The Development of Sustainable Assessment Method for Saudi Arabia Built Environment

by

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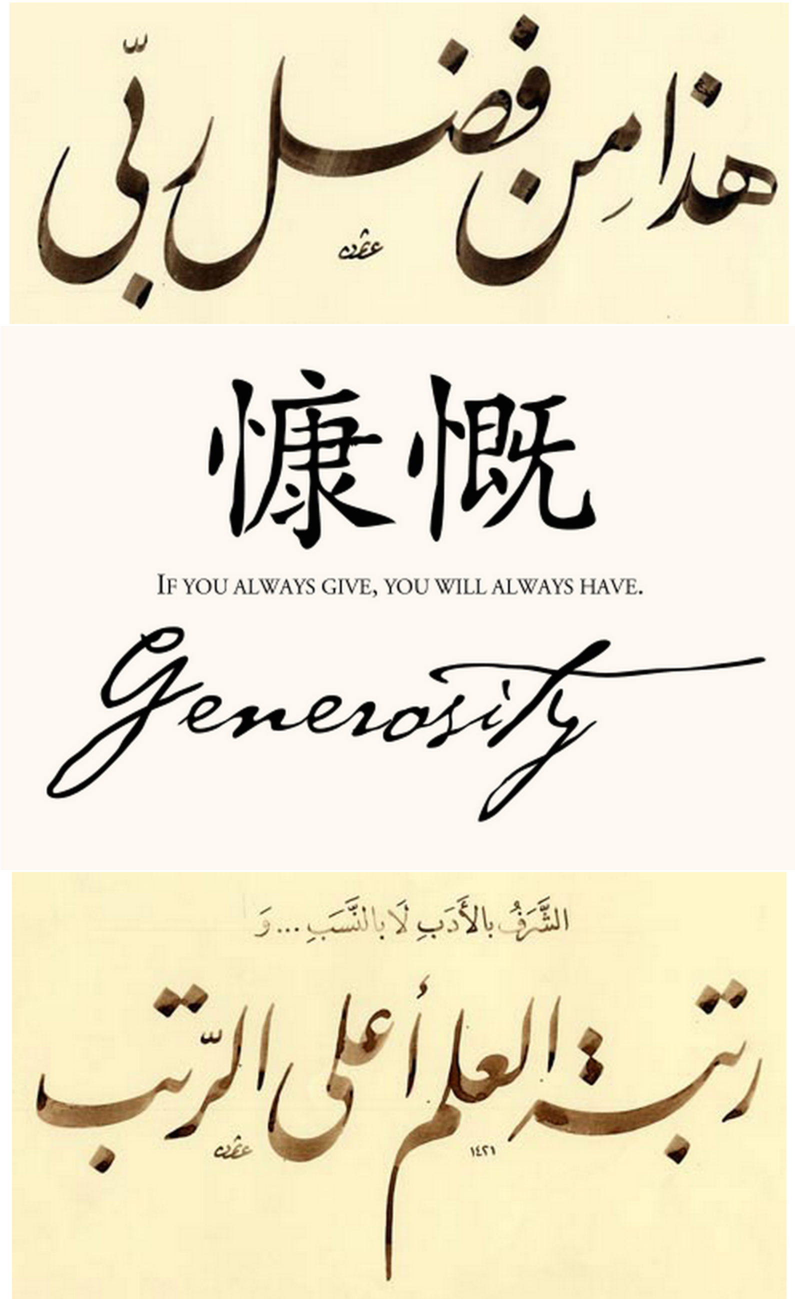
Dedication

I dedicated this work to my family and I would like to express my loving thanks to them all, without their support and encouragement, this thesis would not have been accomplished.

Quotations



هذا من فضل ربي
慷慨
If you always give, you will always have.
Generosity
الشرف بالأدب لا بالنسب ... و
رتبة العلم أعلى الرتب

Abstract

Our built environment is responsible for some of the most serious global and local environmental change. The construction industry therefore faces pressure to increase the sustainability of its practices reflected in the development of stringent regulations and sustainability assessment methods, designed to mitigate such negative impacts. However, the well-established methods (e.g. BREEAM, LEED, SBTool, and CASBEE) have not originally been designed to suit developing countries (including Saudi Arabia). This study therefore proposes to customize an adapted Saudi Environmental Assessment Method (SEAM). This study to begin with investigates the most important and globally widespread environmental assessment methods: BREEAM, LEED, SBTool, and CASBEE. It identifies areas of convergence and distinction in order to enable the consolidation of environmental criteria into new potential schemes. As sustainable and ecological context are usually regarded as multi-dimensional, scientific evidence proposes that a technique based on consensus is most appropriate for the establishment of inclusive and efficient building environmental assessment schemes. Therefore, a consensus based approach is used to deliver: (a) applicable assessment categories and criteria for the Saudi Arabia context and (b) its weighting system. Hence, the Delphi technique and Analytic Hierarchy Process (AHP) are selected and conducted in four successive systematic consultation rounds, involving world leading experts in the domain of environmental and sustainable assessment schemes, as well as professionals and highly-informed local experts from academia, government and industry. These two stages resulted in the development of SEAM criteria and its weighting system.

keywords: Environmental Assessment Method (EAM), Saudi Arabia, Sustainable Building, Built Environment, Saudi Environmental Assessment Method (SEAM).

List Of Publications

Alyami SH, Rezgui Y (2012) Sustainable building assessment tool development approach. Sustainable Cities and Society 5 (0):52-62. doi:http://dx.doi.org/10.1016/j.scs.2012.05.004. Elsevier.

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Alyami SH, Rezgui Y, Kwan A (2014). The development of sustainable assessment method for Saudi Arabia built environment: Weighting system. DOI: 10.1007/s11625-014-0252-x. Sustainability science. Springer.

Alyami SH, Rezgui Y, Kwan A (2014). The process of adapting a sustainable building assessment method worldwide: SEAM a case study http://dx.doi.org/10.1061/9780784413616.245. American Society of Civil Engineer (ASCE), Florida, Orlando the USA, June 2014.

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1 Introduction

1.1 Background

The achievement of all Human activities require the use of resources and energy, factors such as improved living standards, high levels of economic growth, urban sprawl and continuous industrialisation have had a profound impact on the demand for the most dominant ways to generate energy, which is currently the combustion of fossil fuels (Dakwale et al., 2011). However, growing evidence of climate change has increased the necessity for immediate action to avoid potentially serious consequences for future generations (IPCC, 2007; Field et al., 2014). Worldwide buildings consume a large amount of energy and natural resources (e.g. one sixth of the worlds fresh water, one quarter of the harvested wood); in particular residential and commercial buildings consume approximately 40 % of the totally energy amongst all sectors (Paudel et al., 2014). This amount of consumption contributes both to the depletion of natural resources and the production of harmful CO_2 emissions, exacerbating global environmental problems. The situation is even worse in the developing countries; CO_2 emissions in the Gulf Cooperation Countries (GCC), for example, are approximately three times higher than the average of 25-European Union EU (IEA, 2011).

This may be attributable to the absence of environmental assessment tools capable of diagnosing built environments for best practice. It is for this reason that a scheme for the measurement of the environmental performance of buildings has been essential (Crawley and Aho, 1999). Significant effort worldwide has therefore gone into the development of such systems to measure the environmental performance of buildings, with intensive studies devoted to this purpose (Ali and Al Nsairat, 2009; Chang et al., 2007; Cole, 2006; Cooper, 1999; Crawley and Aho, 1999; Ding, 2008; Haapio and Viitaniemi, 2008; Wong and Abe, 2014; Gou and Lau, 2014).

Since the 1990s, there has been extensive development of building environmental assessment methods, many of which have subsequently gained considerable success (Todd et al., 2001; Cole, 2006; IEA, 2001; Seo Tucker, 2006; Cole and Jose Valdebenito, 2013); and recently, this has led to the adaptation of well-established tools (Seinre et al., 2014). The Building Research Establishment Assessment Method (BREEAM) was the first real attempt and various schemes such as the Sustainable Building Tool (SBTool), Leadership in Energy and Environmental Design (LEED) and the Comprehensive Assessment System for Building Environment Efficiency (CASBEE) have subsequently emerged. This is illustrated in Table 1, which includes the primary features of each method. In parallel with that evolution, the standardisation of issues that pertain to environmental building has also improved. For instance, The International Organization for Standardization (ISO) and the European Committee for Standardization (CEN) have been active in providing definitions for the standardised requirements for the environmental assessment of buildings (ISO, 2000; ISO, 2006; CEN, 2005; CEN, 2007).

1.2 Context: Saudi Arabia

Saudi Arabia is considered to be amongst the driest regions of the world. The desert nature of Saudi Arabia makes the land very difficult for habitation. The absence of permanent sources of water (e.g. rivers, lakes) makes the situation even more challenging. The climatic conditions, topography, and limited water supply hinder the development of communities, neighbourhoods, and cities. However, since the early 1970s, when the country began to experience an unprecedented economic growth from oil revenues, living patterns have substantially changed toward the adoption of modern, luxurious, and energy-demanding lifestyles (Al-Ajlan et al., 2006; Bahammam, 1998; Aljarboua, 2009).

The building sector in Saudi Arabia has embarked on an ambitious and large scale built environment development programme (Ali and Alfalah, 2010). Traditional buildings and their associated local materials have been replaced by reinforced concrete structures, combined with contemporary architectural styles that use a wide range of building components (KACST, 2002, Taleb and Sharples, 2011, Bahammam, 1998). This steady transformation of building practices has required a massive amount of construction material, energy, water supply and other infrastructure (such as sewage and sanitation systems), in order to deliver buildings that are appropriately linked with utility networks and other civil services and healthier dwellings with more comfortable indoor environments.

The building sector in Saudi Arabia is currently placing intensive pressure on the countrys reserves of natural resources. It is estimated that about two-thirds of the electric energy generated in the Kingdom of Saudi Arabia is used by the building industry (Al-Sanea et al., 2012). Hence, conventional construction operations impact seriously on the environment as a result of their excessive use of energy. Continuing in this vein is neither feasible nor sustainable. Viewing this statement from a frame of reference, in 1975 the total peak electricity load was 300 MW. By 2007, it had increased to 34,953 MW. By 2023, according to the forecast of current projections, total peak electricity is set to achieve 57,808 MW (Obaid, 2008). On the other hand, the government has made a huge effort to overcome the problem of water demand, by constructing 33 desalination plants, making Saudi Arabia the largest global producer of desalinated water. Water desalination then requires additional energy, making fresh water in Saudi Arabia a particularly costly commodity. Still, even though in many wet regions around the world water tariffs exceed $6/m3, water tariffs in Saudi Arabia are set at around $0.03/m3, as a result of high subsidising by the government (El-Ghonemy, 2012). The high subsidising provided by the government for both water and electricity makes the consumer less motivated when it comes to conservation strategies (Taleb and Sharples, 2011).

The massive area of Saudi Arabia creates another challenge. The growing population or utility customer is spread out in a region larger than two million km2, making the kingdom one of the worlds least densely populated countries (Aljarboua, 2009). As a result of its large area and low density the country requires infrastructure networks that extend over many thousands of kilometres and demand huge amounts of energy for their construction and operation. Further, there are still some rural areas in the southern, central, and western regions which are not yet connected to the electricity network; connecting them over the coming years would require additional increases in power generation (Hepbasli and Alsuhaibani, 2011).

Typically, a Saudi residence is designed in such a way that luxurious living is the priority; scant regard is paid to principles of sustainability. By contrast with the rest of the world, Saudi houses are fairly large reinforced concrete residences, with air conditioning units constantly running in each room (Taleb and Sharples, 2011). Since, Saudi Arabia is blessed with rich oil fields, and because the citizens have their water and electricity heavily subsidised, people are not motivated to take heed of the environment, or to concern themselves with sustainability. This is pointed out by Taleb (2011) who also indicates that the lack of policies and a robust regulatory environment of sustainability has become a great obstacle to Saudi Arabian sustainable development.

The kingdom has a pressing need to adopt innovative solutions over conventional practices. Therefore, strong commitment, by the government, to green energy and sustainable practices has been considered an imperative issue. A progression of environmental awakening is also being observed in the kingdom. It is realised that the employment of renewable energy resources can offer a major contribution to improving environmental protection, thereby ensuring better health and well-being for the public. Beside governmental organisations (e.g. King Abdulazize City for Science and Technology), many non-governmental organisations have been launched to promote sustainable development in the kingdom, for example: the Saudi Environmental Society (SENS, 2013) and the Saudi Green Building Council (SGBC, 2013).

Both organisations promote and facilitate green building practices within Saudi Arabia, including: raising public awareness; offering advice to the construction industry as to green building requirements; encouraging building materials manufacturers and suppliers to produce and supply environmentally friendly products; promoting green labelling; and providing relevant training & educational services (SENS, 2013; SGBC, 2013). However, they still rely on international building sustainable assessment tools such as LEED, which were not originally designed to suit the Saudi Arabian built environment. In an attempt to address this discrepancy, this study was initiated to lay the foundations for an adapted environmental assessment system suitable for Saudi Arabias local built environment.

1.3 Research aim and objectives

The aim of this study is to develop a sustainable building assessment method for Saudi Arabias built environment. The reason for developing this method is to provide a credible and coherent environmental labelling system for buildings, which will enable their categorisation based on their specific environmental performance and benefits. It is anticipated that once adapted this assessment method will contribute to the conservation of non-renewable resources and the employment of potential renewable resources within the Kingdom of Saudi Arabia. To achieve this aim, a number of objectives have been developed to guide both the theoretical and empirical research; the specific objectives of the study are as follows:

- Review current building assessment methods, and classify them based on their application and domain.
- Consolidate sustainable building assessment categories and criteria through a comparative analysis of well-established assessment methods (BREEAM, LEED, SBTool and CASBEE). The primary objective of this stage is to lay a solid foundation for the development of the new model. As existing assessment methods are both comprehensive and tested in practice, a comparative analysis of these can provide a robust starting point for the development of new schemes, as recommended by key and active expert in this domain.
- Identify applicable categories and criteria to form the dimensions of the Saudi Environmental Assessment Method (SEAM). Ideally, participating experts should reach a consensus regarding those dimensions.
- Determine an applicable weighting system for SEAM. This system should prioritise its main categories based on specific environmental, economic and social aspects of the built environment in Saudi Arabia.
- Define a mode that underpins a single rating; combining SEAMs credit allocation strategy, weighting coefficient and rating formulas.

