dealt with the objectives of renewable energy differently. Whilst DGNB has met these objectives by means of multiple criteria, BREEM covers this investigation under the criterion of "low or zero carbon (LZC) technology". Similarly, GBCA incorporates this into the "Accredited GreenPower" criterion, while in LEED it is assessed by the "Renewable Energy" criterion.

One more distinctive environment-related aspect is the 'Sandstorm Prevention' criterion. In the context of desert sandstorms, the term sandstorm is most often used to refer to a high amount of wind, where the wind speed can lift the top layer of sand from the ground and push it in every conceivable direction. In many countries, especially in the Sahara region, the sandstorm has become a serious social-environmental phenomenon. The Sahara or "Great Desert" is the world's largest hot desert (Worlddata, 2018), which has formed a large area of north Africa, such as Libya. The sandstorm causes considerable hardship and loss of income, disrupts communication and causes serious problems in public health. According to Abdegalieva and Zaykova (2006), it causes death in extreme cases, extensive destruction of livestock and crops and a damaged ecosystem. Due to extreme weather patterns caused by drought, the sandstorms in Libya have increased, as well as increasing development in areas prone to sandstorms (Shawesh, 2016). In recognition of the prevention of sandstorms as one of the objectives of the LSHAM scheme, the use of native plants and trees as a buffer is highly recommended, thereby reducing wind speed and sand drifts while increasing soil moisture, along with the use of sandstorm control measures (e.g. native soil cover, shrubs, terraces, walls, etc.). Whilst these objectives are not widely recognised by BREEAM, LEED, DGNB nor GBCA, as discussed earlier (section 4.5.6, p.91), and in response to this query, the study scored "Sandstorm Prevention" criterion

16.5% in the category of "Waste and Pollution" that is ranked 11 credits within the Sustainability Index. The importance of this criterion is demonstrated by encouraging home providers to carry out sandstorm risk assessments in order to minimise the adverse effects of this phenomenon.

7.6.2 Social Perspective

Social sustainability is a key component to be assessed if sustainable development is to be achieved. Social and cultural considerations greatly influence home projects in Libya. Typical Libyan families are large and dynamic, with close ties to distant relatives and neighbours. Housing projects must, therefore, be designed and constructed to accommodate social events and needs. These issues were raised within the developed index through a number of criteria, including "Internal Layout Functionality and Visual Comfort" and "Cultural and Architectural Heritage Consideration,".

Internal layout and visual comfort form the basis of general well-being and satisfaction. Many cultural aspects must be taken into account in the design of a home project in order to establish sustainable homes in Libya. In Libya, visitors are traditional, yet local culture hides the socialisation of both genders in one place. This can affect Libyan housing's architectural design style. For example, most Libyan housing typically includes separate guest rooms, one for men and one for women, for the same reason. These rooms are usually spacious and supplied with electricity for cooling and lighting to meet the comfort needs of both occupants and visitors. In addition, since the typical Libyan family size is relatively high, household members often need more bedrooms. Housing projects, on the other hand, should preserve and improve existing cultural areas and heritage and minimise negative visual impacts. Where a project is set up in historical sites, it must be in accordance with local culture and heritage. Archaeological remains are more unique and irreplaceable than other aspects of the environment, as stressed by Addis and Talbot (2011). In line with this, consistency with natural appearance as Almansuri *et al*. (2009) asserted, should also be taken into account. The careful design can protect and improve several landscape features such as ponds, hedgerows and grasslands (BRE, 2016). The importance of these criteria is demonstrated by minimising negative visual effects and maintaining harmony with the surrounding environment and with local culture and heritage. Nevertheless, the study does not much consider the criterion of 'Internal Layout

Functionality and Visual Comfort' (11.2%), whilst the criterion of 'Cultural and 'Architectural Heritage Consideration' came last (4.5%) amongst the area of Health and Wellbeing that was allocated 13 credits in the Sustainability Index. By contrast, as discussed earlier (Section 4.5.6, p.91), these objectives are well recognised in GBCA through multiple criteria including 'Base Building Cultural Heritage Significance'; 'Indoor spaces to facilitate communication'; 'Additional provisions for users'; 'Family-friendly, child-friendly and senior-citizen-friendly design'; and 'Quality of interior access and circulation area'. Otherwise, BREEAM, LEED and DGNB do not recognise these goals, which again support the argument that the leading global models for the assessment of sustainability have not assessed the cultural and social characteristics or the Libyan environment. This clearly justifies the need to customise an applicable sustainability assessment tool that can respond to the actual characteristics that distinguish the Libyan built environment.

7.6.3 Economic Perspective

In the assessment of sustainability, financial considerations are essential. However, neither BREEAM nor LEED take financial aspects into account in their evaluation framework, which is likely to contradict the ultimate principle of sustainable development, since financial benefits are essential for both providers and homeowners of home projects. The LSHAM scheme has incorporated economic criteria by which home projects in Libya can play an important role in improving the economic aspects. This includes "Minimis Life Cycle Cost", "Use of locally available materials" and "Maintainability and Flexibility".

The concept of sustainability applied to housing projects initially, aims to promote maximum efficiency and reduce financial costs (Lombera & Garrudo, 2010). While minimising costs is the main concern in sustainable homes, house developers and suppliers have realised that the selection of the lowest initial cost option cannot guarantee the financial advantage over other house project options. There has traditionally been an imbalance between sustainable measures and the project budget, as Goh and Yang (2009) observed. They found that decisions concerning the design and construction of home projects are mainly based on the first-cost approach. As such, sustainability innovators often push for a sustainable home with lower costs. However, the contemporary orientation encourages home providers to adapt current and emerging global sustainability issues while remaining profitable. The analysis of Life cycle cost (LCC) in this respect, can play an important role in the economics of a housing project in order to ensure that these orientations are valid. The costs of the life cycle of a built asset include: the costs of acquisition, including consultancy, design, construction and equipment; operating costs, including utilities, renovation, repair and maintenance; and internal resources and overheads, risk allowances, forecast changes in known changes in business requirements, renovation costs and costs related to sustainability, health and safety aspects (Goh & Yang, 2009). As such, LCC as an approach, can predict a building's costs from operation, maintenance and replacement until the end of its life. The LCC analysis allows decision-makers to assess competing initiatives and identify the most sustainable growth path for the common home project (Goh & Yang, 2009). A cost analysis study conducted by Emmitt & Yeomans (2008) shows that the costs of running a building can be significant and often exceed the initial costs. Therefore, decisions based solely on initial costs may not be the best long-term selection, and LCC method can be used effectively to realise the benefits of the long-term cost implications of sustainable development in home projects. Aligning with this, minimising the cost of the life cycle was highly recommended in the developed Sustainability Index, classified as a two-top priority with 22.3%, yet the Management and Process cluster was not greatly recognised whereby achieving only 5 credits in the Sustainability Index which to some extent, reflects the assessment orientations towards the real and physical interventions rather than the compliance with typical processes. The main value of promoting the provision of full life value by promoting the use of LCC is to improve design, specification, maintenance and operation throughout its life. The importance of this criterion can be shown trough the sharing of data generated from LCC analysis and disseminating the reporting of capital costs which can greatly raise awareness and understanding of the project's financial viability and clearly promote economic suspension.

From another economy-related perspective, the use of local materials can significantly support the local economy and reduce the harmful effects of long-distance transport. A significant amount of energy is used to transport materials from manufacturing plants to building sites. The selection of local products will reduce the use of embedded energy for transport in connection with construction, as a significant amount of energy is used to transport materials from production plants to construction sites. With such an unnecessary transport, smaller emissions would be produced, and less congestion would be encountered. In addition, it is helpful to encourage the use of local materials to achieve a more sustainable outcome. Housing projects can strengthen a successful local economy by creating jobs, training local people, increasing demand for local materials, supplying local suppliers, promoting new businesses, improving access to services and attracting local people to live and work. To do so, local authorities may encourage suppliers to use local work, local procurement or local subcontracting. Their contribution would generally be to integrate requirements relating to community benefits to be delivered in a locality into their contracts and specifications. Yet the participants in the questionnaire stage found greater interest in the use of local materials, the least important aspect was the estate's appearance where it ranked last with 8.9% among the Materials Efficiency section which is assigned with 10 credits in Sustainability Index. This can be traced to the fact that, through the decision-making process for selection materials, the quality and performance of materials is more critical than the locality or the economic benefits. Again, these objectives are not well-recognised by BREEAM, DGNB and GBCA, whilst LEED has allocated the criterion of 'Regional Priority' to partially fulfil this enquiry. This thus, advocates the judgment that SAMs are not suitable for use in different contexts, since there are a number of economic and social features that must be met in any logical assessment of the built Libyan environment.

Another distinctive aspect of LSHAM related to the economy is the "Maintainability and Flexibility" criterion. Flexibility means not only ensuring that the home meets its functional objectives and meets the needs of the current occupants, but also ensuring that long-term adaptability is taken into account. The ease with which a homeowner can implement the functionality of maintenance and change rooms helps to reduce the cost of the home's life cycle and increases the satisfaction and viability of homeowners. Therefore, the idea behind this concept is to meet the requirement of the occupants within the definition of value for money (Addis & Talbot, 2001). In view of the fact that maintenance and flexibility are objectives of the LSHAM scheme, it is recommended to assess the recognition of flexibility in the aspects of the floor plan and structural design, in addition to ensuring that technical home systems are highly adaptable. It is considered crucial to use this information to ensure that a home is implemented efficiently, and that sustainability is targeted. The importance of this criterion is demonstrated by promoting solutions that allow minimal loss of maintenance and development work. The study rated maintenance issues as a two-tier priority among the health and wellbeing category in LSHAM index, with the aim of encouraging home developers to make the design of the home as flexible as possible and create the greatest potential for extension. However, as discussed earlier (Section 4.5.6, p.91), these objectives are not widely recognised by LEED nor BREEM, while they are assessed in the context of the criteria "Development and maintenance care" and "Concept for easy cleaning" in the DGNB, and in the context of the "Services and Maintainability Review" criterion in the GBCA.

7.7 Chapter Summary

This chapter has developed and discussed the Sustainability Index scheme. LSHAM categories were prioritised using AHP technique. AHP-OS software was the main tool for analysing pair wise comparison input data. Water efficiency was at the top of the LSHAM weighting system as Libya experiences water scarcity. Libya also has an alternative and abundant natural resource (i.e. solar energy), which can provide a more sustainable energy resource. This has put energy efficiency issues at the second highest priority. Since the sustainability assessment index strategy is to provide a single score, the allocation of credits and the rating formula for the LSHAM index have been addressed. The use of the Sustainability Index is intended to enable public housing projects to identify the best performance that maintains environmental, economic and social characteristics. The value generated by the developed scheme shows broad aspects that have been combined to improve decision-making processes in housing projects towards a more sustainable approach that ensures value for money while also strengthening social and environmental considerations. Finally, within the Composite Sustainability Index, it is necessary to reaffirm that the proposed model is perceived as a facilitating device rather than an objective model of reality. It is therefore the responsibility of home providers and developers to shape the ideal performance to ensure the desired improvement in their projects towards greater sustainability. Next, the Sustainability Index is subject to the validation process conducted with knowledgeable experts in the relevant field in a small-scale interview.