1.4 Rationale for the research

The construction and subsequent maintenance of modern buildings has been shown to have potentially severe repercussions for global resources, as well as running the risk of causing severe ecological issues including: climate change, air and water pollution, and land degradation. The adverse effects of the construction industry on the environment can also be seen in the KSA. In recent years, the country has been experiencing a tremendous economic boom. As it usually happens during such periods of financial growth, the built environment in the KSA is also experiencing an unprecedented development. However, in most cases, this expansion has relied upon unsustainable practices (Obaid, 2008; Taleb and Sharples, 2011; Hepbasli and Alsuhaibani, 2011).

Therefore, it is of vital importance for this industry to be subjected to regular and consistent evaluation; steps should be taken to benchmark the effects of the attendant changes on the environment, and to take remedial action, where necessary, to mitigate these effects and to improve the quality of building practices. The research area of environmental and sustainable assessment methods has newly emerged to meet these objectives across the developed world (Cole, 1998; Lee et al., 2002; Burdov and Vilekov, 2012). A number of publications (Cole, 2005; Chew and Das, 2008; Ding, 2008; Lee and Burnett, 2008) present a heavy criticism on the way of using the existing EAM including (a) the use of methods to assess regions for which they were not originally designed for; (b) the lack of an adapted weighting system; and (c) the relative absence of overall transparency in terms of the nature and significance of their constituent elements.

What can be noticed here is that the newly established methods are in competition to be used worldwide, without giving due attention to the regional, economic and socio-cultural aspects of the regions in which they will be employed. This study therefore posits that a customised tool should be designed to suit the Saudi Arabian built environment. This tool (SEAM) should be developed in ways that overcome the shortcomings of the existing methods. In order to achieve this broad aim, SEAM should be developed through a reliable process that would determine the applicable categories and criteria for the context of Saudi Arabia as well as a transparent weighting system that would prioritise those dimensions effectively. To this end, the present study will rely on reaching a consensus among a panel of experts by using the Delphi technique (DT) and the Analytical Hierarchy Process (AHP), So in the methodology shaper, there will be a justification of using these research instruments (DT and AHP).

1.5 Research hypothesis and questions

The overarching hypothesis of this study is that the leading global environmental assessment models currently in use, such as BREEAM and LEED, have not been adapted to the political, environmental, and social specificities and context of the Saudi Arabian built environment. This limitation encompasses a lack of recognition for regional variations, including the constraints of available resources, local architecture, specific environmental conditions, and certain other important economic and socio-cultural factors. Under this overarching hypothesis, a number of specific hypothesises have been set, including:

The building assessment categories and criteria of the leading international environmental and sustainability assessment schemes (such as BREEAM and LEED) are not fully applicable to the Saudi Arabia built environment.

Weighting system of the well-known assessment methods currently in use, such as BREEAM and LEED, have not been adapted to prioritise the environmental, economic, and social specificities and context of the Saudi Arabian built environment.

This research is therefore underpinned by the following research questions:

RQ1. What is the applicable theoretical model or roadmap that promotes robust development of a coustomised sustainable assessment method?

RQ2. What are the required categories and criteria that form the best sustainable assessment method for the Saudi Arabian built environment?

RQ3. What is the applicable weighting system, rating formulas and benchmarking expressions that reflect the most accurate appraisal of the Saudi Arabian context?

1.6 The scope and limitations

The present study belongs in that portion of Sustainable Development that focuses on building assessment tools. Given the vastness of this area of research and the time restrictions of a Ph.D. thesis, this study had to adhere to strict conceptual and time limits. Thus the scope of this study has been defined as follows: The adaptation of a coherent sustainable building model (based on the groundwork of existing well-established methods) for Saudi Arabia with a focus on residential building. For the design of this model then, particular attention has been paid to delivering applicable assessment categories and criteria and an appropriate weighting system incorporating rating formulas and benchmarking expressions.

In order to ensure that this topic with its associated objectives have been comprehensively addressed, this research was organised into the following theoretical and empirical phases: The first theoretical phase involved (a) a critical review of environmental assessment rating tools, (b) a selection of well-established assessment tools and (c) their comparative analysis in order to identify key similarities and differences and consequently determine appropriate categories and criteria for SEAM model. This process also provided a broad theoretical background for the development of the new scheme; these steps were undertaken in order to form initially the potential sustainable assessment method for the Saudi built environment, with a particular focus on residential buildings.

The components of the model that were determined through the above process were then evaluated further. The Delphi consultation process was utilised, in an effort to reach expert consensus on the most applicable categories and criteria for use within the Saudi built environment. AHP was then used to deliver a reliable weighting system that prioritises the approved categories and criteria that have been derived from the Delphi phase.

A number of limitations affected the development of SEAM, for example, the panel (in both the Delphi technique and AHP) was dominated by male participants. This is in large part because of the shortage of female expertise in this field within Saudi Arabia. Within the context of this study, the researcher has decided to employ the expertise of three international female experts, who have work experience in the KSA and/or working in similar built environment, in an attempt to partially overcome the limitation with regards to female experts in the Saudi context.

An additional challenge faced by this study is related to the large number of criteria (more than 90) involved in the customised SEAM assessment dimensions. This number means that the use of a pairwise comparison to determine the weight of each criterion is complicated and results in a vast body of data (more than 90 tables) that would require analysis by the panel. However, the experts agreed to participate with reasonable tasks. For this reason, the pairwise comparison (PCs) is limited to the eleven SEAM assessment categories, which have been deemed to be the most influential and which can determine the overall influence of the lower level (SEAM criteria). Moreover, the integration of the Delphi technique and AHP has played an important role in allocating the credits for the lower level (SEAM criteria).

It has also been found that there is a lack of reliable data (e.g. research papers, official reports etc.) regarding the use of international assessment methods (e.g. BREEAM, LEED) in the KSA. A number of green buildings have been recently assessed using LEED in the KSA and they would provide a useful point of comparison with the SEAM criteria. However, detailed information about these buildings is considered to be private property, meaning that the agents who are in charge of this data are forbidden from sharing it with external researchers.

1.7 Contributions to the body of knowledge

Through the development of SEAM, a number of new contributions have been made to the literature and body of knowledge within this discipline. The most important of these are as follows:

- Organisations that have launched well-known sustainable assessment methods tend to avoid explicit disclosure of the processes by which their methods have been developed. This study not only proposes a theoretical model but also makes the processes by which its components were devised transparent. It is hoped that in this manner the theoretical model becomes more flexible and consequently more adaptable, when require similar customisation of other parts of the world.

- The foundation of any building assessment method is embedded in its assessment categories and criteria. Consequently, this study has disclosed the applicable categories and criteria that form the main structure of Saudi Arabias building environmental assessment method (SEAM).

- Weighting systems are integral to reliable evaluation. This study has therefore determined a weighting system, for the approved categories, that form the most applicable dimensions for the sustainability development of the built environment in the KSA. This weighting system includes a calculation procedure (weighting coefficient, rating formulas and benchmarking expression), which provides a single result to clearly indicate the level of sustainability of the given built environment within the context of the KSA.

1.8 Organisation of the thesis

This thesis comprises seven chapters, organised in accordance with the standard structure of a PhD thesis (Abstract, Introduction, and Literature Review, Methodology, Results, Discussion and Conclusion). The results and related discussion of salient points can be found in chapter four and five. A brief overview of the content of each chapter is described as follows:

Chapter One: This chapter provides an overview of the study, introducing the specific background of the Saudi Arabian built environment. It also presents the current situation and challenges encountered in this study, followed by the aims and objectives, with the underlying research hypothesis and questions. The scope and limitations are identified and the contributions of this thesis outlined.

Chapter Two: This chapter reviews related works in the field. A critical comparison and review of well-known building assessment methods is then conducted in order to consolidate the appropriated building assessment categories and criteria that will be utilised to support the SEAM development phase.

Chapter Three: This chapter presents an overview and classification of research paradigms. Details of the chosen research design and methodology are provided, along with references to the critical comparison of well-established building assessment methods. The Delphi technique, the analytical hierarchy process are the used research instruments, to customise the appropriateness of SEAM across the KSA. Therefore, an explanation and justification of using these research instruments is also considered in this chapter.

Chapter Four: This chapter presents the building assessment categories and criteria deemed to be most suitable for use in SEAM. More specifically this chapter discusses the approved categories and criteria that were produced through the Delphi consultation and the process, by which they were evaluated and edited, to arrive at the final framework.

Chapter Five: This chapter discusses the weighting system employed in this study, along with the credits allocation, rating formula and rating benchmark. A discussion is also provided of the significance of SEAM weighting, in contrast to the well-known schemes. It also discusses the adaptation of SEAM in country (the KSA) that includes different climatic conditions and highlight significant idea and arguments around this adaptation.

Chapter Six: This chapter summarizes the overall achievements of this thesis and provides directions for further research based on the findings of the study. Based on the findings of this study, this final chapter argues that it is significant for Saudi Arabia (and other developing countries) to have its own customised sustainable assessment system that utilises adaptable building assessment criteria and their corresponding applicable weighting system.

1.9 Summary

The objectives and development process of this study have been presented in this chapter, including an overview of the research motivation and an introduction to the Saudi Arabian built environment. Key research elements have been presented, including the research aims and objectives; research rationale; hypotheses; and research questions. This chapter sought to contextualise the research to follow and clarify its intended contribution to the literature, providing the reader with an initial understanding of the subject matter, as well as with the associated development and research tasks. The review of building assessment method will be presented in the next chapter.

2

Literature Review

2.1 Introduction

Since the early 1990s, the principles of environmental performance has been a heated subject matter; that is, to consider the way in which buildings were designed and operated, in order to reduce harmful environmental impact of building during its lifecycle. In the quest of meeting this objective, Crawley and Aho (1999) states that, a yardstick for measuring environmental performance was essential. Thus, significant research and considerate purpose has gone into developing such systems to measure a buildings environmental performance over its lifespan (Cole and Jose Valdebenito, 2013, Lee, 2013). Since then, appropriate methods took progressive steps to assess how successful any projects is, in terms of energy efficiency design and its consequences on buildings environment and ecology, taking into consideration both the social and economic aspects of projects (Cole, 1998; Cooper, 1999; Crawley and Aho, 1999; Cole and Jose Valdebenito, 2013).

Then, Environment Assessment Method (EAM) have expanded and become a vast area of research (Gibberd, 2005; Gibberd, 2003; Cole, 2001; Cole, 2000; Cole, 1998; Cole, 2006; Ali and Al Nsairat, 2009; Cole and Jose Valdebenito, 2013; Lee, 2012). It includes diverse schemes that are interested in different scope of studies (e.g. life cycle assessment, economic assessment, design and quality assessment) (Berardi, 2012). This chapter will review and analyse EAM and focus on the rating system. This selected domain of building assessment method are critically analysed, and more specifically, this chapter will include: (a) the identification of well known assessment methods (b) a comparative analysis of these assessment methods (based on its assessment categories and criteria) (c) a critical review on these well known assessment methods (d) The identification of common components (categories and criteria) in leading EAM that could be employed as a starting point for developing a new scheme.

2.2 Background of environment alteration

Since the beginning of civilisation, humans have been reliant upon the natural environment, although most of ancient civilisations sought the right land, to meet their undemanding lifestyle. These human activities were limited to essential activities that focused on the fundamental aspects of living (e.g. drinking water and food nutrition). However growing knowledge and mastery of the environment has eventually resulted in humanity dramatically altering the Earth systems (Vitousek et al., 1997). For instance, the industrial revolution remains one of the most important contributors to the development of human living standards. While this development across all industries has undeniably had a positive effect on human life, such as increased life expectancy rate and general health and wellbeing, the resultant population growth and ever-improving technology has put tremendous pressure on the natural environment, leading to global warming and climate change (Oskamp, 2000; IPCC, 2007; Field et al., 2014). Due to the relevance of this to the subject of this thesis, a brief overview will be provided of the most common, interrelated factors that exacerbate global environmental problem. The key points that will be discussed are (a) population growth, (b) climate change/global warming, and (c) building activity, with its consequences on changing the earths environment.

Population growth: For millions of years, the global population remained comparatively small, only reaching one billion in 1830 (as illustrated in Fig 2.1). After this, it took a further century to reach the second billion. The growth from this point has increased exponentially, requiring a mere 30 years to reach three billion and a further 15 years to reach four billion, which occurred in 1975. Only twelve years later, in 1987, the world population reached five billion and 12 years after this hit six billion (Oskamp, 2000). This dramatic increase in population growth will evidently exacerbate the alteration of global eco-system and strongly suggests that the future pressure on, and manipulation of, the environment is only likely to grow. At this time, between 33% and 50% of the total land surface has been transformed by human development, with the concentration of carbon dioxide in the atmosphere having risen by nearly 30% since the beginning of the industrial revolution (Vitousek et al., 1997).

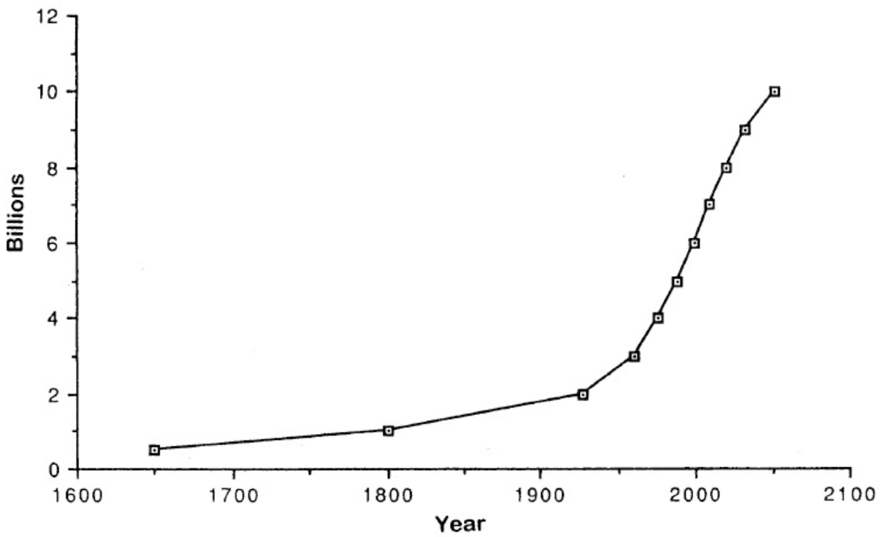

Figure 2.1: Human Population Growth Since 1650 (Oskamp, 2000)

Climate change: Since the early 1980s, the earths climate and its changeable conditions have been a source of much debate (Alfsen and Skodvin, 1998; Field et al., 2014). Although measured temperatures have increased around the world, and numerous natural disasters (such as tsunami or earthquakes) have occurred, there has been a degree of uncertainty about the cause of these abnormal conditions. This uncertainly, to greater degree, was resolved when the Intergovernmental Panel for Climate Change (IPCC) launched its first report in 1988. The IPCC confirmed, through the consensus of its member scientists, that the greenhouse effect and the increased atmospheric concentration of carbon dioxide CO_2 was the major cause of the observed climatic change (IPCC, 2007; Field et al., 2014). Even though the major driver of human activity is burning fossil fuels oil, coal, and gas which produce concentrated CO_2 emission, the IPCC claimed that human activity is also the primary cause of climate change and global warming (Alfsen and Skodvin, 1998).