8 Validating the Developed Model

8.1 Chapter Overview

In earlier chapters, the research sought to expand existing knowledge by creating a theoretical framework for sustainable homes based on an integrated analysis with well-established evaluation systems (i.e. BREEM; LEED; GBCA; DGNB). In an attempt to customise the applicable scheme for the Libyan built environment, Chapter 6 presented the efforts of the relevant stakeholders by conducting an interview with the focus group and a broad questionnaire survey, suggesting overall interventions to shape sustainable development in the public housing sector. The research continued in response to the given question in order to develop a Composite Sustainability Index in which the establishment of a rigorous weighting system is considered to be the cornerstone of its structure. Using the AHP technique, Chapter 7 showed the process used to rate the defined set of criteria and categories to design the Composite Index weighting system. This chapter presents a final assessment of the developed index in order to obtain an assessment of the views of recognised experts with sufficient expertise to extend the discussion and provide a critical view of the validation of the index. It also identifies other possible refinements or possible directions for research that more likely enhance sustainability practices in housing sectors. However, the current chapter outlines what is meant by validation along with its various techniques and the rationale behind each technique adapted for validating this research.

8.2 Validation and its Techniques

Validation is a key part of the model development process which increases the level of evidence and recognises the model's truthfulness (Kennedy *et al.,* 2005). In this manner, the internal and external validities should be distinguished. Internal validity refers to the question of whether the effects observed in a study are due to the manipulation of the independent variable and not another factor (Creswell, 2007). In other words, the independent and dependent variables have a causal relationship. On the other hand, external validity refers to the extent to which the results of the study can be generalised to other settings (ecological validity), other persons (validity of the population) and/or over time (historical validity) (Creswell, 2007). Throughout this research, the internal validation was improved by carefully selecting the participants for focus group interview and was tested through using Cronbach's alpha coefficient in questionnaire. The external validation, on the other hand, was achieved through conducting a large-scale survey recruited a broad range of stakeholders and also through the use of Kendall's W test. In addition, the validation process can continue to investigate whether the model results are sufficiently accurate for the intended purpose of the model (Sargent, 1998). As such, the validation process may not be aimed at absolute validity, but rather at checking the process of establishment or 'operational validity'. In this essence, as defined by Sargent (1998), there are different techniques for validating a model, each of which can be used either subjectively or objectively, the brief descriptions of which are encapsulated in Table 8.1, as defined in the body of literature (e.g. Creswell, 2007; Kennedy *et al*., 2005; Sargent, 1998; Gass, 1983).

Table 8.1: Different Techniques for Validating a Model

Types of validity	
Face Validity	Asking system experts whether the model and/or its outputs are reasonable, this technique can be used to determine whether the logic in the conceptual model is correct and whether the input output relationships of the model are reasonable.
Fixed Values	The model results can easily be checked against calculated values using fixed values (e.g. constants) for different model inputs and internal variables and parameters.
Historical Data Validation	If there are historical data (or if data is collected on a model building or testing system), part of the data is used to build the model and the remaining data is used to determine whether the model acts as the system does.
Predictive Validation	Use the model to predict the system pattern and then compare the behaviour of the system and the model forecast to determine whether they are the same.
Comparison to Other Models	The model output can be compared to the results of other valid systems models.
Degenerate Tests (simulation)	Whether the model degenerates as expected by simulating these situations in the model with the appropriate selection of input and internal parameter values.
Construct Validity	Refers to the extent to which a test captures a particular theoretical construct or characteristic and overlaps with some other validity aspects.

8.2.1 The Technique Adopted for Validation

According to Gass (1983), the appropriate method for validating a model depends primarily on the real-world analysed aspect and the model type used. Taking into account the previously discussed dimensions and various validating techniques, it is suggested that face validity is the most appropriate techniques for validating the developed sustainable home index. With exception to time and fund limits, this choice can be also justified as being the desired aim of this study is to validate the proposed index for industry-wide application. This in fact makes this choice more preferable upon such target and under the given circumstances. In this case, the objectives of the validation of experts' opinions are to assess the feasibility and clarity of the model and to make the model reasonably robust and applicable (Creswell, 2007). To do so, three validation options were considered: (i) the focus group (ii) the interviews, and (iii) surveys. The use of focus groups or surveys has been handicapped by the research's time and cost constraints, leaving interviews as the most appropriate option. However, the advantages associated with interviews include flexibility and opportunity to clarify interviewees' doubts, as opposed to the restrictive nature of questionnaires in terms of lack of communication with the participants.

8.2.2 Development of Validating Interview

In order to carry out a rigorous validation, a semi-structured interview was adopted to allow the researcher to maximise the wealth of information collected while managing the interview session to cover the desired queries, as advocated by Creswell (2007). The aim of the interviews was to cover the main contributions to the knowledge and practice reported in the thesis, including the set of sustainability criteria and the Composite Index. The interviews were, however, guided by a number of criteria to validate a model. The body of literature (e.g. Reed *et al.,* 2006; Macal, 2005; Gass, 1983) suggests a criterion for the evaluation of indicators whereby ensuring best practices. This criterion is based on the definition of characteristics of the best indicators to determine the reliability and validity of the Composite Sustainability Index. In line with this, a number of criteria were adopted to validate the developed model. This includes: (i) comprehension (ii) precision, (iii) applicability and (iv) feasibility. This led the interview to be structured by four-bullet points, as shown in Table 8.2 below.

Table 8.2: Validation Interview Agenda

	Criteria Examined	Discerption
1	Comprehension	*Whether the model is clear and understandable to the stakeholders*
2	Precision	*Whether the index captured all important sustainability features required for public housing sector*
3	Applicability	*Whether the model is applicable in reality or what are potential difficulties in its implementations*
4	Feasibility	*Whether the model would assist in enhancing the current practice of the public housing sector*

In addition, the interview opens doors for further suggestions to allow the participants to express their perceptions, either generally or specifically, on the content of the developed index.

8.2.3 Selection of Expert Group and Validation Process

It is crucial that the validation phase generates valuable and relevant expert opinions for the model to be acceptable and valid to form a sustainable home. This can only be achieved if the chosen experts participating in the validation phase possess the necessary knowledge and expertise. Thus, the choice of experts responding to the request were based on relevant expertise and experiences, and academic and professional qualifications. Therefore, a discriminatory sample was employed, recruited from a range of senior public housing practitioners and professors, and drawn from architectural and design firms, construction corporations, and academia scope.

Following the development of an initial sample of ten senior professionals and professors, an invitation letter was sent to each potential participant via email, requesting their kind assistance in the validation exercise, stating the purpose of the research and validation process and accompanied by a brief description of the model and the consent form. Five experts, who demonstrated the needed knowledge and experience, ultimately responded, expressing their desire to take place into this stage. All of which have not participated within the previous stages of research. Two participants were based in the UK, selected on the basis of their academic knowledge and involvement in housing investments in order to academically and practically improve the effectiveness of the findings of this study. Table 8.3 below shows the final sample and profile of the participants in terms of their organisations and roles.

Table 8.3: Profile of the Validation Participants

Participant	Organisation	Role
V01	Construction firm	Director of Development & Planning
V02	Construction firm	Director of Performance Valuation
V03	Architectural & Design firm	Chairman of the Board
V04	Architecture department	Lecturer
V05	Construction Management department	Lecturer

8.2.4 Validation Process

Once the agreement to participate was received, participants were provided with the interview agenda along with all relevant information regarding research problem, data collection methods and the findings obtained through the previous stages of study, so as to ensure that they had sufficient familiarity with the subject of research. A pre-dialogue meeting has been held in most cases to talk about the relevant study issues and to clarify what is needed during the validation phase. After this phase, the arrangement to conduct the interviews was made via email communication with every subject. Each participant was interviewed by telephone for about 30 minutes at a convenient time. Interviews were recorded and transcribed. The interviews with the local participants were conducted in Arabic. Therefore, a translation of their responses was required. Using the thematic analysis approach, the data collected from the semi- structured telephone interviews were finally analysed. The forthcoming section presents the analysis results of the interviewees' responses, supported with appropriate associated quotations based on the main identified themes.

8.3 Results from the Validation

The validation interviews sought to validate the Sustainability Index model developed for housing projects and reported in Chapters 6 and 7. In carrying out the interviews as early detailed, the researcher examined in detail whether the model is comprehensive, precise, applicable and feasible.

The first stage in the process was to evaluate "*Whether the model is clear and understandable to the stakeholders*". The aim was to identify the extent the model is clear in terms of structure, general outlook, weighting approach, rating benchmarks, terms used, title, etc. In this regard, most experts found the model clear enough and simple to understand. Expert V01 clearly avowed and put an obvious sign:

> *"I like the way you presented the model and the link between the criterions and the categories" (V01).*

Yet, a local participant was concerned about the comprehension of some users as they may not quite speak English, requested an Arabic translation of the model. Interviewee V02 suggested:

> *"I think... by the way, actually it was quite understandable for me, but if the purpose to be involved into the Libyan context I think it is important to give an Arabic version of this model, as you know not all users can understand English" (V02).*

In terms of the set of features examined, the majority of the respondents did not consider the inclusion of 43 criterion of sustainability problems, although expert V03 suggested that some terms such as 'Greywater' might be more preferable if replaced with 'Sanitary System':

> *"It really looks great. . . it is broad, covering almost everything, … but I think you can use the term Sanitary System rather than 'Grey Water', it's up to you but I see it would look more proper to me". (V03)*

The various weighting systems and rating benchmarks were appropriate for evaluating the selection criteria. The scale for the rating of the methods was also appropriate. However, the raised concerns were related to the comparison technique adopted in the model on a pair basis. Expert V04 opined that:

> *"… the pairwise comparison used to facilitate the experts' judgments in AHP seems to be to some extent, ambiguous, as the weights are determined so that it might be meaningless" (V04)*

However, the researcher agreed with this in principle, but considered the weightings to be ideally robust, needing a sense of objectivity to be more meaningful.

In terms of the title suggested for the developed model, again, expert Vo1 seemed not quite satisfied with the acronym used, he suggested that:

> *"… just one simple note on the acronym used, 'LSHAM' don't you think it's a bit weird, sorry but it seems too similar to word 'shame'… I'd rather use words such as 'system' or 'index' instead of model, so this will make it more appropriate and catchier" (V01)*

With regard to the colours used to display each component in the model, the expert V03 requested the use of lighter colours as he comments:

> *"I see, the colours used are extremely heavy, as you see (laughing and referring to his shirt) I always prefer brighter colours. … it would be better" (V03).*

Finally, expert V01 suggested the need for guidelines to describe how each criterion should be assessed. He also suggested that definitions of terms used in the model should be provided, stating:

> *"I think it will be very useful if you give a clear definition to each criterion you used in the model, this will extremely help decision makers or assessors to understand the tool and thereby gaining better outputs" (V01).*

In the second investigation "*Whether the index captured all important sustainability features required for public housing sector*" the aim was to examine whether the adopted criterion efficiently addressed the true complexity of sustainability related to the housing investments. In this regard, the experts considered the model to be accurate and detailed, addressing all relevant criteria for the assessment of sustainability in housing projects. Three participants were interested in evaluating the seven dimensions of sustainability in housing projects and expressed the importance of this criterion, not only in order to improve the environmental and economic aspects, but also it is importance in improving the health and well-being of occupants.

> *"This is very good classification divided into seven themes. The categories of sustainability identified for me, I can say, are inclusively representative, they cover all aspects that one might think of, it even gave spaces to my bicycle (laughing)... really it covers...". (V01)*

> *"It's good set of criteria I think they help to assess and improve housing quality in the local communities, and I think they would meet the homeowners' expectations". (V01)*

> *"... it seems very broad, very rigorous, nothing to say it brought everything in one. I really like it... it seems also balanced and deeply assessing areas from various aspects". (V05)*

Expert V03 was interested in the development of a sustainability assessment tool in general as a starting point for shaping an ideal practice that enables providers to efficiently design and implement their projects. He says:

> *"I think it is very true that projects need a sort of model helping decision making process to meet the expectations not only with money considerations but also by enhancing the environmental and social performance" (V03).*

Precisely, expert V04 advocates the necessity to evaluate the categories of Health and Wellbeing and Location Quality as two key features if the sustainability is to be achieved, he critically avowed:

> *"... obviously, what is more catching in the set of categories, the consideration given to these aspects [i.e. assessing health & wellbeing and location quality] they are very important categories not only to improve the social values but also to increase occupants' satisfaction in our communities, from my side, they're beyond the success achieved" (V01).*

The third area of exploration sought to collect the experts' views on "*Whether the model is applicable in reality or what are potential difficulties in its implementations*". The objective was to examine the extent to which the participants believed that the proposed criteria in each category were applicable in practice. Interesting discussion emerged on the possibilities to implement the developed model together with a discussion on possible difficulties might be faced. Expert V01 agrees that the model for assessing the complexity of sustainability in housing projects is clear and easy to use:

> *"Yes, it has covered a wide range of aspects of sustainability assessment in a clear and logical manner, I think, it would not be difficult to apply in practice" (V01).*

Interviewee V05 comments on the possible limitations, suggesting that the collection and scoring of data against some of the identified criteria may present problems:

> *"Gathering the desired data is always a matter, some of the identified criteria are highly depend on information from different sources such as transportation networks, water supplier, nature risks, etc. all these could cause difficulties". (V05)*

Whilst expert V04 questioned the applicability of the proposed criterion for the shape of sustainability for the quality of the location as it has complex relationships with development and infrastructure. In such reality, he opined that the criterion of sustainability would be very varied, with issues such as community service or transportation:

> *"… to some extent, the criterion might be disparate based on the development of the intended district so some urban areas and will take advantages in relation to the location quality, for example" (V03).*

Subjectivity is another concerning issue triggered from one of the experts. Expert V04, from one of the UK's universities, opines that the model seems to be subjective in many areas of its approach. He instead suggests that the model should be aligned with the set of verified standards, thus giving the model a sense of objectivity.

> *"Maybe, the subjectivity of some of the criterion of sustainability would be a major concern to its implementation. … This is true a common barrier, however if the authorities such as Housing authority adopts a range of standards, this can be extremely helpful" (V04).*

Accordingly, a possible solution, suggested by interviewer V01, identified some potential opportunities helping to effectively embed the model into the existing systems. He opined: there would be a possibility to make the index more powerful by aligning it to the Urban Planning Regulation (UPR), this allows it to be a part of the agenda for assessing the new housing investments. Another practical suggestion from interviewee V05 was that the model should be computerised to improve its use:

> *"From my point of view, it would be much better if it was presented with software so this will help the users and will be easy to communicate with the relevant stakeholders" (V05)*

However, final comment was expressed by expert V02 who concludes that:

> *"… I can see some of the content seem to be assessed subjectively… it seems unavoidable, but this not to say it's not applicable, … I think, it is useable, this industry [housing sector] is quite often criticised as following financial based approach in evaluation of their investments. Adopting this [model] will undoubtedly raise the value of homeowners' satisfaction. Honestly, I highly recommend it" (V02).*

The major final query was "*Whether the model would assist in enhancing the current practice of the public housing sector*". The objective was to examine the extent to which respondents believed that the model would improve the sustainability practice in the housing sector. In their view, participants reached close consensus that the model provides a positive opportunity to shape sustainable homes. It also reorients the decision-making process towards more sustainability-based approach in assessing their investments. The opinions of the experts were in favour of that the model would be a valuable tool for assessing sustainable homes. An obvious opinion was voiced by Expert V03, who again referred to the real need for such an evaluation tool in practice. This evaluation was outlined in the literature review and in the interview with the focus group:

> *"… it's timely and responsive, indeed, we [sector]need such a paradigm shift from scheme limited to financial appraisal to a contrastive sustainability tool. I think this [model] to far extent, can achieve these targets" (V03)*

The value of the developed model also, confirmed through the opinion of interviewee V01 and V02, who were impressed with the model:

> *"Yes, the model is really interesting. I am quite impressed. … I think this will add value to the industry, and I expected, it will highly contribute to the development of the housing sector". (V01)*

> *"Frankly, the housing sector particularly is looking forward to adopting a range of criteria guiding the assessment process in relation to embedding the concept of sustainability in practice" (V02).*

Expert V05 in turn, supports the growing consensus declaring that the developed model can make a significant contribution to practice, he raised the importance of overarching scheme in assessing the housing investments and establishing the regeneration homes that meet the residentials' expectations whilst not threaten the environment:

> *"… when we're looking at regenerations, investment decisions should be made not only on the basis of monetary considerations, so obviously multiple dimensions approach can make a big difference"*

Finally, Expert V04 regretfully opined that the developed model would make a significant contribution to practice:

> *"One thing I cannot get over, is when we [sector] have all of these mechanisms provided from local experts, why we cannot drive the wheel of development forward, … but again I hope I can see these attempts take place in our country" (V04).*

8.4 Overview of the Findings from Validation

In light of the results obtained from the analysis of validation investigation, it must be acknowledged that the developed model has clearly proven meaningful and capable of reflecting the complexity of sustainability experienced in the public housing sector. The developed model was also supported as being applicable in practice and can make exceptional difference in public housing sector. However, further refinements were suggested by group expert involved in the validation process, these amendments to the developed model are listed as follows:

1. Refine the title;
2. Refine the colour;
3. Substitute some criterion terms;
4. Translate the model into Arabic;
5. Prepare detailed guidelines to the model; and,
6. Develop software that facilitates the model application.

Responding to these suggestions, the researcher recognised the queries 1-3 within this thesis, whilst recommendation 4 was attached in Appendix 6. The fifth suggestion has been done but due to size restrictions it was excluded, yet a detailed discussion of all the identified parameters has been provided in Section 6.4 (p.172). However, the last query has been done and will be presented in the section which follows.

8.5 Computerising LSHAS Model

A computer base program has been established to calculate the overall score of the LSHAS model (see Figure 8.1). The main excel sheet includes project information, site, location and 43 bespoke parameters assigned with its relative weight displayed in the seven sections (i.e. Management and Process; Material Efficiency; Energy Efficiency; Water Efficiency; Waste & Pollution; Health & Wellbeing; Location Quality). As detailed in Section 7.5 (p.237), the total result of each criteria is achieved from multiplying the score of each criterion (using a three-ordinal scale (0 ; ½ ; 1) by the 'credits' granted. The sum of each section comes from calculating these results of all parameters included. The total result in each category appears on the program screen which comes from multiplying the sum each section by its corresponding weighting coefficient. This represents finally, the contribution of each section into the overall score which is shown in the bottom of the result sheet. Moreover, the project performance can be displayed graphically showing the overall score as well as the results achieved in each category. in LSHAS the overall score is expressed as 100% through 6 different rating benchmarks levels (UNCLASSIFIED; PASS; BRONZE; SILVER; GOLD; DIAMOND), see Section 7.4.2 (p.237) for a detailed discussion. Figure 8.1 shows an example of the result sheet generating from the computer base LSHAS program.

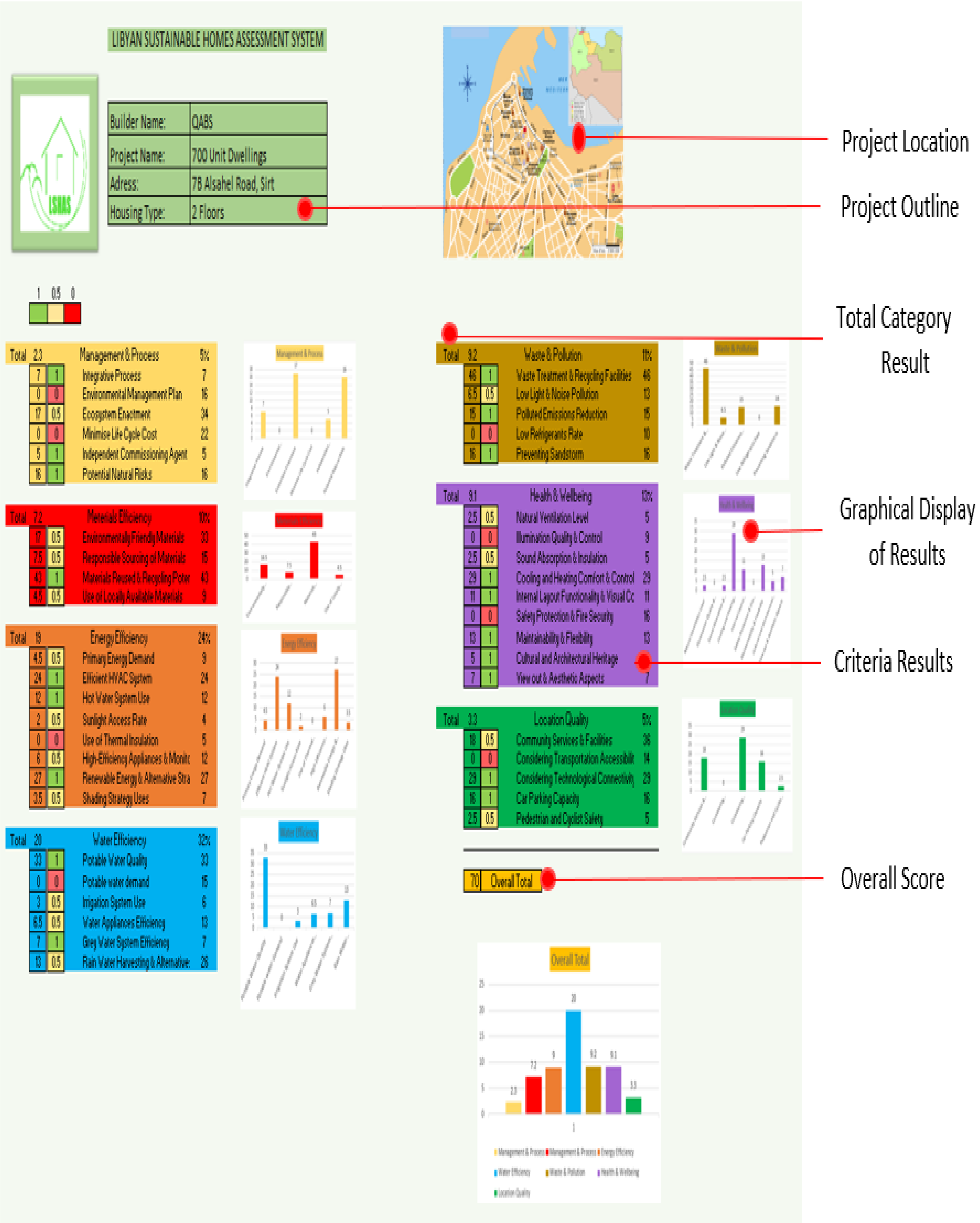


Figure 8.1: LSHAS Software – An Example of the Result Sheet

8.6 Chapter Summary

This chapter reports the validation stage, which has been conducted with the primary objective of critically investigating the model developed. A small-scale interview with group expert was conducted to infer their knowledges and experiences with regard to the working in public housing. The experts' opinions on the comprehension of the model, its precision, applicability, and feasibility have shown a very high degree of consensus in favour of the developed model. they state that the model is a positive contribution to the field of sustainable development in the public housing sector. The review indicates that the comprehensive set of the identified criteria were at the heart of the desired appraisal that the housing sector aims to achieve. It was further demonstrated that the developed model is clear and simple enough to be easily applied in practice with a high range of benefits for the regeneration housing. The research journey, the response to each objective, and the intended implications along with future orientations in research are to be at the heart of the subsequent and final chapter in this thesis.