As living creatures are profoundly affected by the composition of the atmosphere, the anticipated consequences of global warming are devastating. The global temperature will also lead to melting ice caps which will expand the oceans and raise sea levels (Lelieveld et al., 2012). It is currently estimated that the sea level is rising by an average of approximately 6 cm per decade for each temperature rise of between 1.5 to 5.5C, with the result that the sea levels can be expected to rise by as much as 50 cm by 2100. This would pose a major threat of erosion to many inhabited islands and coastal regions (Houghton et al., 2001). Increased heat would also create a suitable environment for the spread of infectious diseases such as malaria, as well as significantly affecting the agricultural sector, as can be seen in the lowered productivity of grain farming. Overall various consequences such as: acid rain, sea levels rise, flooding, soil erosion, drought and storm damage to some coastal regions are significantly expected to cause more change to the earths environmental system (Lelieveld et al., 2012).

Building sector: Economic growth has led to widespread developments all over the world, with the key driver of this global boom being the investment into natural resources such as fossil fuel (oil, gas and coal), material, water and land. As previously mentioned, advances in scientific and technological knowledge coupled with intensive exploitation of these resources has massive changes to the context of the built environment. The doubt regarding the sustainability of these resources, with the progression of economic growth inevitably leading to many global problems, including severe environmental degradation, and economic or social collapse (Roodman et al., 1995; Lelieveld et al., 2012; Almazroui et al., 2012).

The building sector represents one of the more extraordinary achievements of modern civilisation, making life more comfortable and populations healthier. However, its execution and operation severely impacts upon the environment. Buildings intensively consume a large portion of natural resources (Paudel et al., 2014). Exploitation of resources on this scale certainly has enormous side-effects, such as air and water pollution, deforestation, stratospheric ozone depletion, or increasing the threat of global warming (Houghton et al., 2001; Vitousek et al., 1997; Field et al., 2014). For this reason, the concept of sustainable development in the pursuit of a remedy, with the goal of enabling humans to live more wisely and start a new, more informed era of industry.

2.3 Sustainability development (SD)

The concept of sustainability is not a new concept. Early human activity, going as far back as ancient hunter-gatherers, recognised that humans are completely reliant on nature, and as a result, they utilised a pragmatic approach that enabled them to survive and adapt with the available resources (Hill and Bowen, 1997). Nowadays, there is increased global recognition of the building environmental performance in sustaining the natural resources (Wong and Abe, 2014; Cole and Jose Valdebenito, 2013). Official efforts have been undertaken at the highest level to secure sustainable development, with the International Union for Conservation of Nature and Natural Resources (IUCNs) launching its first report nearly twenty years ago on the subject of sustainable practice. The aim of the World Conservation Strategy Report was to protect natural resources for the future.

Previously, in 1987 the World Commission on Environment and Development (WCED) published Our Common Future Report, which defined sustainable development as: "development that meets the needs of future generations without compromising the ability of future generations to meet their own needs", Caring for the Earth defined 'sustainable development as development which 'improves the quality of human life while living within the carrying capacity of supporting eco-systems (Brundtland, 1987).

The United Nations Framework Convention on Climate Change (UNFCCC) was the first international agreement regarding the consequence of human interaction with the environment; the Kyoto Protocol, was the first step towards achieving this ultimate goal of (UNFCCC). This protocol was endorsed by more than 190 countries, who stated a shared goal of lowering greenhouse emissions (Karadayi and Oguzturk, 2012).

As this study is focused on the building sector, it should be noted that construction activities have a significant impact on natural resources, which in turn affects the inhabited environment, economy and society as a whole (Zuo et al., 2014). The building industry engages in intensive utilization of energy and materials, which are completely reliant on the conventional power generation systems, namely burning fossil fuel. The high-energy consumption and GHG emissions have raised awareness within the industry. The IPCC states that the building sector has the highest potential for energy saving and pollution reduction, also the IPCC anticipates that with the adoption of suitable sustainability development in the building sector, a potential fall of almost 6 Gt CO_2 per year is conceivably possible in the next 20 years. This estimation indicates the importance of the implementation of sustainable buildings concepts on a global scale (Berardi, 2012).

It can be claimed that the overall objective of sustainability efforts should be to mitigate any negative impact that activities may have on human life, considering both long and short-term effects. Since the energy crisis of 1970, the efficient use of energy is widely considered to be a key component in improving human life, while simultaneously sustaining the potential resources for future generations (Gibberd, 2005). The concept of sustainability therefore encourages the use of renewable energy and ensuring the incorporation of high or relevant thermal mass materials into building design. A number of related studies (Li et al., 2013; Jaber and Ajib, 2011; Wang et al., 2009) support the assertion that this energy efficiency design is potentially one of the most effective solutions to mitigate air, land and water pollution, as well as to reduce overall stress on the environment. The value of sustainability may even transcend environmental issues, potentially remedying significant socio-economical problem. For instance, sustainability seeks fairness and equity in terms of the provision of essential services, such as transportation or housing, which have been shown to support improvements to the overall quality of human life. This progressive of the sustainability movement may therefore be an effective way to tackle the global poverty crisis (Drexhage and Murphy, 2010).

2.4 Well-Known Building Assessment Methods

The industrial sectors in general and building industry in particular are starting to rethink about their practices. In other words, these sectors have to make significant changes to reduce its environmental impact. Building sector is taking further steps toward the protection of the ecosystem. This practical shift comes from the need to improve building practise as well as the growing market demand for environmental friendly products and services (Crawley and Aho, 1999). In early 1990s, The concept of environmental building assessment method emerged to measure the building environmental performance. The Building Research Establishment (BRE) was the organisation to launch the first system that set the standards for best practices in sustainable building design and operation (BRE, 2011). Subsequently, many nations recognise the importance of such a tool, so as to assist construction key stakeholders to evaluate their projects with regard to sustainable development principles (Wong and Abe, 2014).

The initial intention of EAM is to assess building environmental performance. In 1999 Cole pointed out the general characteristics of the role of building assessment method are: (a) it assesses buildings by taken into account the reduction of pressure on natural resource and maintaining the ecological value (b) it assesses buildings with view on the occupants health and wellbeing (c) it provides a scoring system through a simple additive process to denote priority (Cole, 1998). Further, BRE states that a building assessment method can play an important role of stimulating the market demand on sustainable building which, in turn, will raise the awareness amongst key stakeholders and even the residents about low environmental impact buildings (BRE, 2011).

In various publications (BREEAM, 2011; CASBEE, 2011; Ding, 2008; iiSBE, 2011; LEED, 2011; Sam, 2010; Seo Tucker, 2006; Todd et al., 2001; Kajikawa et al., 2011 Lee, 2013) a general view of the well-known environmental building assessment methods used in different countries can be summarised as follows:

BREEAM (UK- 1990): The Building Research Establishment Environmental Assessment Method is the first rating system that sets the standard for best practise in sustainable building design and operation. More information about this method will be presented below. **BEPAC(Canada-1993)**: The University of British Columbia developed building Environmental Performance Assessment Criteria. It is a voluntary tool limited to new and existing office; in most of its features it is similar to BREEAM but a more detailed and comprehensive assessment scheme. **BEES (USA-1994)**: Building for Environmental and Economic Sustainability (BEES) measures the environmental performance of building products by using the environmental life-cycle assessment approach specified in the ISO 14040 standard. Economic performance is measured using the ASTM (American Society for Testing and Materials) standard life-cycle cost method, which covers the costs of initial investment, replacement, operation, maintenance and repair, and disposal.

GBTool(International-1995): Green Building Challenge is the most comprehensive framework. It was developed Internationally to suit over 20 countries with the adjustment of regional variations. It has four levels of weighting, The assessment framework has been produced in the form of software (GBTool) that facilitates a full description of the building and its performance, and also allows users to carry out the assessments relative to regional benchmarks. **BEAM (Hong Kong- 1996)**: The Hong Kong Building Environmental Assessment Method is a voluntary scheme first launched in December 1996, similar to BREEAM scheme. However, It has separate assessment methods for new and existing office buildings. Moreover, it assesses the quantifiable criteria but the non-quantifiable social and environmental issues have been on purpose ignored, and assessing new building as built rather than as designed.

EMGB(Taiwan- 1998): Evaluation Manual for Green Buildings method was operated and implemented by the Ministry of Interior. It Consists of 9 environmental criteria which merely the evaluation of the quantifiable criteria and non quantifiable issues are omitted. Moreover, it is a single tool for all types of buildings and not able to reflect regional differences. **Quantum (Netherlands- 1999)**: Eco-Quantum is the only method that is explicitly and comprehensively based on life-cycle assessment. It assesses the environmental burden of a complete building on the basis of LCA. Also it is easy to use and has extensive database of the most commonly used materials and products. It is only applicable to single residential buildings.

Ecoprofile (Norway-1999): Ecoprofile is a method for simple environmental assessment of buildings, is a top down method for environmental assessment of existing office buildings. It includes three principal components that are given the designations External Environment, Resources and Indoor Climate. **LEED(USA- 2000)**: Leadership in Energy and Environmental Design was developed by the US Green Building Council (USGBC. It is a certification process developed to create an industrial standard. It uses a simple checklist format to rate building Performance for new and existing commercial, institutional, and high-rise residential & major renovation. This assessment method also has a self-assessment system that awards silver, gold and platinum certifications in five distinct areas of sustainability. So far LEED is one of the most recognized building environmental assessment schemes. Therefore, the registered projects are in progress in 24 different countries, including Canada, Brazil, Mexico, India and China.

ATHENA (Athena- 2000): Athena is a LCA-based environmental decision support tool for building materials and buildings which was developed by Athena Sustainability Institute in 2000. Assessment criteria cover embodied primary energy use, Global warming potential, Solid waste emissions, Pollutants to air, Pollutants to water, and Natural resource use. **GHEM (China- 2001)**: Green Home Evaluation Manual was introduced by the Science and Technology Development Promoting Centre and the Ministry of Construction, and incorporates environmental standards and design guidelines relating to energy performance of residential projects. It is simple rating scheme that does not take account of an explicit weighting system to address resources allocation and indoor environmental quality.

CPA (UK-2001): Comprehensive Project Evaluation was developed by the Royal Institution of Chartered Surveyors and the Environment Agency. It is a multi-criteria analysis approach to assess environmental and social impacts of a project by utiliseing a checklist-type evaluation framework that requires an independent assessor to undertake the assessment. It is a voluntary tool and different from a building performance method as it is used to assess projects during the development process using a combination of financial and economic approaches. **GreenStar (Australia- 2002)**: Green Building Council of Australia developed this rating tool (GreenStar). It is Australias first comprehensive method for evaluating the environmental building performance that merely take account for commercial buildings, rated on a scale from 0 to 6 stars.

CASBEE (Japan- 2001/02): Comprehensive Assessment System for Building Environmental Efficiency was developed by a committee set up in the Institute for Building Environment and Energy Conservation (IBEC) under the initiative of the Ministry of Land, Infrastructure and Transport (MLIT) in 2001 is co-operative project between industry and government. This system is applicable in various stages of a buildings lifecycle (design, new construction, existing building and renovation) and is based on the concept of a closed ecosystem to evaluate and rank buildings in terms of their environmental performance.

Green Globe (Canada- 2002): Green Globes is an on-line building and management audit tool that helps property owners and managers measure the environmental performance of their buildings against best practices in areas such as energy, water, hazardous materials, waste management and indoor environment. Green Globes is the newest addition to the BREEAM/Green Leaf suite of environmental assessment tools for buildings. **ENVEST (UK-2002)**: Environmental impact estimating design software was developed by BRE. It is the first UK software tool that estimates the life cycle environmental impacts of a building from the early design stage. ENVEST presently considers the environmental impacts of materials used during construction and maintenance, and energy and resources consumed over the buildings life. **BASIX (Australia -2004)**: Building Sustainability Index was developed by the Department of Infrastructure, Planning and Natural Resources. It is a Web-based planning tool for residential development to assess the water and energy efficiency of new residential developments. It is mandatory for all new residential development.

ABGR (Australia-2005): Australian Building Greenhouse Rating was developed by (the Department of Commence NSW). It is a performance-based accredited assessment tool using star rating on a scale of one to five stars. It provides a national approach to benchmarking greenhouse performance of buildings and tenancies based on 12 months of energy consumption. **GSBC(Germany, 2009)**: German sustainable building certificate is the first Garman standard for new certificates for sustainable buildings has been developed under the Federal Ministry of Transport, Building and Urban Affairs (BMVBS) and the German sustainable Building Council (DNGB) to be used for planning and evaluating buildings. It is one of the most recent building rating and assessment methods on the market.

2.5 Categorising building assessment methods

The above list of environmental assessment schemes makes apparent both their multiplicity and their complexity. In response to this complexity then, various institutes and agencies undertook to investigate and clarify the roles and classifications of the available assessment tools. The ATHENA Institute and the International Energy Agency, for example, have developed classification systems that delineate the assessment field and facilitate discussion and analysis within specific parameters (Haapio and Viitaniemi, 2008; IEA, 2011).

2.5.1 ATHENA classification system

The ATHENA Institute has introduced a classification system Assessment Tool Typology (Trusty, 2000) which has three levels: Level 1: Product comparison tools and information sources. This level is used primarily at the procurement stage and might include both economic and environmental aspects (e.g BEES). Moreover, they can be valuable for building databases and for making comparisons and choices at the procurement stage. (Examples: Environmental Resource Guide; LCExplorer; SimaPro; TEAM and BEES) (Trusty, 2000). Level 2: Whole building design or decision support tools. Level 2 tools typically focus on a particular area such as life cycle cost, life cycle environment effect, lighting operating energy and so on. Additionally, these tools are uniformly data-oriented and objective and try to adhere to formal ISO, ASTM, ASHRAE or other standards and guidelines. All of these tools can provide important inputs to level 3 tools. (Examples: ATHENA; EcoQuantum and Envest) (Forsberg and Von Malmborg, 2004, Trusty, 2000). Level 3: Whole building assessment frameworks or systems. Level 3 tools provide a very broad coverage of environmental, economic and social issues seeking to be the relevant tools for sustainability development. (Examples: BREEAM; GBTool; LEED and CASBEE). Some tools such as LEGEP, BeCost , BEAT (2002), EQUER, Environmental Status Model, and PAPOOSE were not cited in the ATHENA classification.