9 Conclusions

9.1 Chapter Overview

The study used a mixed approach to address the research problem related to the development of an applicable evaluation model to handle sustainability issues in the public homes of Libya. A five-fold objective has been set to serve the central aim of research. This chapter brings together the results of the research and concludes them. It also revisits the research objectives and how they have been achieved. Further, this chapter highlights the contribution of the study to the existing knowledge and states the limitations of the study. Finally, it offers recommendations for the key parties that are likely to advance the sustainable homes agenda and suggests for further work that have emerged as a result of the findings of this study.

9.2 Concluding Remarks

The research journey has passed through numbers of steppingstones (see figure 9.1 below). This study has evolved around the concept of sustainable development in the scope of housing investments. The study argued that the evaluation of housing projects is predominated by monetary approach with a clear avoidance of overarching appraisal covering environmental and social aspects. It is also argued that the leading Sustainability Assessment Models (SAMs), such as BREEAM and LEED, have not been adequately adapted to the specific political, environmental and social characteristics and context of the Libyan environment. This includes recognition of regional variations, restrictions on available resources, local architecture, specific environmental conditions and other socio-cultural and economic variables. The focal research was the lack of development of an assessment model to assist decision makers in addressing sustainability issues in public homes in the Libyan context. In light of this, the research objectives were crystallised in a five-fold objective, utilising a mixed methodology approach to obtain the ideal investigation on these objectives. The relevant literature was critically reviewed, providing a rigorous platform to build a broad theoretical framework of the study which, in turn, has rationally guided the empirical phase. Four well-established SAMs have been analysed, led to proposing a framework for assessing sustainability in housing investments. The theoretical framework structured through reviewing the body of literature was developed through organising a focus group interview with qualified experts before conducting a rigorous questionnaire survey with a wide range of professionals, administrators and academics. The emergent model consists of 43 criteria groped into 7 main categories namely: (i) Management and Process; (ii) Materials Efficiency; (iii) Energy Efficiency; (iv) Water Efficiency; (v) Waste and Pollution; (vi) Health and Wellbeing; (vii) Location Quality. The ranking system of the proposed model was developed by employing AHP technique. Finally, the findings were validated through a small-scale interview before the ultimate results and recommendations obtained in the end of this research journey.

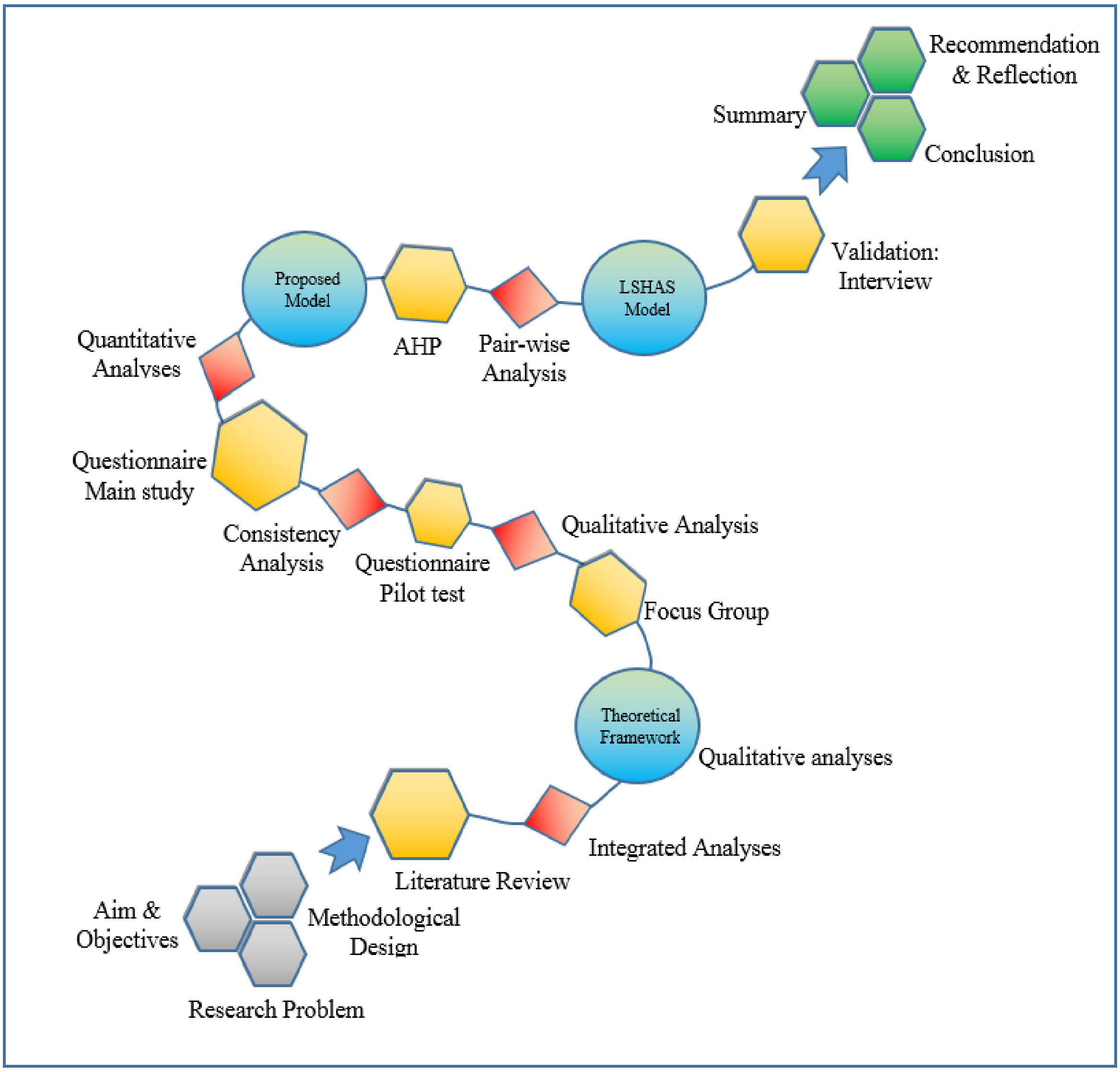


Figure 9.1: Research Journey

9.3 Review of Aim and Objectives

As mentioned in Chapter 1, the purpose of the thesis was to achieve five objectives. The research fulfilled the objectives outlined at the beginning, thus achieving the main aim of this study. First, it was necessary to fully understand what sustainability is and which considerations (social, economic and environmental) should be addressed in the housing project. Once the considerations are identified, there was also a question to investigate the genuine need for developing an applicable sustainability-based assessment tool in housing sector and the impact of such absence (objective 1). Moreover, there is a need to identify a theoretical framework to facilitate the empirical stage. This was accomplished by conducting an integrated analysis of four leading international models (i.e. BREEAM, LEED, GBSA and DGNB), resulting in a set of more likely applicable categories and criteria (objective 2). To examine the defined set criteria, focus group interview was conducted with acknowledged experts. This was followed by conducting a questionnaire in order to establish reliability for the emergent model (objective 3). The developed model was ranked by using AHP technique in order to obtain overall value that can benchmark with alternatives through the decision-making process (objective 4). Eventually, there was a need for refining the developed model with the ranking system through facilitating interviews with qualified experts from housing sector (objective 5). The objectives of the research have been achieved along with the aim of the study (as shown throughout this thesis). More details upon the achievements of the fivefold objective are presented in the following.

9.3.1 The Achievement of First Objective

To critically review the perceived importance of sustainability together with the current sustainability assessment methods for housing investments.

The comprehensive literature review in Chapter 2 evaluated the sustainable development and sustainable homes. The review of the literature identified the perception of sustainable development in the built environment and in particular in the housing sector. The literature review also examined the international orientation of the concept of sustainability and reported how the early concerns for the global environment constituted an international acceptance of the definition of sustainability by the WCED "World Commission on Environment and Development," which included social, economic and environmental dimensions. The literature shows that construction plays an important role in environmental degradation through on-site construction and energy consumption during occupancy. The literature identified a significant gap between the sustainability view promoted by various organizations, including the UNDESA "Department of Economic and Social Affairs of the United Nations" and the CEN "European Standardization Committee," and the sustainability practice reflected in the housing sector. However, the literature has shown that the need for designing sustainability is gaining an increasing interest, whilst investment decisions are rarely single-dimensional, since assessment tools applied such as Life Cycle Cost (LCC) analysis does not fully capture the complex nature of the environment. The literature also revealed that, in many construction companies, the concept of sustainability is now the norm, but they have not fully complied with environmental and social policies and practices. Thus, they need to improve their image and show greater commitment to the principles and regulations of sustainable development. Therefore, additional gaps have been identified in the adoption of a monetary-based approach to evaluate investments, as the project-level decision support system appears to lack a comprehensive evaluation tool that can guide and optimise the targeted performance. The literature also revealed that despite the various attempts to overcome these difficulties, reported in the literature, a paradigm shift remains necessary to bridge these gaps by defining what sustainability means for a project, while at the same time, providing reliable assessment systems in order to allow the expert's professional judgment to be clearly and understandably presented.

9.3.2 The Achievement of Second Objective

To analyse categories and criteria of well-established sustainability-based assessment methods to set the foundation for a new insight of a proposed model.