However, Haapio at al, (2008) states that they have been classified based on the similarity with the other tools in the group. Moreover, CASBEE classified with level 3 according to ATHENA principles. Supporting tools and techniques can be an additional category to the three actual levels in this classification system. It provides more general support for the various tools, or for the design process itself, therefore, it is used for screening, setting priorities or addressing specific concerns such as CO_2 emissions (Trusty, 2000). Baseline Green, Green Balance and Green Building Advisor are examples of a supporting system.

2.5.2 IEA Annex 31 classification systems

In the project IEA Annex 31 Energy related environmental impact of buildings the assessment tools are categorised into five classes (IEA Annex 31, 2001). (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 (5) Environmental Product Declarations, Catalogues, Reference Information, Certifications and Labels. Below, the IEA Annex 31 classification system is joint with the ATHENA classification system to make the comparison clearer.

2.5.3 ATHENA vs. IEA Annex 31 classifications

It is clear from the above classification that all of the tools classified in the ATHENA classification belong to the second or third category in the IEA Annex 31 classification thus; the field of classified systems is much wider in the IEA Annex 31 classification than in ATHENA. Mainly, ATHENA classification focuses on the assessment systems depending on where assessment processes are used, and for what purpose (Trusty, 2000). Whereas, the IEA Annex 31 includes energy modelling software, different environmental standards and guidelines, checklists, product declarations and certifications.In addition, IEA Annex 31 (2001) is distinguished between interactive software and passive tools, in other words, interactive software is more reliant on information technology than the passive tools. In contrast with ATHENA classification, Levels 1 and 2 tools are more dependent on information technology than Level 3 tools. According to the ATHENA classification, Level 1 tools are mostly for product comparison and information resources, and Levels 2 and 3 tools are mostly for the environmental assessment of a whole building (Trusty, 2000).

In order 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 schemes should be compared only with other Level 1 schemes and not with Level 2 or 3 schemes, etc. By categorising the schemes within the ATHENA classifications, it is likely to analyse the differences between the different Levels and furthermore, compare the schemes within the Levels. This, in turn, will facilitate recognising the similarities and the differences of the schemes and subsequently weakness area can be detected. Considering that, contrast results will be fed into the development of the schemes. It is worth to mention here that this study in hand is interested in the development of ATHENA level 3; which is the class number three in IEA Annex 31 classification, Environmental Assessment Frameworks and Rating Systems.

2.6 The Selected EAM: Comparative Analysis

2.6.1 BREEAM

BREEAM was launched and operated in 1990 by BRE, an organisation with a history stretching back over 90 years, Thus, BRE is an independent and impartial, research-based consultancy, testing and training organisation, that offers expertise in every aspect of the built environment and associated industries. Furthermore, BRE have been developed various tools and schemes that consider aspects of environmental certification and rating, such as, BREEAM (brought under the BRE Global brand), Envest and EcoHome (BRE, 2011). More features about the selected methods are presented in (Table 2.4).

BREEAM has established a foundation for best practice in sustainable design leading it to become the most effective scheme around the world for the measurement and description of the environmental performance of a building (BREEAM, 2011). BREEAM utilises a fixed weighting system (as illustrated in Table 2.1) developed through the national consultative process (Sev, 2011).The assessment involves the comparison of key issues with predictable practices and performance level, after which credits are then awarded in ten categories. Each category has a number of different allocated criteria, with pre-weighed credits that can either be cumulative or dependent on performance against certain specified standards such as Standard Assessment Procedure (SAP 2009). These credits are then added together to produce a single overall score on a scale of Pass, Good, Very Good, Excellent and Outstanding (BREEAM, 2011).

Table 2.1: BREEAM Environmental

Category	Weightings %	Credits available
Management	12	10
Health &Wellbeing	15	14
Energy	19	21
Transport	8	10
Water	6	6
Materials	12.5	12
Waste	7.5	7
Land Use & Ecology	10	10
Pollution	10	12
Innovation	10	10

2.6.2 LEED

LEED was developed by the U.S. Green Building Council (USGBC).The USGBC is a non-profit trade organization that promotes sustainability in how buildings are designed, built, and operated. A steering committee of USGBC developed LEED aiming to encourage and accelerate global adoption of sustainable green buildings (USGBC, 2011) BREEAM Environmental Weightings. LEED is a voluntary certification program developed through a consensus process involving key stakeholders in order to provide an inclusive simple framework for assessing building performance and meeting sustainability goals (Zimmerman and Kibert, 2007). To calculate the achieved credits LEED uses a simple additive approach (1 for 1) with all criteria being weighted equally, rather than using a weighting system (See Table 2.2).

Table 2.2: LEED Credits Distribution

Category	Possible points
Sustainable Sites	26
Water Efficiency	10
Energy and Atmosphere	35
Materials and Resources	14
Indoor Environmental Quality	15
Innovation in Design	6
Regional Priority	4

2.6.3 SBTool

SBTool, formerly called GBTool, is structured in four levels, with the higher levels logically derived from the weighed aggregation of the lower ones, using 1 goal, 7 issues, and 29 categories (Chew and Das, 2008). This is designed to enable users to reflect the different priorities, technologies, building traditions, and cultural values existing in the various regions and countries involved in the assessment process. For this reason, its benchmarks and weights are improved by national teams (Table 2.3), by means of various methods such as the analytic hierarchy process (AHP) (Chang et al., 2007, Lee and Burnett, 2006). The criteria and sub-criteria of each performance issue are scored using a linear scale from -2 to +5.

Table 2.3: SBTool Environmental Weightings

SBTool Categories	Weightings %
Site Selection, Project planning& Development	7.6
Energy and Resource Consumption	21
Environmental loadings	25.2
Indoor Environment Quality	21
Service quality	15.1
Social & Economic aspects	5
Cultural & perceptual Aspects	5

2.6.4 CASBEE

CASBEE is a joint governmental, academic, and industrial sector approach used in Japan. The main four aspects of CASBEE include energy efficiency, resources efficiency, local environment and indoor environment which comprise a total of 80 sub-criteria which are further re-categorised into two main groups: Q (Quality), and L (Loadings) (Horvat and Fazio, 2005). In order to evaluate the sustainability of green building, CASBEE adopts the value of BEE (Building Environmental Efficiency), as illustrated by the equation below (Mao et al., 2009). Building Environmental Efficiency Equation (BEE) (IBEC, 2008).

$$BEE = \frac{(BuildingEnvironmentalQuality)}{(BuildingEnvironmentalLoadings)} \tag{2.1}$$

CASBEE is differentiated from other assessment systems by its unique approach to the completion of its final result. Rather than relying upon a simple additive approach, CASBEE introduces the concept of Building Environmental Efficiency (BEE) with weighting coefficients for the assessment of different kinds of buildings (Chew and Das, 2008). These are based on the outcome of a questionnaire survey of key stakeholders such as designers, building owners and operators and subsequently the responses are analysed by the analytic hierarchy process (CASBEE, 2011).

Weighting system: Due to the inherent complexity of the environmental weighting system and the lack of an objective basis, the determination of the weighting system mainly involves consensus process. In other words, expert opinion seeks to rank the parameters, after which weightings are allocated by collecting and analyzing data through various methods, such as the analytic hierarchy process (Chew and Das, 2008). Such systems can be classified as (Chew and Das, 2008; Horvat and Fazio, 2005):

- Simple additive (1 for 1) such as LEED.
- Pre-weighed credits such as BREEAM.
- Weighing after scoring such as SBTool.
- Others such as CASBEE.

Table 2.4: Main features of BREEAM, LEED, SBTool and CASBEE

Comparison items	BREEAM	LEED	SBTool	CASBEE
Location, year	UK, 1990	US, 1998	Canada, 1998	Japan, 2001
Developed by:	BRE(*non-profit third party*)	USGBC(*non-profit third party*)	iiSBE *(international non-profit collaboration*)	JaGBC (*joint of government, industry, academy*)
Sustainable Categories	Management, Health and Wellbeing, Energy, Transport, Materials, Water, Waste, Land Use and Ecology, Pollution and Innovation.	Sustainable Site, Indoor Environmental Quality, Water Efficiency, Energy & Atmosphere, Materials &Resources, Innovation, and Regional Priorities	Site Selection, Project Planning and Development, Energy and Resource, Environmental Loadings, Indoor Environmental Quality, Service Quality, Economic and Social aspects, Cultural and Perceptual Aspects	***Building environmental quality:*** Indoor Environment, Quality of Service, Outdoor Environment on Site; ***Environmental Load:*** Energy, Resources & Materials, Offsite Environment
Assessed building	Residence, Retail, Industry unit, Office, Court, School, Healthcare, Prison, Multi-function building, Unusual building.	Residence, School, Retail, Commercial building, Multifunction building, Healthcare.	Almost any building	Residence (multi-unit), Retail, Industrial temporary construction, Multi-function building
Flexibility	Flexible in the UK, and relatively overseas	Flexible in the USA, and relatively overseas	High flexibility around the world	Flexibility in Japan, and relative low flexibility overseas
Approach to Scoring Criteria	Additive Pre-weighted credits approach	Additive Simple approach (1 for 1)	Additive improved weighted scoring approach	Special
Ratings	Unclassified <30 Pass ≥30 Good ≥45 Very good ≥55 Excellent ≥70 Outstanding ≥85	Certified40–49 points Silver 50–59 points Gold 60–79 points Platinum 80+ points	-1 = unsatisfactory • 0 = minimum acceptable performance • 5 = best practice • 1 to 4 =intermediate performance levels • 2 = normal default	BEE=3.0 (*Excellent*), BEE=1.5~3.0 (*V.Good*), BEE=1.0~1.5(*Good*), BEE=0.5~1.0(*Fairy Poor*), BEE=less than 0.5(*Poor*)
Reference	(BREEAM, 2011, Horvat and Fazio, 2005)	(Horvat and Fazio, 2005, LEED, 2011)	(Horvat and Fazio, 2005, iiSBE, 2011)	(CASBEE, 2011, Horvat and Fazio, 2005)

2.7 Justification for developing new scheme

Almost all environmental assessment methods have been designed to suit a specific territory. Evidence suggests (Cole, 1998; Cooper, 1999; Crawley and Aho, 1999; Kohler, 1999) that EAM were developed for different, local purposes, and are not fully applicable to all regions. More specifically, certain environmental factors may hinder the direct use of any existing environmental assessment. Examples of such factors are as follows:

- Climatic conditions
- Geographical characteristics
- Potential for renewable energy gain
- Resource consumption (such as water and energy)
- Construction materials and techniques used
- Building stocks
- Government policy and regulation
- Appreciation of historic value
- Population growth

In recent years, a gradual move to support sustainable assessment has been observed in the Gulf nations (GCC) (Assaf and Nour, 2014; QSAS, 2013). For example, the United Arab Emirates has established sustainable techniques of assessment; the PRS (pearls rating system) is the main division of the Estidama scheme, utilised as a construction appraisal structure in Abu Dhabi (Estidama, 2015). The establishment of this scheme was a national endeavour backed by private institutions aiming to change Abu Dhabi into a sustainable city. The key elements of PRS sustainable categories (Estidama, 2015) are as follows:

Integrated Development Process: promotes teamwork to maintain the constructed environment and sustain standards of administration throughout the lifetime of the undertaking.

Natural Systems: safeguards environmental value and ecological habitat within the area.

Liveable Structures: promotes a good standard for interiors as well as exterior setting.

Precious Water: promotes water efficiency planning and use.

Resourceful Energy: promotes energy efficiency and use of renewable resources.
Stewarding Materials: promotes the employment of green construction techniques focusing on whole-of-lifecycle.

Innovating Practice: promotes creative resolutions for construction design.

Additionally, the state of Qatar has taken steps toward the application of values for sustainable progress. This is evident in the establishment of Qatar Sustainable Assessment System (QSAS) (QSAS, 2013). The sustainable categories of QSAS comprise:

Urban Connectivity: comprising criteria for urban loading and movement (e.g. traffic overcrowding, and limiting air, light and noise pollution).

Site: includes criteria for choice of land, development and planning.

Water: encompasses criteria for water efficiency planning and use.

Energy: encompasses criteria for energy efficiency planning and CO_2 minimisation.

Indoor Environment: encompasses criteria for indoor ecological standards.

Materials: encompasses criteria for materials employment throughout the lifetime of the structure.

Management & Operations: encompasses criteria for structural design, administration and operations.

Cultural & Economic value: promotes the maintenance of the domestic economy and heritage.

Before this advancement, in the UAE and Qatar, global sustainable assessment methods LEED and BREEAM were proposed in altered form for use by GCC bodies; the BREEAM Gulf, and Emirates LEED. However, the LEED program employed in the UAE was mainly based on the initial US LEED, including almost identical construction assessment categories and criteria. The differences observed in LEED UAE raised overall credits to 72 from 69. This minor alteration aimed to bestow additional credits for water efficiency in view of the insufficiency of water within the UAE. Thus, the Emirates LEED is unsuitable for employment in the UAE as it lacks numerous features that should be reflected in any logical appraisal of the UAE built environment; notably, social and economic features (Al Salmi et al., 2013). Sharma argued that the LEED rating structure is entirely unsuited for desert environment; he points regarding site selection (wetlands and flood plains) and storm water design, bicycle storage, changing rooms, certified wood, and maximising views and day light, are all of little relevance. Thus, the UAE government resolved to establish its own sustainable assessment system Estidama to acknowledge the reality that LEED was not fitted to the context of the UAE (P. Sharma, 2010).

Additionally, BREEAM-UK has advanced and progressed over the past few years. This development tool has been criticised for its absence of general transparency (Inbuilt, 2010). BREEAM has had a considerable impact on BREEAM Gulf/Middle East and on the majority of methods of environmental assessment (Mao et al., 2009). In fact, a critical review of BREEAM Gulf/Middle East classes disclosed a strong similarity with the initial BREEAM-UK, with just a few small alterations in some criteria. For instance, watercourse contamination was a criterion employed in BREEAM Gulf/Middle East, although in Saudi Arabia, watercourses are uncommon; thus, it would have been better to offer criteria for sand storm contamination and dust shielding, as the incidence of these events is more frequent than watercourse contamination. Additionally, the BREEAM weighting structure seems to have been initially established for use in one place, and was only applied to numerous other areas subsequently when closely observing initial categories and criteria environment.

A critical appraisal of both QSAS (Qatar Sustainable Assessment System) (QSAS, 2013) and Estidama (PRS) (Estidama, 2015) find that QSAS is very influenced by LEED and BREEAM. It excludes some sustainable categories and criteria, such as Quality of Services (Strength, Operations, etc.), building expenses and alternative economic elements. Moreover, regarding credit distribution tactics, QSAS relies on global codes and directions; thus, buildings must comply with global codes and ecological standards to be awarded credit. Additionally, the UAE Estidama was regarded as a state endeavour to construct a sustainable city in the form of a Master city. This influences the perspective of policy makers seeking to encompass particular standards, and to satisfy the vision of decision makers, as well as surpassing social and economic standards, that could be regarded as less significant by decision makers.Therefore, evidently, prime building performance standards in developed countries tends to have limited application to other regions. Therefore, achieving a consensus from Saudi and allied experts regarding applicable sustainability criteria will be the optimum solution upon which to base an appropriate calibration for local conditions, while also taking into account aspects that have been overlooked, such as vernacular architectural principles, cultural and social aspects, and economic factors.

2.8 Comparison of the selected EAM

As mentioned earlier that IEA Annex 31 (2001) and ATHENA institute (2000) - the most illustrious classification systems in environmental assessment methods - the investigation of assessment systems requires them to be within the identical classification level. It is therefore important to note that BREEAM, LEED, SBTool and CASBEE were classified in the same domain: passive tools for rating systems (IEA, 2001, Trusty, 2000). The central function of environmental assessment methods is the examination of building environmental performance, involving a list of criteria being ranked against environmental performance in order to evaluate appropriately the degree to which the assessed building is sustainable. In order to fully understand these systems, each scheme has been examined to comprehensively and coherently consolidate their strengths into potential new systems.

2.8.1 Health of Indoor Environment

Quality of indoor environment is considered to be one of the key objectives in all environment assessment tools, with the aim of delivering an appropriate healthy level of lighting & illumination, noise & acoustics, ventilation rate and thermal comfort, as well as protecting the occupants from microbiological contamination or any hazardous substances that might be emitted from the indoor materials (BRE, 2011).

Table 2.5: Comparison of health of indoor environment criteria

Health of Indoor Environment		**BREEAM**	**LEED**	**CASBEE**	**GBTool**
Noise & Acoustics	Noise level	✓	✓	✓	✓
	Sound insulation	✓		✓	✓
	Sound absorption	✓		✓	✓
Lighting & Illumination	Lighting controllability	✓	✓	✓	✓
	View out	✓	✓	✓	✓
	Glare measure & control	✓	✓	✓	✓
	Illumination level	✓	✓	✓	✓
	Daylight factor (DF)	✓	✓	✓	✓
Ventilation	Potential for natural ventilation	✓	✓	✓	✓
	Ventilation system	✓	✓	✓	✓
	Air purification- supply of fresh air	✓	✓	✓	✓
	Air quality sensors- CO_2 Monitoring	✓	✓	✓	✓
Contamination level	Volatile organic compounds (VOC)	✓	✓	✓	✓
	Electromagnetic pollution				✓
	Microbiological contamination level	✓	✓	✓	✓
Thermal comfort	Zoned control	✓	✓	✓	✓
	Cooling/heating/humidity control & comfort	✓	✓	✓	✓

This category is called Health and Wellbeing in BREEAM and Indoor Environment Quality in LEED, CASBEE and SBTool. All four tools cover the main indoor environment criteria differently (See Table 2.5): central criterion in LEED is low-emitting material, while the dominant criteria in BREEAM and SBTool are the HVAC system, plus lighting and illumination. CASBEE covered all these criteria to some extent, with more consideration of sonic environment, whereas the LEED evaluation process seems to neglect consideration of acoustic performance (Papadopoulos and Giama, 2009). While there is some uncertainty about the health effects of exposure to magnetic fields, SBTool includes an examination of Electro-Magnetic Pollution, based on a belief that these have the potential to harm building occupants (Cole and Larsson, 2002).

2.8.2 Building Management

The core management subjects of most environmental assessment tools are management of site activities and the construction process, with the goal of ensuring the protection of both social and environment aspects, in addition to an appropriate level of commissioning. Providing building guidance that demonstrates clear understanding of how buildings can be sufficiently operated and maintained is one of BREEAMs sustainable principles. Another important consideration is increasing levels of local ownership by consulting relevant stakeholders in the design process; thereby various perspectives would consider conserving resources and improving management strategy (BREEAM, 2011).

Table 2.6: Comparison of management criteria

Management	BREEAM	LEED	CASBEE	SBTool
Commissioning	✓	✓	✓	✓
Consultation	✓			
Considerate constructors	✓			✓
Home user guide	✓			✓
Construction process planning				✓
Construction site impacts	✓			
Security	✓			

The above table 2.6 demonstrates that BREEAM has independently established the most significant principles of sustainable management, whereas both LEED and CASBEE can be considered relatively weak in this regard. SBTool has similar trends to BREEAM, dealing with management issues in a separate category with more consideration of construction process planning criterion (Lee and Burnett, 2006).

2.8.3 Sustainable Site & Ecology

The key purpose of this category is to reduce the potential on site pollution from construction activities, with ecological care ensured through control of soil erosion, watercourse sedimentation, CO_2 emission and biodiversity protection. This category also aims to deliver a good level of communication, through easy access to public services and relevant facilities and adequate provision for cyclists, drivers and pedestrians (See Table 2.7)(BRE, 2011, USGBC, 2011).

Table 2.7: Comparison of sustainable site & ecology criteria

Sustainable site & Ecology		**BREEAM**	**LEED**	**CASBEE**	**SBTool**
Construction Site	Site selection	✓	✓	✓	✓
	Site protection	✓	✓	✓	✓
Ecological Value	Contaminated land	✓	✓	✓	✓
	Mitigation ecological impact	✓	✓	✓	✓
	Enhance site ecology	✓	✓	✓	✓
	Biodiversity protection	✓	✓	✓	✓
Transport	Accessibility	✓	✓	✓	✓
	Density development	✓	✓	✓	✓
	Community connectivity	✓	✓	✓	✓
	Pedestrian & Cyclist safety	✓	✓		✓
	Car parking capacity	✓	✓	✓	✓

In BREEAM this category was divided into Land Use & Ecology and Transport, which is equivalent to the Sustainable Site category in LEED. The CASBEE and SBTool consider these issues under Outdoor environment on site and Site development respectively. While BREEAM and LEEDs approaches in this regard are similar in terms of criteria, LEED pays more attention to Brownfield redevelopment and Public transportation access (USGBC, 2011). SBTool considers Land for building use of vital importance; whereas CASBEE gives more attention to Local characteristics, Outdoor amenity and townscape & Landscape (Kawazu Y Yokoo N, 2005), without consideration of the safety of pedestrians or cyclists (Sev, 2011).

2.8.4 Energy Efficiency

Due to its significant impact on environment, energy efficiency design has the largest proportion of credits distributed amongst the environmental categories (BRE, 2011, USGBC, 2011). Assessment systems therefore place vital importance on energy design, renewable energy strategies, energy conservation and monitoring when targeting efficient use of environmental resources or the care of surrounding atmosphere, especially with increasing concerns about many ecological threats such as global warming, sea level rise and acid rain (See Table 2.8) (Lee and Burnett, 2006).

The evaluation of CO_2 emissions and energy consumption under both BREEAM and LEED requires the use of supplementary tools and guidance such as Standard Assessment Procedure (SAP), American Society of Heating, Refrigerating and Air-conditioning

Table 2.8: Comparison of energy efficiency criteria

Energy efficiency		BREEAM	LEED	CASBEE	SBTool
Energy Performance	HVAC System	✓	✓	✓	✓
	Ventilation rate	✓	✓	✓	✓
	Lighting: internal	✓	✓	✓	✓
	Lighting: external	✓		✓	✓
	Hot water system	✓	✓	✓	✓
	Heat transmission	✓	✓	✓	✓
Natural Resources	Renewable energy technology	✓	✓	✓	✓
Efficient Operation	Energy monitoring	✓	✓	✓	✓
	Optimum performance and energy saving	✓	✓	✓	✓
	CO_2 Mitigations strategy	✓	✓	✓	✓
	Insulant GWP	✓			

Engineers (ASHRAE). Papadopoulos and Giama (2009) state that extra criteria have been listed in BREEAM, however, such as Internal and External lighting, insulant Global Warming Potential (GWP) and Ecolabelled goods. Additionally, commissioning in the LEED evaluation framework is a prerequisite, without which it cannot be assessed (Papadopoulos and Giama, 2009).

CASBEE is generally considered to be strong in assessing Efficiency in Building Service System, whereas this area is not important in BREEAM, LEED or SBTool (Kawazu Y Yokoo N, 2005). SBTool has a different approach to the issue of energy efficiency, evaluating the electrical peak demand for building operations (Cole and Larsson, 2002).

2.8.5 Water Efficiency & Waste Management

One of the more prominent current issues worldwide is water conservation. In recognition of water being a limited and therefore valuable resource, the assessment systems seek to effectively manage action toward water use. These steps aim to ensure reduction of the consumption of primary water resources through the implementation of strategies such as rain water harvesting, grey water recycling and irrigation system insulation(Environment-agency, 2011) . Due to their hazardous impact on human health and environmental pollution both wastewater and solid waste are of vital importance. Waste treatment and recycling facilities used in parallel with sophisticated waste management have the potential to insulate humans and their surrounding environment from the consequences of waste risk, and also attain the advantages of treatment and recycling (See Table 2.9) (BRE, 2008, IBEC, 2008).

Table 2.9: Comparison of water efficiency & waste management criteria

Water efficiency & Waste management		BREEAM	LEED	CASBEE	SBTool
Water	Water consumption	✓	✓	✓	✓
	Rain water harvesting	✓	✓	✓	✓
	Grey water recycling	✓	✓	✓	✓
	Innovative wastewater technology	✓	✓		
	Water fixture & conservation strategy	✓	✓	✓	✓
	Irrigation system	✓	✓	✓	✓
	Recharge of ground water				✓
Waste	Construction waste management	✓	✓	✓	✓
	Waste treatment	✓	✓	✓	✓
	Recycling facilities	✓	✓	✓	✓

The majority of the criteria and sub-criteria in this section are assessed under all four assessment schemes. However, the SBTool evaluation framework examines the criterion Recharge of ground water under Environmental Loading (iiSBE, 2011), which makes it relevant to be evaluated within the efficiency of water consumption. This is because in some parts of the world, ground and underground water storage stills comprise the main source of water (Environment-agency, 2011).

2.8.6 Materials

A fundamental aim of sustainable principles is ensuring best practice in terms of resource consumption (Energy, Material, and Water). This means that building materials are an important category in the majority of assessment schemes, due to their complicated lifecycle process from extracting raw materials till disposal stage. Sam (2010) states that environmental assessment methods aim to mitigate the potential consequences of consuming materials, by taking to account the following practices (Sam, 2010): Avoid using virgin resources as much as possible. Less energy used in the process of extraction, processing and transport to the construction site. Water- efficiency processes at the manufacturing stage. Avoid using polluted and non local materials. Encouraging the use of recyclable and environmentally friendly material.

Table 2.10: Comparison of material criteria

Material	BREEAM	LEED	CASBEE	SBTool
Material with low environmental impact	✓	✓	✓	✓
Use of non-renewable -virgin materials	✓	✓	✓	✓
Re-use of structural frame materials	✓	✓	✓	✓
Use of non-structural materials	✓	✓	✓	✓
Building fabric component (insulation)	✓	✓	✓	✓
Use of finishing materials	✓			✓
Responsible source of materials	✓			
Material efficiency over its life cycle (LCA)	✓	✓	✓	✓

To some extent BREEAM has extra and more specific criteria in this category (See Table 2.10). This may be due to the large database that BREEAM relies on, the Green Guide to Specification, which contains over 1500 specifications used in various types of building. This database plays an instrumental role in supporting designers in making decisions based on the performance of a material against a particular environmental impact. In other words, this knowledge encourages the use of materials that have a lesser impact on the environment, taking account of the full life cycle and responsible sourcing of materials for basic building elements and for finishing elements targeting to recognise and encourage the specification of responsible sourcing of materials (BRE, 2011).

In LEED, greater emphasis is placed on the reusability and maintenance of construction materials, with the use of finishing materials and the responsible source of materials being relatively poorly covered in its evaluation framework (Papadopoulos and Giama, 2009). In terms of the consideration of environmental loading, CASBEE and SBTool both emphasise the reduction of the usage of non-renewable resources, in conjunction with avoiding the use of materials with pollutant content (CASBEE, 2011, Cole and Larsson, 2002).

2.8.7 Economic Aspects

Attaining superiority in the construction industry is the goal that attracts the interest of most key stakeholders and therefore sustainable principles must be built upon a careful consideration of the financial aspect. Thus to meet best practice, environmental assessment methods are concerned with the management of life cycle cost, construction cost, and operating maintenance cost in a sustainable manner (iiSBE, 2011).

Table 2.11: Comparison of economic aspects

Economic aspects	BREEAM	LEED	CASBEE	SBTool
Construction cost				✓
Life cycle cost				✓
Operating and maintenance cost	✓	✓		✓
Investment risk				✓
Affordability of residential rental				✓

One of the barriers confronting most environmental assessment methods is financial issues. SBTool covers a wide range of economic aspects, whereas BREEAM, LEED and CASBEE cover these issues poorly in their assessment framework, As illustrated in table 2.11 (Grace K.C, 2008, Lee and Burnett, 2006).

2.8.8 Pollution

The protection of the surrounding environment is a key objective in sustainable construction and is therefore given due consideration during the assessment of building environment. The potential natural risk, harmful substances, hazardous emissions and lighting pollution are all deemed to be vitally important in the evaluation of building environment (Environment-agency, 2011).

Table 2.12: Comparison of pollution & risks criteria

Pollution & Risks	BREEAM	LEED	CASBEE	SBTool
Refrigerant GWP – Building services	✓	✓	✓	✓
Night light and noise pollution	✓	✓	✓	✓
Preventing refrigerant leaks	✓			
Watercourse pollution	✓	✓	✓	✓
Heat island effect		✓	✓	
NOx emissions from heating source	✓			✓
CO_2 Emissions	✓	✓	✓	✓
Fire risk	✓	✓	✓	✓
Natural disaster (Flooding, Hurricanes. etc.)	✓	✓	✓	✓

Potential natural risks and pollution are dealt with in various ways by these four schemes. For instance, BREEAM assesses the factors more likely to exacerbate global warming potential and its related impacts, which it achieves through an evaluation of refrigerant leaks and other hazardous emissions such as NOx and CO_2. The Heat island effects criterion is evaluated by LEED and CASBEE, and mistreated in BREEAM and SBTool (Kawazu Y Yokoo N, 2005). SBTool uses a number of different criteria for the appraisal of atmospheric emissions, such as ozone-depleting substances, acidifying emission and emissions leading to photo-oxidants during facility operations (Cole and Larsson, 2002). As CASBEE was established for evaluation within the specific local conditions of Japan, the potential risk and pollution has been listed under the Of-Site Environment category which includes further issues such as wind damage and sunlight obstruction, and earthquake resistance, See Table 2.12 (CASBEE, 2011).