The integrated analysis of the leading sustainability models (i.e. BREEAM, LEED, GBSA and DGNB) has been carried out and reported in Chapter 3. The review of the SAMs led to several advantages of this research. First, understanding sustainable evaluation method and rating system has led to the identification of weaknesses in existing and leading well-established methods. The literature has shown that the pre-vailing methods of assessment (e.g. BREEAM, LEED) are not applicable to the assessment of the built environment in Libya. The literature defined a range of shortcomings in the recognition of regional variations, including restrictions on available resources, local architecture, specific environmental conditions and other economic and socio-cultural factors. A multi-dimensional evaluation model is required to effectively assess material sustainability, as derived from the literature. Furthermore, the integrated analysis was an ideal instrument in providing a solid basis of the emerged theoretical framework, providing the most applicable criteria for assessing sustainability in the Libyan housing sector by which the claimed weaknesses are more likely to be overcome. The integrative analysis of four schemes resulted in a theoretical framework from which a range of 45 nodes were emerged, split down into seven principle clusters of sustainability, namely: (i) Management and Process; (ii) Materials Efficiency; (iii) Energy Efficiency; (iv) Water Efficiency; (v) Waste and Pollution; (vi) Health and Wellbeing; (vii) Location Quality.

9.3.3 The Achievement of Third Objective

To customize applicable categories and criteria that constitute the main characteristics of sustainability in Libya's housing investments.

To meet this objective, an empirical study was carried out using an interview with a focus group followed by a questionnaire, which was extensively covered in Chapter 6. The focus group interview has been conducted with five acknowledged experts, representing the housing associations and providers, and local authorities. The principle purpose of conducting focus group was to obtain the most applicable set of criteria to assist in assessing sustainability features in the public housing projects in Libya. However, the focus group confirmed previous findings from literature that housing projects in Libya claim to take a high level of responsibility for the adverse environmental impact of their activities and how the decision support systems contribute to satisfy this. The focus group has shown that decision-makers in the Libyan housing sector continue to support the use of financial assessment schemes for investment evaluation. In relation to the core aim of conducting focus group, the theoretical framework was refined in order to present an updating view of sustainability, which was considered the most applicable criterion in the Libyan environment. In addition, the expert group has recognised five innovative criteria which were not thought of within the given proposal framework whilst potentially believed that they will optimise decision support systems in public housing projects in favour of sustainability performance. This includes 'Shading Strategy Uses', 'Potable Water Quality', 'Rainwater Harvesting and Alternatives', 'Preventing Sandstorm Strategy', and 'Technological connectivity consideration'. Ultimately, panellists have showed consensus upon 43 separate nodes, again grouped into seven key clusters, which are more likely to adequately react the concept of sustainability in housing sector.

Following the focus group, a questionnaire was conducted to establish reliability for the emergent model. This further investigation employed a large-scale questionnaire with a wide range of professionals, administrators and academics who are involved in the housing sector. The questionnaire was aimed to engage as many as possible with the relevant stakeholders and obtain the agreement of participants on the applicable assessment categories and criteria which resulted of both integrative analysis of the four-leading models (i.e. BREEAM; LEED; GBSA; DGNB) and the consensus raised from the panellists of the focus group. The results of the questionnaire have showed that all criteria were scored with "Important" or "Extremely Important" levels, which clearly approve how significance the criteria identified to shape sustainability in assessing home projects are. The results have provided further evidence to argue that the housing sector should focus on the performance that ensures energy and water efficiency as the two top priorities in the way to embedding sustainability in housing investments.

9.3.4 The Achievement of Fourth Objective

To determine the weighting coefficient for the customised model that ensures prioritising its main categories and criteria based on the specifications of Libyan context.

With reference to the deficiency of SAMs and the need for an applicable sustainability-based assessment tool in the literature, a Composite Index for sustainable homes compassing a multi criteria for assessing sustainability in housing investments have been developed and presented in Chapter 7. The criteria, in fact, have emerged earlier through an integrated analysis, focus group and questionnaire. Based on structured interview, the emergent model of sustainability was ranked using AHP technique to be incorporated in a Composite Index. AHP as an effective technique, supporting a multi-criteria decision-making approach and allowing users to model a complex problem in a hierarchical structure by converting the research problem's subjectivity into a mathematical form. AHP in this sense was facilitated to develop a customised weighting system for Libyan Sustainable Housing Assessment System (LSHAS) and obtain an overall value that can be benchmarked with alternative investment options in way which allows to optimise the decision support systems in housing sectors. The results of the AHP process represent the establishment of a customized weighting system that reacted to the importance of each criterion and category, with the highest priority given to water and energy efficiency among the seven sustainability clusters in the context of Libya's built environment. The results of the AHP have shown the percentage weights for each category: Water efficiency (32 percent), Energy efficiency (24 percent), Health and Well-being (13 percent), Waste and Pollution (11 percent), Materials Efficiency (10 percent), Location Quality (5 percent), Management and Process (5 percent). For more details on the criteria's resulting weights, see Table 7.11 (p.236).

9.3.5 The Achievement of Fifth objective

To refine the developed assessment model for sustainable homes and provide recommendations for further development.

The ultimate goal of this research was to test the effectiveness and usefulness of the LSHAS model by conducting a small interview with senior Practitioners and Academics involved to the housing industry. The views of experts on the comprehension of the model, its precision, applicability, and feasibility have shown a very high degree of consensus in favour of the developed model, stating that the model is a positive contribution to the area of sustainable development in the public housing sector. The review has exhibited that the comprehensive set of criteria identified were at the heart of the housing sector's desired interventions. The results show that the model is applicable and effective in aggregating the attribute of sustainability into a Composite Sustainability Index. The developed model is also capable of ranking sustainability features and in obtaining a single comparable value, that is, more likely to optimise housing project decision support systems. The developed model has also been proven to be clear and simple enough to be easily applied in practice with a wide range of benefits for regeneration housing.

9.4 The Contributions of the Study

This thesis makes a threefold contribution to the existing body of knowledge: Theoretical, methodological and practical, as discussed below.

9.4.1 Theoretical Contributions

By addressing the significant gaps in research that have not yet been addressed, this study contributes to the academic area. Yet extensive studies (e.g. Shawesh, 2016; 2000; Ali *et al*., 2011; Amer, 2007; El-Hasia, 2005; Abbas, 1997) focus on the development issues for the Libyan built environment, only a few researches have addressed the specific aspects relevant to housing sustainability for the Libya context. In addition, although some publications (e.g. Elgadi *et al*., 2016; Almansuri *et al*., 2009) have highlighted many useful sustainability principles in general, the extent to which sustainability is incorporated into housing projects has not been fully assessed. The need for research to investigate a set of standards for sustainable buildings in the Libyan context has been emphasized by a number of authors including, Elgadi *et al.* (2016), Shibani and Gherbal (2016) and Almansuri *et al*. (2009) who have corroborated previous studies from Ngab (2007), and El-Hasia (2005). The developed model has highlighted all the criteria which are most capable of assessing sustainability in housing projects. Areas of sustainability which received insufficient attention have been highlighted, including sustainability criteria such as 'Shading Strategy Uses', 'Potable Water Quality', 'Rainwater Harvesting and Alternatives', 'Preventing Sandstorm Strategy', and 'Technological connectivity consideration'. The research has therefore extended the existing knowledge of sustainability practice in the housing sector by developing an understanding of the assessment characteristics to be carried out in the decision-making process. It has also extended the earlier work of Elgadi *et al.* (2016) Mohamed (2013) and Almansuri *et al*. (2009) in terms of developing a sustainability-based scheme to assist decision makers in the evaluation of the housing investment. Thus, this, in fact, has broadened our horizons from merely finance-based appraisal to an overarching perspective of the main social, economic and environmental characteristics in the evaluation of the housing investment.

9.4.2 Methodological Contributions

The contribution in relation to the methodologies has mainly been structured through the adoption of triangulating methods. Yet, triangulation considerations facilitate convergence in the findings and can therefore improve the reliability and the validity of the results. It is often shown that management researchers tend to compromise triangulations-related issues (Bryman & Bell, 2015). The powerfulness and robustness of the research might be significantly affected by failing to triangulate. For this study, efforts have been made to overcome the failure to triangulate the research into construction management. The triangulation considerations thus, have been utilised within and across the adopted methodological approaches. This can be demonstrated by using more than one method and technique to achieve the research goals. The criteria and categories identified, which constituted the developed model, were established using several stages and resources. These include integrated analysis, interview with the focus group and questionnaire. The other way in which this study made triangulation was through data collection by means of recruiting a wide variety of participants through conducting either focus group interview or questionnaire. This spectrum of responses represents a range of stakeholders including professionals, administrators and academics. By following this technique, the researcher can engage with different views and perceptions which ultimately have been reflected in the results obtained.

9.4.3 Practical Contributions

The significant contribution of this research is the practical one, which has been made through developing the Composite Index for the evaluation of sustainable features in housing investments. This research satisfies the need for a useful assessment scheme to integrate sustainability in a meaningful way. This has been emphasised by a number of authors including Elgadi *et al.* (2016), Shibani and Gherbal (2016) and Almansuri *et al.* (2009). The research addresses this need by developing a Composite Index to provide a comprehensive set of practical sustainability features. This index consists of 43 nodes grouped into seven core sustainability features, which are the most relevant attributes capable of responding to the Libyan environment. The identification of these characteristics provides an in-depth understanding of sustainable development in relation to investment in housing. Whilst they are not considered in other schemes, the developed model has identified the most important sustainability characteristics that need to be assessed when making decisions on investment assessment for housing projects in Libya based on sustainability. As earlier mentioned, this includes 'Shading Strategy Uses', 'Potable Water Quality', 'Rainwater Harvesting and Alternatives', 'Preventing Sandstorm Strategy', and 'Technological connectivity consideration'. Further, the output Composite Index is dissimilar to some international models (e.g. BREEM; LEED). It is transparent and presents an adequate weighting system that effectively react to the local specifications. As demonstrated earlier, and for validation purpose, the final Composite Index has been subjected to group expert scrutiny through the validating interview, recruiting five senior Practitioners and Academics to test its applicability for practical use. Guidance demonstrating how potential users can apply the Sustainability Index in the decision support systems to evaluate alternatives in housing investments have also been provided to ease the application of this scheme. The developed model is designed to optimise the decision support systems through the evaluation of the proposal investments and options. The developed model is distinguished as moving away from the dominant financial appraisal to investments towards a comprehensive approach. The Composite Sustainability Index for the evaluation of sustainable homes has been developed to fill this gap in practice, supporting decision-makers in their overall vision of their investments. It allows housing investors to evaluate and weight subjective sustainability elements when these scores are translated into a Sustainability Index. The LSHAS scheme will enable the public housing sector to reorient investments in a way that achieves both value for money and raises sustainability principles. LSHAS has the potential to effectively enhance how Professionals deal with sustainability by offering a structured method to the evaluation of sustainable features in their projects. Sustainability can be more effectively integrated into public housing projects, which are considered to be an important in the construction industry. Thus, the scheme has such a crucial role to play in helping the industry as a whole to become more sustainable. Establishing a benchmarking scheme for the housing sectors is also an important aspect which can be facilitated through such an assessment method in order to assess their sustainability performance. The development of industry benchmarks depends heavily on the co-operation of industry practitioners. The sector can therefore become more aware of the benefits of research and promote more practice sustainability. The development of the Sustainability Index, therefore, will help to make better decisions as sustainability issues are successfully measured and incorporated into the decision support systems. There is no doubt, therefore, that a better decision can be taken as long as the overall quality of the built environment is improved. Against this great influence, it is evident that the development of the Sustainability Index demonstrates a significant contribution to the improvement and implementation of sustainable development and shows a way to bridge the gap between the current practice of evaluating the assessment of housing and the requirements for sustainability.

9.5 Limitations of the Study

It is clearly obvious that the research findings are useful for housing practitioners to help them incorporate sustainability into their projects. However, there seems to be a range of limitations associated with the study at hand. First of all, there is an issue related to the bases of establishing the key sustainability criteria which derived from an integrative analysis of four well-known tools (i.e. BREEAM, LEED, GBSA and DGNB). Yet these leading models are well established and internationally recognised, the research results may be influenced by these systems. As such, further work might be beneficial if it elaborates on the model by involving wider resources. In addition, the researcher has aggregated a wide range of analogous criteria in one term. However, there are two reasons behind this. First, yet, the researcher considered his role as a moderator to involve minimal interference with the research process, the reduction of the list of nodes was obtained as a result of a rigorous integrated analysis. It was estimated that this would help the panellists to focus more on viability and to be less confused with duplicated factors. Secondly, the researcher considered that any list of factors resulting from the analysis would be validated during the subsequent research stages. Moreover, there is a limitation in relation to the number of interviewees within focus group. Five qualified experts were recruited, covering housing associations, providers and local authorities. There are two main reasons for the limited number of interviewees. First, specific sustainability expertise in the housing sector was required for the type of information needed. As a result, it was difficult to find many qualified panellists for the purpose of study. Second, since the interviewees focused on confirming the results obtained from the integrative analysis, the panellists' main mission was to examine the identified theoretical framework and refine the results. It is also recognised that there are shortcomings in the questionnaire sampling strategy. In this case, the survey participants were derived from a purposive sampling of practitioners, administrators and academics to create a composite sample. However, this method of sampling does not include key stakeholders such as the client and marketing representative, which to some extent this might alleviate the preventiveness. Last but not least, there were temporal and funding constraints. However, it is acknowledged that these limitations are not compromising the value of the study, rather it simply gives scope to further research.

9.6 Recommendations and Scope for Further Work

The development of a Composite Sustainability Index with a weighting system was the core aim of the study. While the research journey arrived its distance at this edge, a series of recommendations on empowering LSHAS in practice have been raised. Further work has been suggested to leave doors open of research opportunities in numerous areas of development. The recommendations have been encapsulated in the following subsection.

9.6.1 Recommendations

- ® The government parties and housing associations are probably the ones who are most capable to advancing the regeneration agenda and promoting sustainable home codes such as LSHAS in order to optimise sustainability performance among housing sectors.

- ® Local authorities have the option of inviting bidders for partnerships to include optional and priced proposals in their offers, in which LSHAS's sustainability issues could be incorporated.

- ® Sustainability values can be integrated into educational curricula, along with providing training on sustainability issues. This facilitates the understanding of the concept and provides simpler guidance, such as LSHAS. It can have a positive impact on people's attitudes to sustainability and can stimulate the demand for sustainable products from users.

- ® Sustainability evaluators working on LSHAS should be qualified with a solid background in the development of sustainability to ensure that the evaluation process reflects the real performance of sustainability.

- ® Sustainability assessment methods such as LSHAS are quite often subjected to regular updating review and revision; either annually or every two years in order to meet the rapid change and satisfy the desired development.

- ® It is not recommended to impose prerequisite criteria through the promotion phase of LSHAS. After being extensively used, a set of prerequisite criteria can be identified to maintain more robustness and reliability of the scheme.

9.6.2 Calling for Further Work

- © An important question remains open concerning the implementation of sustainability codes. It is suggested that further research on how to promote and embed the sustainability-based criteria for Libyan housing projects is highly recommended in this context.

- © As described in the research limitation Section, the scope of this research was initially based on integrative analysis of well-known assessment tools (i.e. BREEAM; LEED; GBSA; DGNB). The potential research might be beneficial if it employs a wider range of resources or adopting different methods.

- © It is suggested that further research that allows effective engagement with the key stakeholders such as clients marketing representatives is recommended.

- © It is hoped that the developed model of LSHAS can be further improved and computerised through extending work. This would highly facilitate the use of LSHAS code for public housing investments.

- © It is of greater importance for the Sustainability Index to be examined on different types of construction. The weighting system of the developed model was based on the housing buildings. Further research can be carried out to explore the changes in this model in the context of their impact on various types of buildings. The Composite Index is important in all types of building as a comprehensive guidance towards more sustainable built environment.

- This LSHAS scheme was designed to specifically shape sustainable homes. Thus, further research on similar schemes for the development of urban development sustainability codes, such as schools or hospitals, etc., is recommended.

- Since the design of LSHAS applicability is limited to a typical public house, further research on the assessment of sustainability in different sizes and types of homes is also recommended. This is particularly important for large-scale infrastructure projects that are more likely to cause environmental degradation.

- The literature review considers that environmentally friendly materials are more expensive than conventional assets. This means that the cost reduction remains an essential necessity to ensure sufficiently incorporating sustainability into housing investments. Further research needs to be carried out to investigate this perception and recommend a range of measures that foster the movement towards environmentally friendly homes that are affordable.

- Finally, the research area can be expanded to investigate countries other than Libya and to conduct international comparisons. This can draw an interesting benchmark whilst consolidates the robustness of the adopted methodology.

Word Count

Excluding 11,220 words of front matter and ancillary data (allowable under the regulations), references and appendices, the total word count for the PhD thesis is 90,406 words (< the 100,000-size restriction).

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Appendix 1: BREEAM Categories & Criteria

BREEAM Categories & Criteria "The Code for Sustainable Homes"					WF
	Energy & CO2 emission			31	36.4
1		Dwelling Emission Rate	10		
2		Fabric energy efficiency	9		
3		Energy display devices	2		
4		Drying Space	1		
5		Energy Labelled White Goods	2		
6		External Lighting	2		
7		Low or Zero Carbon (LZC) Technology	2		
8		Cycle Storage	2		
9		Home Office	1		
	Water			6	9.0
10		Internal Water Use	5		
11		External Water Use	1		
	Material			24	7.2
12		Environmental Impact of Material	15		
13		Reasonable sourcing of Material – Building Elements	6		
14		Reasonable sourcing of Material – Fishing Elements	3		
	Surface water Run-Off			4	2.2
15		Management of Surface Water Run-Off Developments	2		
16		Food Risk	2		
	Waste			8	6.4
17		Storage of Non-recyclable waste and Recyclable Household Waste	4		
18		Construction Waste Management	3		
19		Composting	1		
	Pollution			4	2.8
20		Global Warming Potential (GWP) of Insulants	1		
21		NO_x Emissions	3		
	Health & wellbeing			12	14.0
22		Daylighting	3		
23		Sound Insulation	4		
24		Private Space	1		
25		Life Time Homes	4		
	Management			9	10.0
26		Home User guide	3		
27		Considerate Constrictors Scheme	2		
28		Construction Site Impacts	2		
29		Security	2		
	Ecology			9	12.0
30		Ecological Value of Site	1		
31		Ecological Enactment	1		
32		Protection of Ecological Features	1		
33		Change of Ecological value of Site	4		
34		Building Foot Prints	2		
					100.0

Appendix 2: LEED Categories & Criteria

	LEED Categories and Criteria "LEED for HOMES DESIGN AND CONSTRUCTION (v4)"			
	INTEGRATIVE PROCESS			2
1		Integrative Process	2	
	LOCATIN & TRANSPORTATION			15
2		Floodplain Avoidance	Prer	
3		LEED for Neighbourhood Development	15	
4		Site Selection	8	
5		Compact Development	3	
6		Community Resources	2	
7		Access to Transit	2	
	SUSTAINABLE SITES			7
8		Construction Activity Pollution Prevention	Prer	
9		No Invasive Plants	Prer	
10		Heat Island Reduction	2	
11		Rainwater Management	3	
12		Nontoxic Pest Control	2	
	WATER EFFICIENCY			12
13		Water Metering	Prer	
14		Total Water Use	12	
17		Indoor Water Use	6	
18		Outdoor Water Use	4	
	ENERGY & ATMOSPHERE			38
19		Minimum Energy Performance	Prer	
20		Energy Metering	Prer	
21		Education of Homeowner, Tenant, or Building Manager	Prer	
22		Annual Energy Use	29	
23		Efficient Hot Water Distribution System	5	
24		Advanced Utility Tracking	2	
25		Active Solar-Ready Design	1	
26		HVAC Start-Up Credentialing	1	
27		Home Size	Prer	
28		Building Orientation for Passive Solar	3	
29		Air Infiltration	2	
30		Envelope Insulation	2	
31		Windows	3	
32		Space Heating and Cooling Equipment	4	
33		Heating and Cooling Distribution Systems	3	
34		Efficient Domestic Hot Water Equipment	3	
35		Lighting	2	
36		High-Efficiency Appliances	2	
37		Renewable Energy	4	
	MATERIAL & RESOURCES			10
38		Certified Tropical Wood	Prer	
39		Durability Management	Prer	
40		Durability Management Verification	1	
41		Environmentally Preferable Products	4	
42		Construction Waste Management	3	
43		Material-Efficient Framing	2	
	INDOOR ENVIRONMENTAL QUALITY			16
44		Ventilation	Prer	
45		Combustion Venting	Prer	
46		Garage Pollutant Protection	Prer	
47		Radon-Resistant Construction	Prer	
48		Air Filtering	Prer	
49		Environmental Tobacco Smoke	Prer	
50		Compartmentalization	Prer	
51		Enhanced Ventilation	3	
52		Contaminant Control	2	
53		Balancing of Heating and Cooling Distribution Systems	3	
54		Enhanced Compartmentalization	1	
55		Enhanced Combustion Venting	2	
56		Enhanced Garage Pollutant Protection	2	
57		Low-Emitting Products	3	

	INNOVATION			6
58		Preliminary Rating	Prer	
59		Innovation	5	
60		LEED Accredited Professional	1	
	REGIONAL PRIORITY			4
61		Regional Priority	1	