2.8.9 Quality of Service

There are a number of building characteristics that facilitate both a higher quality of operation and attendant services. These have indirect but significant effects on resource use, environmental loadings and indoor environmental quality (Cole and Larsson, 2002).

Table 2.13: Comparison of quality of service criteria of pollution & risks criteria

Quality of Service	**BREEAM**	**LEED**	**CASBEE**	**SBTool**
Functionality and Usability			✓	✓
Flexibility and Adaptability			✓	✓
Durability and Reliability			✓	✓
Controllability of system	✓	✓	✓	✓
Maintenance of performance	✓		✓	✓
Impact on quality of service and adjacent property			✓	✓

Quality of services is considered at great length in both SBTool and CASBEE (As illustrated in Table 2.13), whereas neither BREEAM nor LEED focus on this area (Lee and Burnett, 2006). In CASBEE, however, various criteria such as earthquake resistance are not listed in the SBTool framework evaluation, because, as mentioned above, it was originally established to evaluate Japans provinces that are active in earthquakes.

2.8.10 Innovation

In order to encourage and recognise exemplary performance in all sustainable aspects, such as procurement strategy, design feature, management process or technological development BREEAM and LEED established supplementary criteria to reflect exceptional performance.

Table 2.14: Comparison of innovation criteria

Innovation	BREEAM	LEED	CASBEE	SBTool
Exemplary performance	✓			
Innovation in design	✓	✓		

LEED displays a similar trend to BREEAM, in terms of the way in which design teams and projects are able to meet the opportunity to achieve exceptional performance that exceeds the requirements (LEED, 2011). In terms of CASBEE and SBTool, no measurement of supplementary criteria is possible with regards to their evaluation framework(See Table 2.14).

2.9 Critique on the well-known EAM

Techniques for preparing sustainable and environmental assessment methods have an increasing role in the identification of human activities which will potentially affect ecological loading, economic elements, and social aspects (Wallhagen et al., 2013). Therefore, the initial direction taken during this research involved concentrating on classifications for sustainable assessment. However, it was observed at this stage that there are different categories of building assessment that are also commonly considered, a case in point, in (Berardi, 2012) explains different types including: building lifecycle assessment, quality assessment, environmental assessment, etc. Hence, following a critical review the selection of a well-known EAM was made. This assisted in the study of the most relevant and matching domains, that support the meeting and setting of research objectives.

A critical review of well-known EAM (BREEAM, LEED, SBTool and CASBEE) was conducted, and resulted in identification of principal deficiencies, which should be improved upon by any new assessment method. These critical aspects included: (a) weighting systems, (b) building assessment criteria, (c) economic aspects, (d) quality of services, (e) environmental aspects, and (f) flexibility of adaptation. Details of these will be given in the following section.

It is a challenge for any single EAM to be appropriate to all world regions, as every area has its own specific individual components related to geographical and environmental differences (Kajikawa et al., 2011; Wong and Abe, 2014; Lee, 2013; Cole and Jose Valdebenito, 2013). Thus, a weighting system comprises a means to manage perspectives for credit distribution, which can be implemented by providing techniques and environmental assessment methods (Ali and Al Nsairat, 2009; Lee and Burnett, 2006). The EAM systems employ various strategies for assessment, for instance, the BREEAM and SBTool employ a weighted system that prioritises environmental issues, while LEED employs a simple additive approach (1 for 1) which simplifies the process. However, making an assessment without weighting inevitably leads to criticism, because it is still the only approach approved to comprehensively evaluate and prioritise issues regarding the built environment (Lee, 2013). In consideration of this, CASBEE proposes weighting coefficients that can be modified to suit local conditions, such as climate, or that reflect the prioritisation of policies (CASBEE, 2011). Therefore, when intending to develop a new EAM, it is appropriate to offer a customised weighting system to meet local and regional priorities, through a process of consensus (iiSBE, 2011).

Another important consideration is that due to the similarity of EAM techniques in broad categories (energy, water, materials, etc.), certain sets of criteria are considered central assessment dimensions; for instance, LEED and BREEAM encompass around 70 criteria; CASBEE encompasses 80 criteria; and SBTool has over 150 criteria. This has resulted in complex structures, comprising large quantities of specific information that needs to be arranged and evaluated (Haapio and Viitaniemi, 2008). Numerous schemes have tended toward generalisation to capture the majority of environmental assessment criteria inside their assessment structure. Embracing multiple criteria limits the accuracy of EAMs, and does not lead to a specific reflection of performance in the built environment. Therefore, emphasis should instead be placed on a single common goal (e.g. efficiency of the built environment), consulting professionals about the most relevant criteria to pursue to meet that goal.

Financial considerations are an important aspect of sustainability advancement and have a considerable impact on both developing and developed nations. Developed nations aim to decrease the ecological damage caused by maintaining living standards, while living standards are considerably lower in developing nations (Cole and Jose Valdebenito, 2013) signifying that economic and social issues are more significant than ecological issues to these nations (Libovich, 2005). Thus, EAM should prioritise essential economic and social concerns (Gibberd, 2005). Nonetheless, LEED and BREEAM have both excluded the inspection of financial elements from their analytical structure. This opposes notions concerning the final value of sustainable development, as economic returns are crucial for all undertakings, and environmentally friendly actions remain costly to implement.

One point to be considered in the CASBE and SBTool, as mentioned in this research, relates to its assessment of significant criteria in the quality service category, which was partially disregarded by LEED and BREEAM. The significance of this category is encompassed by sustainable activities, such as adaptability and flexibility in the construction of structures, and alteration of inhabitants needs. Instances of this could encompass the amenability of HVAC structures, and future alterations to a new fuel, or to technologies for renewable energy, as well as the supply of sufficient clearance and access points to permit imminent adjustment (iiSBE, 2011). In addition, the complexity of structures often results in considerable ecological effects, rendering it challenging to approximate quantitatively the ecological effects of a structures environment, e.g. green plants, landscaping, pavements, parking lots, and infrastructure close to the structure (Lee and Burnett, 2006). Thus, each of the EAMs chosen has made attempts to integrate these effects in various ways aimed at decreasing discharges and managing resources. For example, CAS-

BEE competently addresses the issue by modelling exterior settings, like landscapes and townscapes, domestic features, and exterior facilities (Kawazu & Yokoo, 2005). LEED and BREEAM appraise plans for energy efficiency and the reduction of CO_2 discharges as chief ecological issues. The SBTool appraises matters of ecological effect within the operational phase, considering a variety of issues, several of which are beyond the influence of the designer, like greenhouse gas discharges, discharge of ozone-diminishing materials, acidifying discharges, and discharges resulting in photo-oxidants (Larsson and Cole, 2002).

The SBTool is regarded as the most customised assessment instrument available for enhancing regional green construction. As a result, it has been implemented in over 20 nations (Mao et al., 2009). Professional opinions (architects and experts, state authorities, intellectuals, and professors) relate to principal regional concerns and changes to local government that have been implemented; in particular the AHP, which can offer a suitable direction for SBTool implementation (Chang et al., 2007). Comparably, LEED and BREEAM modify structural assessment based on consensus, evaluating the views of professionals from various fields as a means to prioritise construction and accounting for ecological matters aimed at maintaining best practices. Nevertheless, it seems clear that most assessment systems play a significant role in reflecting sustainable development in the building sector with regard to building performance. However, their gradual evolution has the potential to enable such systems to surpass their roles as design tool. For example, by tackling issues such as financial returns, public awareness and willingness to cope with further development; these have the potential to make environmental assessment schemes more successful and to meet the overall objective of sustainability.

2.10 Summary

The above review and comparative study has investigated the most reliable and commonly used schemes in the global context (BREEAM, LEED, SBTool and CASBEE). Particular attention has been given to the credits allocation (weighting system) and sustainable development criteria in each scheme, with a focus on identifying the obvious similarities and differences between them. These tools have been highlighted as fundamental to successfully implementing the principles of sustainability, serving to map an essential road to sustainability in the construction sector (Mao et al., 2009a). Certain categories that are considered in both SBTool and CASBEE, such as Economic aspects and Quality of service, have been noted for consolidation into the potential new scheme, in addition to the most important environmental categories evaluated by BREEAM and LEED. This integration seeks to achieve superiority through a consideration of the most reliable criteria to reflect and diagnose environmental performance, as well as to encourage a smooth transition to sustainable practices, such as renewable energy, passive design and rainwater harvesting systems.

3 Methodology

3.1 Introduction

Research can be considered as being a careful investigation or journey towards discovery, with the applied process and technical aspect of the subject under investigation potentially leading to other indirect discoveries or support of a particular body of knowledge (Liu, 2008). The Economic and Social Research Council (ESRC) defines research as Any form of disciplined inquiry that aim to contribute to a body of knowledge or theory. Essentially, research methodology denotes the principles and procedures of the logical process for any given research project, describing the techniques for data collection and analysis chosen to answer certain research question and increase knowledge in the particular field (Liu, 2008).

This chapter presents the research design and methodology chosen for this study. It presents an overview of the research paradigm and an overview of the strongly related research approaches, including the qualitative research, quantitative research and triangle approach, along with examples of each. The specific research design of this study is then presented, beginning with a theoretical model (as illustrated in Fig 3.1). An explanation will then be presented of the chosen research instruments for data collection and analysis, including the Delphi technique (DT), and the Analytical Hierarchy Process (AHP). Each stage is proposed to test a hypothesis and answer a research question.

3.2 Research Paradigm and Approach

Research methodology describes the strategic way by which data will be collected and analyzed in order to meet the specific desired objective of the subject under investigation (Oates, 2006) The research methodology can be classified and informed by the underlying philosophical assumptions of a given researcher (Liu, 2008). There is no universally accepted philosophical research paradigm, with three principal, predominant schools of thought: positivism, interpretivism and critical theory (Oates, 2006). Positivism explained as:

Reality is objectively given and can be described by measurable properties which are independent of the observer, and his or her instruments. Positivist studies generally attempt to test theory, in an attempt to increase the predictive understanding of phenomena.(Myers and Avison, 1997).

Positivism is often strongly related to qualitative research. In contrast, interpretivism sees the knowledge of reality as a social construction by a particular person or observer. In another words, the reality derived by observation from one person is likely to be different from another, due to their different social perspectives, meaning that interpretivist researchers should endeavor to find out the truth from the perspective of participants. As such, this paradigm is more likely related to qualitative research. The third paradigm is critical theory research (Bryman, 2006). This was defined by Klein and Myers (1999) as being informed by the assumption that people can consciously act to change their social and economic conditions (Klein and Myers, 1999).

This section will emphasis more on the primary classification of research approaches, which is quantitative and qualitative, as a representative of the above paradigms. Therefore, in a number of various publications (Blum, 1955, Glaser, 1992, Liu, 2008, Yin, 2011), a clear distinction exists between quantitative and qualitative research. For instance, quantitative research methods are typically associated with the natural sciences that are intended to investigate natural phenomena, whereas qualitative research is more likely to perceive human experience and knowledge, this typically is associated with social and cultural investigations. Qualitative research involves a systematic process that is concerned with studying social science phenomenon, enabling researchers to understand various aspects associated with people, social and cultural problems (Myers and Avison, 1997). Examples of qualitative research include: ethnography, grounded theory, case studies, and action research.

Action research: the most cited definition of action research is Action research aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework. Action research seeks to extend the knowledge of the social science community and this make it distinguishable from the applied social science that contribute to the body of knowledge (Myers and Avison, 1997). Blume (1955) states that action research is a diagnosis of certain social problem aiming to improve the situation. All action research involve two stages: (a) a diagnostic stage that analyse the situation and develop a hypothesis; and (b) a therapeutic stage that test the hypotheses from social perspective (Blum, 1955).

Ethnography: it is a discipline of social and cultural anthropology concerned with the description of people or small scale societies. Ethnographic research considers the researcher ethnographer as the research instrument. This means that an ethnographer is therefore required to spend a large amount of time in the field, gathering and recording data as a non-detached observer. This process should be holistic to understand the situation from different angles including social, cultural, and economic (Oates, 2006).

Grounded theory: this is a research strategy that seeks to develop theory through organized data gathering and analysis (Glaser, 1992). According to Martin and Turner (1986), grounded theory can be described as "an inductive, theory discovery methodology that allows the researcher to develop a theoretical account of the general features of a topic while simultaneously grounding the account in empirical observations or data." Unlike many approaches, this research strategy proposes that there should be a continuous interaction between the collection and analysis of data (Myers and Avison, 1997).

Case study: it is one of the most commonly used strategies across many different fields of studies. Case studies are an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin, 2011). Myers (1997) explains that the case study method can be categorised as interpretive, positivist, or critical, depending upon the underlying assumptions of the researcher. Case studies can be broadly categorised as being exploratory, descriptive or explanatory. An exploratory study is used to set a hypotheses and research questions that support subsequent study, meaning that this kind of case study is most appropriate where there is a lack of literature about the phenomenon under investigation. A descriptive study is used to enrich the context of particular phenomenon and analyse the topic in detail. Finally, seeks to identify multiple underlying or causative factors that impacted upon the phenomenon under investigation. This in turn will examine the theories in the literature and see what is better matches the case study (Yin, 2011).

In contrast, quantitative research involves the explanation of a social science phenomenon using mathematical based approaches, using these to measure and control the theoretical variables that are influencing the phenomenon under study. It states that quantitative researchers rely upon numerical and statistical measurements to expand or develop knowledge of social life. Quantitative research has also been described as the adoption of natural science to form a scientific model (Henn et al., 2008). The process of quantitative research is to (a) Collect data using standardised approaches on a range of variables; (b) Explore patterns of causal relationships between the variables; (c) Examine the set theory by either confirming or denying hypothesis (Henn et al., 2008). The most common manifestations of quantitative research are:

Experimental studies: by controlling the tools, participants and environment, experimental studies are designed to study the influence and relation between variables in certain quantitative phenomenon. Experiments should therefore be based on manipulation of independent variables to examine the corresponding changes in the dependent variable (Oates, 2006). Laboratory investigations are an example of experimental research (Abu-Shaban, 2008). In quasi- or field experiments, the researcher does not have total control of the situation but following the spirit of classical experiment, research focusing on the observation of real life that as expected to natural experiment in life settings (Oates, 2006).