Appendix 3: GBCA Categories & Criteria

GBCA Categories and Criteria "Design & As Built v1.2"					
	Indoor Environment Quality				23
1		Indoor Air Quality	Ventilation System Attributes	1	
2			Provision of Outdoor Air	2	
3			Exhaust or Elimination of Pollutants	1	
4		Acoustic Comfort	Internal Noise Levels	1	
5			Reverberation	1	
6			Acoustic Separation	1	
7		Lighting Comfort	Minimum Lighting Comfort	Prer	
8			General Illuminance and Glare Reduction	1	
9			Surface Illuminance	1	
10			Localised Lighting Control	1	
11		Visual Comfort	Glare Reduction	Prer	
12			Daylight	2	
13			Views	1	
14		Indoor Pollutants	Paints, Adhesives, Sealants and Carpets	2	
15			Engineered Wood Products	2	
16			Indoor Plants	2	
17		Thermal Comfort	Thermal Comfort	1	
18			Advanced Thermal Comfort	1	
19		Quality of Amenities	Amenity Space – Performance Pathway	1	
20		Ergonomics	Ergonomics Strategy	1	
	Energy				15
21		Greenhouse Gas Emissions	Conditional Requirement: Prescriptive Pathway	Pre	
22			Lighting	3	
23			Ventilation and Air-Conditioning	2	
24			Domestic Hot Water Systems	1	
25			IT Equipment	3	
26			Appliances and Equipment	1	
27			Accredited GreenPower	5	
	Transport				6
28		Sustainable Transport	Access by Public Transport	3	
29			Low Emission Vehicle Infrastructure	1	
30			Active Transport Facilities	1	
31			Walkable Neighbourhoods	1	
	Water				5
32		Potable Water	Sanitary Fixture Efficiency	1	
33			Domestic Appliances Efficiency	1	
34			Commercial or Industrial Appliances	1	
35			Shared Amenities	2	
	Materials				24
36		Life Cycle Assessment	Comparative Life Cycle Assessment	18	
37			Additional Life Cycle Impact Reporting	1	
38		Responsible Building Materials	Timber	1	
39			Permanent Formwork, Cables, Pipes, Floors and Blinds	1	
40		Construction and Demolition Waste	Reduction of Construction and Demolition Waste - Fixed Benchmark	3	
	Emissions				3
41		Light Pollution	Light Pollution to Neighbouring Bodies	Prer	
42			Light Pollution to Night Sky	1	
43		Microbial Control	Legionella Impacts from Cooling Systems	1	
44		Refrigerant Impacts	Refrigerant Impacts	1	
	Innovation				10
45		Innovative Technology or Process	Innovative Technology or Process	2	
46		Market Transformation	Market Transformation	2	
47		Improving on GS Benchmarks	Improving on GBCA Benchmarks	2	
48		Innovation Challenge	Innovation Challenge	2	
49		Global Sustainability	Global Sustainability	2	
	Management				13
50		GS Accredited Professional	Accredited Professional	1	
51		Commissioning and Tuning	Environmental Performance Targets	Prer	
52			Services and Maintainability Review	1	
53			Fitout Commissioning	1	
54			Fitout Systems Tuning	1	

54			Independent Commissioning Agent	1	
55		Fitout Information	Fitout User Information	1	
56		Commitment to Performance	Environmental Fitout Performance	1	
57			End of Life Waste Performance	1	
58			Ongoing Procurement	1	
59		Metering and Monitoring	Metering	Prer	
60			Monitoring System	1	
61		Responsible Construction Practices	Environmental Management Plan (EMP)	Prer	
62			Formalised Environmental Management System (EMS)	1	
63			High Quality Staff Support	1	
64		Operational Waste	Waste in Operations	1	
	Land Use & ecology				9
65		Sustainable Sites	Base Building Sustainability	5	
66			Base Building Cultural Heritage Significance	2	
67			Hazardous Material	2	

Appendix 4: GBCA Categories & Criteria

DGNB categories and Criteria "New buildings criteria set"					W
	Environmental quality	BUILDING LIFE CYCLE ASSESSMENT			8
1			Life cycle assessments in planning	10	
2			Life cycle assessment optimization	8	
3			Life cycle assessment comparison calculation	100	
4			AGENDA 2030 BONUS – CLIMATE PROTECTION GOALS	30	
5			CIRCULAR ECONOMY	V	
6			Halogenated hydrocarbons in refrigerants	2	
		Local environmental impact			4
7			Environmentally friendly materials	110	
		Potable water demand and waste water			2
8			Potable water demand and waste water volume	90	
9			External works	5	
10			Integration into the district infrastructure	5	
		Sustainable resource extraction			2
11			Sustainably produced raw materials	212	
12			Secondary raw materials	200	
		Land use			2
13			Land use	80	
14			Soil sealing factor and/or compensatory measures	20	
		Biodiversity at the site			1
15			Biotope area quality	30	
16			Diversity of animal species in the outdoor area	20	
17			Diversity of animal species on the building itself	20	
18			Invasive plant species	10	
19			Habitat connectivity	10	
20			Development and maintenance care	10	
21			Biodiversity strategy	10	
	Economic quality	Life cycle cost			4
22			Calculations of the life cycle costs in the planning process	10	
23			Life cycle cost optimisation	10	
24			Building-related life cycle costs	80	
		Commercial viability			2
25			Entrance situation, routing and signposting	15	
26			Parking space situation	40	
27			Market characteristics	22.5	
28			Degree of utilisation/units let at the time of completion	15	
		Flexibility and adaptability			3
29			Space efficiency	20	
30			Ceiling height	10	
31			Building depth	10	
32			Floor layout	15	
33			Structure	5	
34			Technical building services	40	
35			CIRCULAR ECONOMY BONUS – HIGH INTENSITY OF USE	10	
	Sociocultural and functional quality	Thermal comfort			4
36			Operative temperature/indoor air temperature/heating period	30	
37			Drafts/heating period	7.5	
38			Radiant temperature asymmetry and floor temperature/heating period	7.5	
39			Relative humidity/heating period (quantitative)	5	
40			Operative temperature/indoor air temperature/cooling period	35	
41			Drafts/cooling period	5	
42			Radiant temperature asymmetry and floor temperature/cooling period	5	
43			Indoor humidity/cooling period	5	
44			AGENDA 2030 BONUS – CLIMATE ADAPTATION	5	
		Indoor air quality			5
45			Indoor air quality – Volatile organic compounds (VOCs)	55	
46			Indoor air quality – Ventilation rate	50	
		Visual comfort			3
47			Availability of daylight for the entire building	40	
48			Visual contact with the outside	20	
49			Daylight colour rendering	20	
50			Exposure to daylight	20	
		User control			2

51			Ventilation	35	
52			Temperatures during the heating period	30	
53			Temperatures outside of the heating period (cooling)	35	
		Quality of indoor and outdoor spaces			2
54			Indoor spaces to facilitate communication	15	
54			Additional provisions for users	15	
55			Family-friendly, child-friendly and senior-citizen-friendly design	20	
56			Quality of interior access and circulation areas	10	
57			Outdoor facility design concept	20	
58			Outdoor areas	25	
59			Fixtures and equipment	10	
		Safety and security			1
60			Subjective perception of safety and protection against assault	30	
		Design for all			4
61			Quality level 1/DGNB minimum requirement	10	
62			Quality level 2	40	
63			Quality level 3	65	
64			Quality level 4	100	
	Technical quality	Sound insulation			3
65			Sound insulation in residential buildings		
		Quality of the building envelope			4
66			Heat transfer	40	
67			Thermal heat bridges	15	
68			Airtightness	60	
69			Summer heat protection	15	
		Use and integration of building technology			3
70			Passive systems	30	
71			Adaptability of the distribution system to suit operating temperatures in order to enable the use of renewable energy	15	
72			Accessibility of the building technology	20	
73			Integrated systems	35	
		Ease of cleaning building			2
74			Accessibility of the exterior glass surfaces	15	
75			Exterior and interior components	10	
76			Floor covering	20	
77			Dirt trap	15	
78			Unobstructed floor plan	20	
79			Surfaces	10	
80			Concept for ensuring ease of cleaning	10	
		Ease of recovery and recycling			4
81			Ease of recycling	45	
82			Ease of recovery	45	
83			Ease of recovery, conversion and recycling in the planning process	10	
		Immissions control			1
84			Noise Emissions – Emissions guide values	70	
85			Light pollution	30	
		Mobility infrastructure			3
86			Bicycle infrastructure	20	
87			Rental systems (public or private)	10	
88			Electromobility	90	
60			User comfort	10	
	Process quality	Comprehensive project brief			3
61			Requirements planning	40	
92			Informing the public	20	
93			Specifications	40	
		Sustainability aspects in tender phase			3
94			Sustainability aspects in tender phase	100	
		Documentation for sustainable management			2
95			Servicing, inspection, operating and upkeep instructions	30	
96			Up-to-date plans	30	
97			Facility management manual	20	
98			Planning with BIM	20	
		Urban planning and design procedure			3
99			Exploration of different design variants or planning competition	95	
100			Recommendations by an independent design committee	15	
101			Award in the form of an architecture prize	100	
102			Exploration of different design variants or planning competition		
		Construction site/construction process			3

103			Low-noise construction site	25	
104			Low-dust construction site	25	
105			Soil and groundwater protection on the construction site	25	
106			Low-waste construction site	25	
		Quality assurance of the construction			3
107			Quality assurance planning	10	
108			Quality control measurements	60	
109			Quality assurance for construction products	20	
110			Mould prevention	10	
		Systematic commissioning			3
111			Monitoring concept	15	
112			Commissioning concept	10	
113			Preliminary function test	10	
116			Function test and training	15	
117			Final report on commissioning	20	
118			Integral operating concept and systematic commissioning	20	
119			Commissioning management	10	
		User communication			2
120			Sustainability guide	35	
121			Sustainability information system	30	
122			Technical user manual	35	
		FM-compliant planning			1
123			FM check	30	
124			Operating cost projection	40	
125			User-related and use-related energy consumption	30	
	Site quality	Local environment			2
126			Earthquake	30	
127			Volcanic eruption	30	
128			Avalanches	30	
129			Storm	30	
130			Floods	30	
131			Heavy rain	30	
132			Hail	30	
133			Landslide/subsidence	30	
134			Storm surge/tsunami	30	
135			Extreme climates	30	
136			Forest fires	30	
137			Air quality	30	
138			Outdoor noise	30	
139			Radon	10	
		Influence on the district			2
140			Site analysis	15	
141			Image and site value appreciation	15	
142			Potential synergy	40	
143			Boost/attraction	30	
		Transport access			2
144			Motorized private transportation	25	
145			Public transport	25	
146			Cyclists	15	
147			Pedestrian traffic	15	
148			Barrier-free design of stops	20	
		Access to amenities			3
149			Social infrastructure	55	
150			Commercial infrastructure	35	
151			Infrastructure associated with the building/variety of uses	30	