Survey based studies: these type of studies commonly utilise the questionnaire method to generate data. Other possible data collection methods include interview, observation and documentary analysis. Design of survey can go through six different activities: data requirements, data generation method, sampling farm, sampling technique, response rate and non-responses and sample size (Oates, 2006).

Simulation: this research technique involves the use of certain systems or processes (normally computer programs) to represent and investigate (Liu, 2008). Morgan (1984) suggests that a number of different purposes can be met out of using simulation, such as (a) explicit imitation of the behaviour of certain models; (b) examination of the performance of different techniques; (c) simplification of complex mathematical analysis; and (d) evaluation of the interactive aspects of complex random variables (Morgan, 1984).

A combination of the above methods is known as a triangle method approach, also known as the hybrid approach, integrated approach and combined methods approach. This methodological framework involves a process of utilizing more than one research methods to generate and analyse an assortment of data in one subject. There are four techniques for this: (a) Triangulation, which is used in parallel quantitative and qualitative methods; (b) Explanatory, which involves sequential use with quantitative proceedings; (c) Exploratory sequential use in reverse order; (d) Embedding one type of method to supplement other techniques (Bryman, 2006). This study in hand employs an exploratory mixed methodology approach, this due to the natural fluidity of the field of sustainable assessment methods, as it include a wide range of criteria from different ecological and economical dimensions (Ding, 2008).

3.3 Research design in this study

Since no sustainability assessment method has been developed for Saudi Arabia built environment, the design of this research involves various theoretical and empirical investigations as shown in Fig.2 Therefore, this development was divided into:

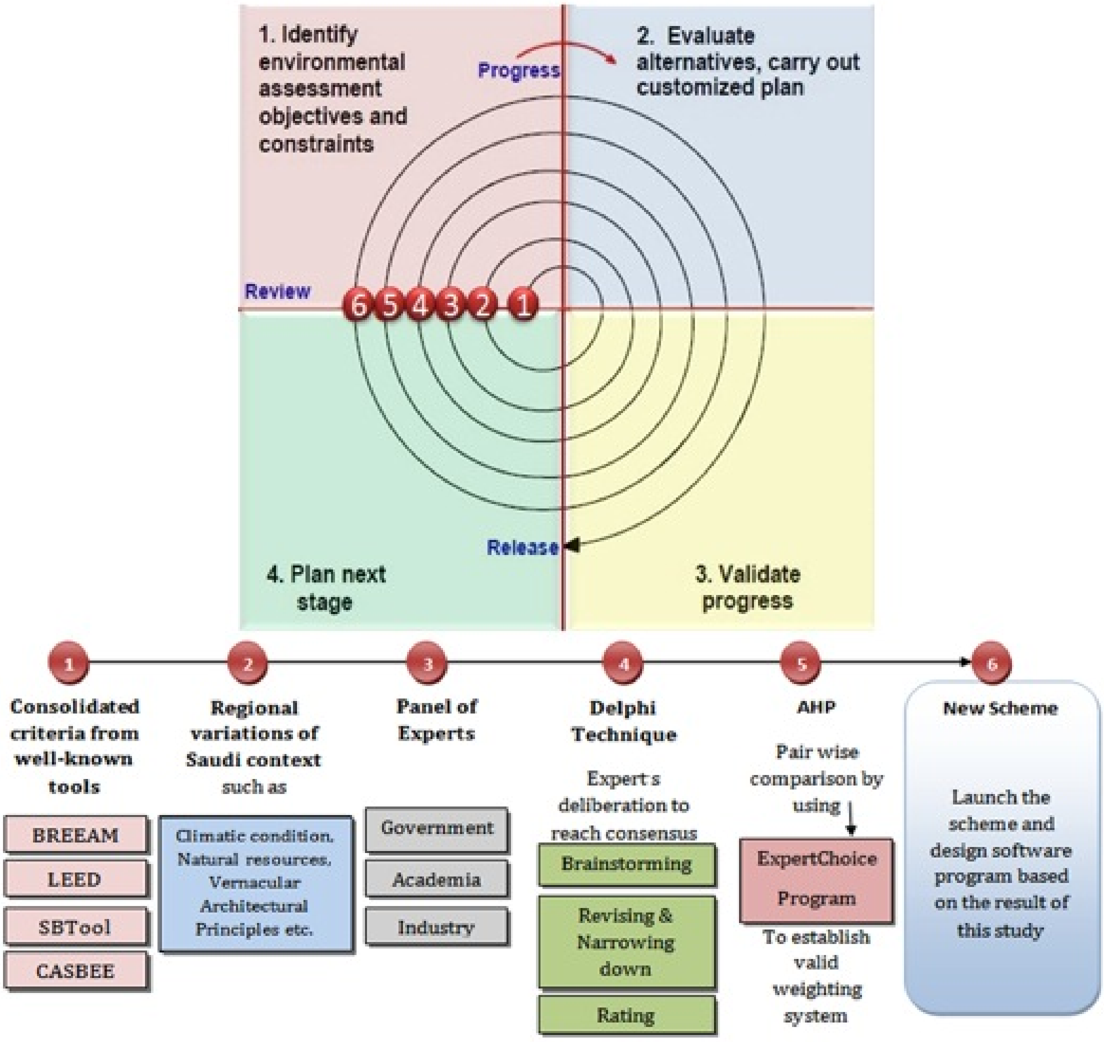

Figure 3.1: Theoretical model of SEAM development

- Use of proposed criteria and review the history and trends of the built environment of Saudi Arabia: it is generally held that the comparison of the most reliable environmental assessment methods shows areas of convergence and distinction. This is a potentially viable starting point in the development of new environmental assessment methods, principally by means of the generation and consolidation of environmental criteria (Cole, 2005).

- Appoint panel of experts: it is crucial to select and acquire expert opinions from a range of different fields on a common platform, such as government, academia and industry (Chang et al., 2007).

- Conduct study of Delphi technique: as sustainable building assessment criteria is considered to be a multi-dimensional method (Ding, 2008), Evidence suggest consensus basis process is the most applicable approach to developing a comprehensive and effective building environmental assessment criteria (Chew and Das, 2008). The Delphi technique is the most applicable approach in this respect, given its use of a three round system based upon extensive questionnaires in order to reach an agreement on the most applicable criteria.

- Conduct study of Analytical Hierarchy Process (AHP): building environmental assessment criteria vary considerably with regard to weight, AHP will therefore play an important role in the development of a potential weighting system that is capable of reflecting local needs as accurately as possible, as well as being able to prioritise building environmental aspects, and both economic and social issues.

- Testing: to ensure that new environmental assessment method is reliable, it should be subject to a rigorous testing stage. This in turn should verify the applicability of SEAM across Saudi Arabia provinces.

3.4 Stage one: Comparison of well-known methods

It is of utmost importance when developing a new environmental assessment method to begin with a comparative analysis of well-established methods (Cole, 2005). Hence the first stage of SEAM development was a comparisons and critical analysis of the most important and globally prevalent environmental assessment methods (Alyami and Rezgui, 2012). The selection of these methods relied on the credibility of the organisations that launched and operated them and their success in the marketplace. On the other hand, for the analysis of their content, this study utilised the technical manuals of the selected methods as primary sources of information as well as related publications that analyse and compare their components (categories and criteria). As indicated in the Literature Review above, the selected methods were BREEAM, LEED, SBTool and CASBEE and their components were compared in order to determine key similarities and differences among their underlying approaches, thereby establishing the potential categories and criteria of a new assessment method. More specifically, BREEAM and LEED are the leading systems, both being operated by very well known organisations (BRE and US-GBC) that have a proven record in the domain of sustainability development. A case in point, BREEAM has been used to certify 200,000 buildings, with over a million registered for assessment (BREEAM, 2011). BREEAM has also been used as a template for the creation of numerous other tools around the world, such as the GreenStar in Australia and the HK-BEAM in Hong Kong (Cole and Jose Valdebenito, 2013). With regards to LEED, the USGBC have stated that the number of projects certified and registered under LEED doubled in 2008, increasing from approximately 10,000 at the end of 2007 to more than 20,000 by the end of January 2009. The square footage of LEED-certified construction simultaneously rose by 92% during the same period, increasing from 148 million to 284 million square feet (LEED, 2011).

The final two methods were selected for slightly different reasons. SBTool was chosen because of its comprehensive nature, the flexibility that was incorporated in it since its inception and its resulting adaptability. Its success becomes apparent by its adoption by such countries as South Africa (Gibberd, 2003), Denmark (Laustsen and 2003), Hong Kong (Lee and Burnett, 2006), Taiwan and China (Chang et al., 2007). It is widely considered the most comprehensive of all environmental assessment methods (Cole and Larsson, 2002). Finally CASBEE has been chosen as its assessment system incorporates special features (particularly the weighting system), allowing for environmental issues to be prioritized in their given context (CASBEE, 2011).

3.5 Stage two: Delphi technique

The Delphi method was developed by the US defence industry during the early 1950s. The RAND Corporation, undertaking a study for the US defence industry, named it Project Delphi. A structured survey for confidential military objectives was conducted by the researchers. Dalkey and Helmer published the study in their article, An Experimental Application of the Delphi Method for the Use of Experts (Dalkey & Helmer, 1963). The studys principal goal was to obtain the most reliable consensus of opinion of a group of experts by a series of intensive questionnaires interspersed with controlled opinion feedback (Linstone et al., 1975) .

3.5.1 Delphi characteristics

The Delphi technique can be characterised as a method for structuring the communication amongst panel of expert seeking their opinion in a complex issue (Linstone et al., 1975). This technique has a systematic approach that assist the researcher to reach the consensus and stability of group judgment in subjective issues. Hence, the reliability and robustness of this technique are dependent on fundamental principles; Rowe and Wright (1999) characterize these by four key fundamental features (Adler and Ziglio, 1996; Linstone and Turoff, 1975) as follows.

Iteration: As Delphi method is a multi-stages process, the panellists must be participated in more than one round. This iterative manner permits the panellists to see the whole previous responses received from the rest of experts. Therefore, the panellists will have another chance to rethink and make his/her judgment accordingly.

Anonymity: Throughout the Delphi process the coordinator must maintain the panelists anonymity in order to eliminate the effects of the position, influence and/or socially dominant nature of certain experts. By implementing this, the panellists can state their opinion without fear or influence by others.

Controlled feedback: The exchange of data between the panellists is subjected to control and filtration stage. The coordinator receives the consultation after each round and carry out relevant analysis that will fed into the development of next stage. This process helps to avoid heated personal debates and facilitates smooth development of the study in question.

Statistical group response: As a Delphi study often deals with complex issues, it is of vital importance to employ reliable analytic methods in order for the study to reflect a precise overall group judgement Therefore, a number of statistical indices (Mean, Median, and IQR) can be used as a device to meet this goal and most importantly to reduce the pressure and influence on individuals toward conformity.

3.5.2 Justification of selecting DT to conduct this research

The development of SEAM involves the application of different research methods. The researcher first reviewed the possible approaches to determine the most suitable as a basis for developing a sustainable assessment method. Two research methods were considered: Firstly, a consensus-based approach to meet applicable building assessment criteria, the justification for selecting this approach is detailed below.

Sustainable and ecological context are commonly regarded as multi-dimensional (Ding, 2008) and the demand for scientific evidence proposes that a technique based on consensus is most appropriate for the establishment of inclusive and efficient building and environmental assessment scheme (Chew and Das, 2008). Therefore, the researcher selected the Delphi method as the research instrument. This is because the Delphi method is a prominent and appropriate research instrument for seeking consensus on complex issues (Loo, 2002). The technique is comprised of an anonymous and multi-phase survey. Responses and group opinions are collected in rounds, with the objective of competing additional rounds until consensus is attained on each criterion (Dalkey, 1951, Dalkey, 1963, Landeta and Barrutia, 2011). Since the first appearance of the Delphi method a number of modifications have been introduced to overcome certain limitations and allow customisation to specific research circumstances and objectives. There are different versions of Delphi techniques: classical Delphi, decision Delphi, ranking Delphi, and policy Delphi. These also involve different ways of communicating, including conventional and real-time Delphi (Okoli and Pawlowski, 2004; Linstone et al., 1975; Rowe Wright, 1991).

Classical Delphi concentrates on obtaining views and acquiring consensus among professionals on a specific portion of research. Data is gathered through a sequence of rounds, whose outcomes are then provided to professionals as background information in subsequent rounds. The procedure is concluded after a round in which outcomes attain consensus, demonstrating stability. Usually, the number of rounds required is three or more. In addition, conventional post is chosen as the method of communication. Therefore, confidentiality is acquired by means of the interaction procedure. Professionals can complete questionnaires in their own time and in the absence of social pressure from within the expert panel (Linstone et al., 1975).

Decision Delphi is an alternative to classical Delphi that arranges the decision making procedure and informs future reality, as opposed to merely forecasting it (Rowe Wright, 1991). In view of this objective, the panellists involved in a decision Delphi must be chosen based on their position and interest in resolution of the problem. Therefore, the panel for a decision Delphi does not need to be large, as it is implemented in circumstances where resolution creates an impact on the imminent development of matters resolved by the Delphi panel. It could be argued that a decision Delphi is not defined or prearranged; it is formed (Hasson and Keeney, 2011). The data gathering process for the decision Delphi may be processed using repetitions and managed response. However, the number of rounds vary. It is not necessary to conduct; three rounds (Hasson and Keeney, 2011). Additionally, confidentiality would be impossible to maintain, and could be termed quasi-anonymity. The names of the panellists are stated at the start of the research to promote responsibility; nonetheless, responses to the questionnaires are kept confidential (Linstone et al., 1975).

In contrast with classical Delphi, Policy Delphi also involves iterative rounds intended to gather data from professionals, although the objective of this Delphi type is not to acquire the assurance of harmony among professionals. The objective of policy Delphi comprises the production of contrasting views on a specific matter like policy options. In this case, professionals are the policy makers chosen to acquire different opinions, while repetitions may be planned as comparable to classic Delphi. Regarding mode of communication, this can take various formats, encompassing group meetings and gathering members together. For this kind of Delphi, confidentiality is established in the first round when the professionals respond to queries on their own. However, the question of confidentiality can be discarded in the following rounds as different perspectives appear and group meetings are required (Hasson and Keeney, 2011, Linstone et al., 1975).

The ranking Delphi is also another common version of the Delphi technique. It shares the same overall principles as other versions of the Delphi. However, it includes three rounds: brainstorming; narrowing dawn; and ranking. This type of Delphi was found to be the most appropriate for this research, as it involves the development and customisation of an environmental assessment method. A further reason for selecting this type is that its goal is to identify and rank key issues using a panel of experts, unlike other versions that simply require the participation of any concerned individuals (decision makers or lobbyist). Schmidt (1997) and Okoli and Pawlowski (2004) provide a comprehensive explanation/guidelines of how to carry out this type of Delphi technique.