Appendix 5: Integrated Analyses Criteria Scheme

1	DGNB	BREEAM	LEED	GBCA	Integrated Analyses
Management & Process	Life cycle assessments in planning			Comparative Life Cycle Assessment	Environmental Management Plan
	Life cycle assessment optimization		Durability Management Verification	Additional Life Cycle Impact Reporting	
	Life cycle assessment comparison calculation				
	Site analysis			Environmental Management Plan	
	Image and site value appreciation				
	Potential synergy				
	Climate protection goals				
	Circular economy bonus			Market Transformation	Circular Economy
	Land use	Ecological Value of Site	Site Selection		Ecosystem Enactment
	Soil sealing factor and compensatory measures	Protection of Ecological Features		Environmental Fitout Performance	
	Soil & groundwater protection on the site	Construction Site Impacts			
	Biotope area quality	Ecological Enactment		Formalised Environmental Management System	
	Biodiversity strategy	Change of Ecological value of Site		Environmental Performance Targets	
	Invasive plant species		No Invasive Plants		
	Diversity of animal species in the outdoor area				
	Diversity of animal species on the building itself				
	Habitat connectivity				
	life cycle costs in the planning process		Durability Management		Minimise Life Cycle Cost
	Life cycle cost optimisation			Ongoing Procurement	
	Building-related life cycle costs				
	Operating cost projection				
	Requirements planning				Integrative Process
	Informing the public				
	Specifications				
	Sustainability aspects in tender phase				
	Facility management manual				
	Up-to-date plans				
	Servicing, inspection, operating and upkeep instructions				
	Integral operating concept and systematic commissioning		Integrative Process		
	Integrated systems				
	Planning with BIM			Fitout Systems Tuning	
	Commissioning concept			Fitout Commissioning	Independent Commissioning Agent
	Commissioning management				
	Final report on commissioning				
	Exploration of different design variants	Considerate Constructors Scheme			
	Recommendations by an independent design committee			Independent Commissioning Agent	
	Award in the form of an architecture prize		LEED Accredited Professional	Accredited Professional High Quality Staff Support	Accredited Professional
	Quality assurance planning				Monitoring of construction site

	Quality control measurements			Metering	
	Quality assurance for construction products				
	Mold prevention				
	Monitoring concept			Monitoring System	
	FM check				
	Preliminary function test		Preliminary Rating		Preliminary function test
	Function test and training				
	Sustainability guide	Home User guide	Education of Homeowner, Tenant, or Building Manager	Fitout User Information	Home User guide
	Sustainability information system				
	Technical user manual		Prescriptive Pathway		
	Earthquake		Floodplain Avoidance		Potential Natural Risks
	Volcanic eruption				
	Avalanches				
	Storm				
	Floods	Flood Risk			
	Heavy rain				
	Hail				
	Landslide/subsidence				
	Storm surge/tsunami				
	Extreme climates				
	Forest fires				
	Radon				
	Boost/attraction	Building Foot Prints	Innovation	Innovative Technology or Process	Innovation Challenge
				Innovation Challenge	
				Global Sustainability	
				Improving on GBCA Benchmarks	
Materials Efficiency	Environmentally friendly materials	Environmental Impact of Material	Environmentally Preferable Products	Base Building Sustainability	Environmentally friendly materials
	Sustainably produced raw materials		Material-Efficient Framing	Permanent Formwork, Cables, Pipes, Floors and Blinds	
	Secondary raw materials				
	Exterior and interior components				
				Hazardous Material	
		Reasonable sourcing of Material - Building	Certified Tropical Wood	Timber	Responsible Sourcing of Materials
				Engineered Wood Products	
		Reasonable sourcing of Material – Fishing			
			Regional Priority		Locally Available Materials
	Ease of recycling				Materials Reuse & Recycling Potential
	Ease of recovery, conversion and recycling				
Energy fficiency	User-related and use-related energy consumption		Annual energy use		Energy Primary Demand
			Minimum Energy Performance		
			Efficient Hot Water Distribution System	Domestic Hot Water Systems	Hot Water System Use
			Efficient Domestic Hot Water Equipment		
	Summer heat protection	Building Fabric	Envelope Insulation		Use of Thermal Insulation

	Availability of daylight for the entire building				daylight Access & Light Systems
		Internal Lighting	Lighting	Lighting	
		External Lighting	Windows		
			Space Heating and Cooling Equipment	Appliances and Equipment	High-Efficiency Appliances & Monitoring
	Fixtures and equipment	Energy Labelled White Goods	High-Efficiency Appliances	IT Equipment	
			Energy Metering		
			Advanced Utility Tracking		
	Distribution system with renewable energy	Low or Zero Carbon (LZC) Technology	Renewable Energy	Accredited GreenPower	Renewable Energy & Alternative Strategies
	Passive systems	Cycle Storage	Building Orientation for Passive Solar		
		Drying Space	Active Solar-Ready Design		
			Heat Island Reduction		
	indoor air temperature/heating period		HVAC Start-Up Credentialing	Ventilation and Air-Conditioning	Efficient HVAC System
	indoor air temperature/cooling period		Heating and Cooling Distribution Systems		
	Heating period				
	Cooling period				
	Relative humidity/heating				
	Radiant temperature asymmetry /heating period				
	Radiant temperature asymmetry /cooling period				
	Indoor humidity/cooling period				
	Heat transfer				
	Thermal heat bridges				
Water Efficiency			Total Water Use		Potable water demand
	Potable water demand and wastewater volume	Internal Water Use	Indoor Water Use		
	External works	External Water Use	Outdoor Water Use		Irrigation System Use
	Surfaces	Management of Surface Water Run-Off Developments	Rainwater Management		
			Water Metering	Domestic Appliances Efficiency	Water Appliances Efficiency
				Commercial or Industrial Appliances	
	Integration into the district infrastructure			Sanitary Fixture Efficiency	Grey Water System Efficiency
Waste & Pollution	Noise Emissions			Internal Noise Levels	Low Light & Noise Pollution
	Outdoor noise				
	Low-noise construction site				
	Light pollution			Light Pollution to Night Sky	
				Light Pollution to Neighbouring Bodies	
				Reverberation	
	Volatile organic compounds			Low Emission Vehicle Infrastructure	Polluted Emissions Reduction
		Dwelling Emission Rate		Paints, Adhesives, Sealants and Carpets	
		NO_x Emissions			
	Dirt trap	Composting	Nontoxic Pest Control		
			Garage Pollutant Protection		
			Enhanced Garage Pollutant Protection		
			Radon-Resistant Construction		

			Environmental Tobacco Smoke		
			No Environmental Tobacco Smoke		
			Low-Emitting Products		
			Contaminant Control		
	Low-dust construction site				Waste Treatment & Recycling Facilities
	Low-waste construction site	Construction Waste Management	Construction Waste Management	Reduction of Construction and Demolition Waste	
			Construction Activity Pollution Prevention	Exhaust or Elimination of Pollutants	
				Waste in Operations	
		Storage of Non-recyclable waste		End of Life Waste Performance	
	Climate adaption	Global Warming Potential of Insulants		Refrigerant Impacts	Low Refrigerants Rate
	Halogenated hydrocarbons in refrigerants			Legionella Impacts from Cooling Systems	
Health & Wellbeing	Space efficiency		Home Size	Ergonomics Strategy	Internal Layout Functionality & Visual Comfort
	Ceiling height				
	Building depth				
	Floor layout				
	Structure				
	Technical building services	Home Office			
	Indoor spaces to facilitate communication	Lifetime Homes			
	Additional provisions for users	Private Space			
	Family, child and senior-citizen-friendly design		Enhanced Compartmentalization		
	Quality of interior access and circulation areas		Compartmentalization		
	Daylight colour rendering	Daylighting		Daylight	Illumination Quality & Control
	Exposure to daylight			Surface Illuminance	
				General Illuminance and Glare Reduction	
				Localised Lighting Control	
				Glare Reduction	
				Minimum Lighting Comfort	
	Ventilation rate		Combustion Venting	Provision of Outdoor Air	Natural Ventilation Level
	Ventilation		Ventilation	Ventilation System Attributes	
	Air quality		Enhanced Ventilation		
	Airtightness		Air Infiltration		
			Combustion Venting		
			Air Filtering		
	Temperatures during the heating period				Cooling and Heating Comfort & Control
	Temperatures outside of the heating period		Balancing of Heating and Cooling Distribution Systems		
	User comfort			Thermal Comfort	
				Advanced Thermal Comfort	
	Visual contact with the outside			Views	View out & Aesthetic Aspects
	Outdoor areas			Indoor Plants	
	Outdoor facility design concept				
	Subjective perception of safety and protection	Security			Safety Protection & Fire Security
	Sound insulation in residential buildings	Sound Insulation		Acoustic Separation	Sound Absorption & Insulation

	Development and maintenance care				Maintainability & Flexibility
	Accessibility of the exterior glass surfaces			Services and Maintainability Review	
	Concept for ensuring ease of cleaning				
	Accessibility of the exterior glass surfaces				
	Floor covering				
	Unobstructed floor plan				
	Ease of recovery				
			Regional Priority	Base Building Cultural Heritage Significance	Cultural and Architectural Heritage
Location Quality	Parking space situation				Car Parking Capacity
	Motorised private transportation			Amenity Space – Performance Pathway	
	Market characteristics				Community Services & Facilities
	Degree of utilisation				
	Social infrastructure		Compact Development		
	Commercial infrastructure		Community Resources	Shared Amenities	
	Infrastructure with variety of uses		LEED for Neighbourhood Development		
	High intensity of use				
	Barrier-free design of stops			Active Transport Facilities	Considering Transportation Accessibility
	Public transport		Access to Transit	Access by Public Transport	
	Electromobility				
	Entrance situation, routing and signposting				
	Rental systems (public or private)				
	Accessibility of the building technology				
	Cyclists				Pedestrian and Cyclist Safety

Appendix 6: LSHAS ‘Arabic Version’

الوزن النسبي	المعايير	الوزن النسبي	الفئات الرئيسية
7	تكامل العمليات	%5	الادارة والعمليات
16	الخطة البيئة		
34	تعزيز النظام البيني		
22	تقليل تكلفة دورة الحياة		
5	التكليف المستقل		
16	المخاطر الطبيعية المحتملة		
100			
33	مواد صديقة للبيئة	10%	كفاءة المواد
15	ضمان مصادر المواد		
43	إعادة استخدام المواد والتدوير		
9	استخدام المواد المتاحة محليا		
9	الطلب الابتدائي للطاقة	%24	كفاءة الطاقة
24	كفاءة نظام التهوية والتكييف		
12	نظام تسخين المياه		
4	معدل الاضاءة الطبيعية		
5	استخدام العزل الحراري		
12	كفاءة الاجهزة والمراقية		
27	الطاقة المتجددة والبدائل		
7	استخدام استراتيجيات الظل		
100			
33	جودة مياه الشرب	%32	كفاءة المياه
15	الطلب على مياه الشرب		
6	نظام الري المستخدم		
13	كفاءة معدات المياه		
7	كفاءة نظام المجاري		
26	استيعاب مياه الأمطار		
46	معالجة القمامة ووسائل التدوير	%11	التلوث والقمامة
13	التلوث السمعي والبصري		
15	الانبعاثات الضارة		
10	انبعاثات اجهزة التبريد		
16	الوقاية من العواصف الترابية		
100			
5	معدل التهوية الطبيعية	%13	الصحة والرفاهية
9	جودة الاضاءة والتحكم		
5	العزل الصوتي		
29	جودة نظام التبريد والتدفئة		
11	التقسيم الداخلي والتناغم البصري		
16	الحماية ومكافحة الحريق		
13	معدل التهوية الطبيعية		
5	جودة الاضاءة والتحكم		
7	العزل الصوتي		
100			
36	الخدمات المجتمعية	5%	جودة الموقع
14	اعتبارات توفر المواصلات		
29	اعتبارات توفر الاتصالات		
16	توفر محطات للسيارات		
5	توفر امن للمشاة والدراجات		
100		100%	