As mentioned earlier, in relation to means of communication, Delphi studies can be categorised into the real time and conventional Delphi. A conventional Delphi is appropriate because it is a regular type of Delphi method used to generate a consensus using sequential rounds of consultations. The procedure commences with questionnaires, established for the initial round and allocated to the professionals. The outcomes are subsequently abridged and re-allocated, and the entire procedure is repeated until agreement or steadiness in reaction is attained (i.e. no more important alterations taking place amid the rounds). The key features of conventional Delphi encompass assured anonymity through the distribution of questionnaires, which can be completed individually by professionals in the absence of social intrusion from group meetings. Features of the conventional Delphi are repetitive consultations depending on groups of professionals and the provision of maintained feedback, as summarised from previous rounds (Linstone et al., 1975, Rowe Wright, 1991, Hasson and Keeney, 2011). Real time Delphi is not applicable in this study because it requires professionals to meet to resolve an issue. This is difficult for an individual PhD student to achieve, and it also shortens the time allocated to the consultation to one day, which does not meet the requirements of the ranking Delphi.

3.5.3 Delphi technique in this study

The first phase of the process was a preparatory one and included becoming familiar with the area of sustainable development and its related institutions in Saudi Arabia and approaching potential experts for the Delphi panel. During this phase I visited a number of different institutions, including: King Abdul-Aziz City for Science and Technology (KACST), Sustainable Energy Technology Centre (SETC), The King Saud University, the Saudi Environmental Society (SENS), the Saudi Green Building Council (SGBC), Riyadh Municipality and Saudi Oger Ltd. Furthermore, the main author attended two important gatherings of experts events in Saudi Arabia, namely: the Environmental Infrastructure Forum in January 2012 and the Gulf Environmental Forum in March 2012. The purpose of this pre-investigation was to inform (a) the research regarding the current practice of building assessment methods in Saudi Arabia, and then (b) the selection and nomination of potential experts.

3.5.4 Selection of the Delphi panel

The selection of the panel is a crucial element of a successful Delphi study (Rowe and Wright, 1999; Rowe and Wright, 2011; Linstone et al., 1975). Therefore, guidelines have been followed to ensure the suitability of the panel in terms of both size and composition (Dalkey & Helmer; 1963, Okoli and Pawlowski; 2004, R.C. Schmidt M. Keil, 2001). The number of experts in a Delphi panel can vary from 10 to 50 members, with the primary consideration being that the panel should be sufficiently large to allow the patterns of responses to be clearly seen; without being so large that complication and dissent becomes more likely (Okoli and Pawlowski, 2004; Delbecq A Gustafson D, 1975). Dalkey and Helmer (1963) argue that research should not put statistical emphasis on the size of a panel, because this issue is not important to the Delphi technique. Instead, the main objective should be to select panellists with the capability, knowledge, professional qualifications and relevant experience in the field under investigation (Loo, 2002). Therefore, the Delphi panel in this study comprises thirty-three members, including some of the worlds leading experts in the domain of sustainable and environmental assessment schemes, as well as professionals and highly-informed local experts from academia, government and industry (see table 16 below for panel composition). The selection of Delphi experts was guided by the following criteria:

- Academic specialist in the area of Sustainable Development (SD).
- Decision-maker, manager, or practitioner in the field of sustainable and green building.
- Accredited professional in one of the leading sustainable assessment systems.
- Individual with practical experience and sufficient knowledge of the sustainable development potential within the kingdom of Saudi Arabia.
- Expert with a level of influence regarding the adoption of the resulting methodology.
- Individual willing to participate.

3.5.5 Development of the Delphi questionnaire

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The questionnaire is designed to allow the experts to offer their judgements, with space provided for them to add, remove, criticise and justify their responses. Additionally, a

Table 3.1: Background of Delphi panellists

Experts	Organisation
Academia	Cardiff University
	King Saud University
	Cairo University
	Jordan University of Science and Technology
Research & Development	Arup
	BRE: Building Research Establishment
Industry	Saudi Aramco
	Saudi Oger Ltd
	Zuhair Fayez Partnership
	Arab Engineering Bureau
	Saudi Green Building Council
	Middle East Centre for Sustainable Development
	Aljabreen Contracting Company
	DEC Consultants
	Arab Contractor
	ETA Engineering & Contracting
	Saudi Diyar Consulting
	PMDC: Engineering Solutions Consultancy
	Perren Partners Company
	Nakheel Company
Government Organisations	King Abdualaziz City (KACST)
	King Abdulah Renwable energy
	Riyadh Munciplity

pre-test pilot study is distributed to seven academic professionals prior to the Delphi survey rounds, and their comments are used to improve the quality and clarity of the survey. As a starting point for the Delphi survey, potential criteria have been consolidated from a comparative study of well-known schemes (e.g. BREEAM, LEED) (Alyami and Rezgui, 2012). These consolidated criteria have been designed in questionnaire format (following a 5 point Likert-type scale), ranked from Not applicable to Very important. This approach seeks to determine the appropriateness of these consolidated criteria for Saudi built environment. The followed section is a brief explanation of Delphi rounds in this study.

3.5.6 Delphi data collection process

The Delphi questionnaire was designed and administered using a web based survey "Survey Monkey (http://www.surveymonkey.com/). This software tool was extremely effective, enabling collection of the entire data within 4 months in three separate rounds.

The first round sought to create a list of sustainable building assessment criteria, that are applicable to the Saudi Arabia built environment. This was based upon brainstorming process, with open-ended solicitation of criteria, in an attempt to obtain and clarify the key sustainable criteria for the Saudi context.The second round allowed the Delphi panellists to anonymously view the responses and feedback from the first round. This gave them the opportunity to revise their previous thoughts and reassess their initial judgements; within a Delphi study, the results of any previous iteration, whether specific statements or criteria can be changed or modified by individual panel members in later versions (Geist, 2010).The third round summarised the outcomes of the previous rounds, reflecting the opinion of the experts in the form of Statistical group response (Mean/Median). The survey was then sent again to the Delphi panel, to invite their final judgement; as this approach generally leads to improved judgements and increased overall accuracy (Schuckmann et al., 2012; Linstone et al., 1975).

3.6 Stage three: Analytic Hierarchy Process (AHP)

The analytic Hierarchy Process (AHP) was originally developed by Thomas Saaty in the 1970s. The AHP is a multi-criteria decision-making approach permitting decision makers to model a complex problem in a hierarchical structure (Saaty, 1994). The initial step in AHP consists in subdividing a research problem into smaller but interrelated components which are then composed into a comprehensive and coherent framework. The AHP framework or (model) is usually developed to break down complex problems into manageable elements. This, in turn, establishes different hierarchical levels (e.g. goal, category, and criteria or alternatives). The first level of the hierarchy model (goal) is the central issue that determines the scope of the subject matter. While the lower levels (categories, criteria and alternatives) are the indictors; by which the research problem can be evaluated (Saaty, 1994).

AHP, however, draws its strength from converting the subjectivity of the research problem into mathematics form. In other words, the assessment of relative importance, likelihood, or preference are analysed and then reflected in a set of priority ratio scale and overall weights. These processes are generated from conducting pair-wise comparisons that estimate the relative importance of a certain parameter with respect to another parameter (Saaty, 1990).

3.6.1 Justification of using AHP

The character of building performance and associated ecological factors continue to result in dispute. To date, no single-dimensional technique has been accepted as offering precise outcomes upon which to measure the effect of a constructed area on ecology (Ding, 2008). Thus, the notion of sustainable development has come to establish a basis for best suitable practice in human communication with ecology; inside multi-criteria techniques, ecological, social and economic viewpoints (Lee, 2013) Building environmental assessment techniques appear to encourage the application of sustainability and establishment values (Cole and Jose Valdebenito, 2013). The identification and promotion of best practice in the construction industry is a key strength of sustainable and ecological appraisal programs (Berardi, 2012).

For a program to be well-developed, a dependable weighting structure should be planned to accept and institutionalise the significance of a wide variety of sustainable construction considerations (Ali and Al Nsairat, 2009). Thus, there are several different evaluative methods created on the basis of available construction appraisal structures (Kajikawa et al., 2011). These methods were impacted by numerous elements, such as regional and geographic differences, climatic circumstances, socio-cultural and economic elements. This is why every area/nation requires its own structure, to assess whether the construction industry is implementing appropriate sustainability practices (Gou and Lau, 2014).

The AHP method is a well-known MCDM technique for providing applicable weighting systems in various scopes, it is an efficient technique for determining the weighting structure for construction appraisal programs in various nations. For example, a study performed by Hikmat and Ainsairat (2009) was intended to advance ecological appraisal instruments based on the local Jordanian context. Following analysis of global building assessment methods and recognising criteria appropriate to the Jordanian setting, AHP was used to offer an appropriate weighting structure. The result of this endeavour was the SABA Green Building rating System (Ali and Al Nsairat, 2009). An additional instance comprised the element of GBTool/SBTool, and was implemented in the Taiwan setting by Chang et al. (2007); cultural and regional elements were altered and prioritised to suit the Taiwan built environment. In this adaptation process AHP was a key tool resulting in the weighing system (Chang et al., 2007).

A related instrument with similar application to the AHP method, is the Analytic Network Process (ANP) (Cheng and Li, 2007). AHP and ANP offer means of quantifying immeasurable elements by employing pair wise comparisons with decisions that signify the prevalence of one aspect above another with regard to a shared feature (Chang et al., 2005). ANP is a simplification of AHP. Numerous resolution challenges cannot be arranged sequentially, as they concern communication and reliance on higher extent aspects in a sequence of lower extent aspects (Saaty and zdemir, 2005). Although the AHP signifies a structure comprising a unidirectional sequential AHP association, the ANP permits intricate associations amid resolution extents and features (Saaty, 1994). However, AHP is the best approach to use in the development of an EAM weighting system, as many publications substantiated (Ali and Al Nsairat, 2009, Chang et al., 2007, Chew and Das, 2008, Lee and Burnett, 2006, Berardi, 2012, Wong and Abe, 2014), this is because the dimensions of EAM are arranged hierarchically to meet a common goal (at the top of the hierarchy). They depend on meeting that goal, and do not implicate independent criteria that might be considered as multiple goals, such as are developed by ANP (Grener, 2012).

3.6.2 AHP design in this study

The construction of a hierarchical structure is a key step in AHP that seeks to simplify the research problem. It provides different levels in which the research issue is decomposed into manageable elements. This, in turn, aids the decision makers, who carry out the AHP study, to understand, focus, communicate and organise the research issue. AHP model can be presented in different diagrams but all share one concept; the most common hierarchy form of the research problem (illustrated in Fig 3.2). This illustrated model is divided into three levels: the highest level of the hierarchy represents the goal of the research problem; the second level represents evaluation categories or criteria; and the third level which represents the decision alternatives. According to Thomas Saaty, the effectiveness of the hierarchical model is used to illustrate how changes in priority at the upper level influence the priority of elements in the lower level. Thus a logical construction of such a model facilitates the identification of interrelationships and connections among the components of a research problem.

As sustainable building assessment criteria are generally considered multi-dimensional criteria (Ding, 2008), scientific evidence suggests that a consensus-based approach is best suited to the development of comprehensive and effective building environmental assessment categories and criteria (Chew and Das, 2008). Furthermore, a reliable weighting system must be designed to acknowledge and formalise the degree of importance of these categories and criteria (Cole, 2005; Lee et al., 2002). Therefore, Analytic Hierarchy Process (AHP) is utilized to develop a suitable weighting system, for the approved categories that resulted from Delphi method.

A specific research hypothesis has been formulated that: The weighting system of well-known assessment methods currently in use, such as BREEAM and LEED, have not been adapted to prioritise the political, environmental, and social specificities and context of the Saudi built environment. This encompasses recognition of regional variations, including the constraints of available resources, local architecture, specific environmental conditions, and other economic and socio-cultural factors. The research is underpinned by the following research questions: RQ 1.What is the applicable environmental assessment weighting system, which reflects the most accurate appraisal of the Saudi Arabian context? RQ 2. What is the relevant approach to allocate credits amongst applicable criteria?

3.6.3 SEAM hierarchy model

The AHP model is usually developed to break down complex problems into manageable elements. This, in turn, establishes various hierarchical levels (e.g. goal, category, and criteria) (Saaty, 1994). Hence, the first level of SEAM hierarchy model (goal) is the central issue determining the scope of the subject matter, while the lower levels (categories, criteria) are the indicators (as shown in Fig 3.2), by which the Saudis built environment can be evaluated.

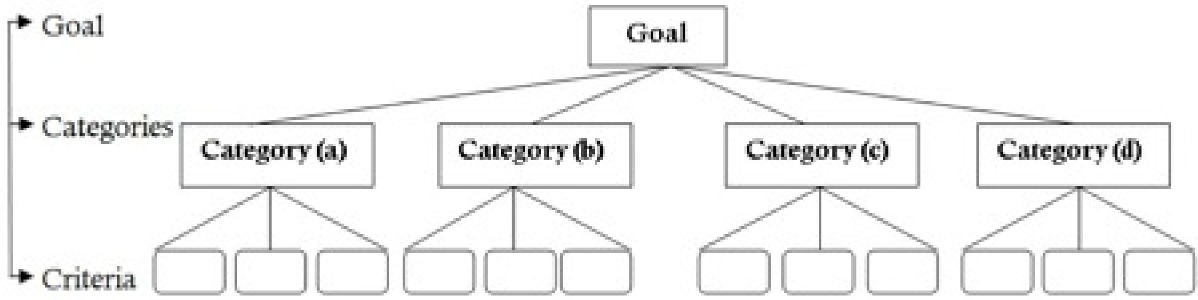

Figure 3.2: Proposed SEAM hierarchy model

3.6.4 Pair wised comparison (PCs)

The Pair wised comparison PCs method is a major stage of AHP (Table 3.2 is an example of PCs). It involves a mathematical structure (Matrixes) that is built upon paired comparison of each category over another (Saaty, 1994). It utilise experts judgment (intensity of importance), following Saatys nine-point scale (shown in Table 3.3).

3.6.5 Analysis stage (Synthesis and consistency)

The extraction of the weighting system involves a number of calculations and analysis of the input data. It is also significant, in decision-making procedures, to know how reliable and valid those decisions are. In AHP, the overall consistency of judgment is measured by means of Consistency Ratio (CR). Consistency ratio is calculated to determine the degree of contradictions in the decision makers judgments (Saaty, 1990). As Saaty states, a CR value less than 0.1 is acceptable; otherwise, a new pair-wise comparison matrix must be reconstructed, which will reflect reliable weight (Saaty, 1990). In order to carry out a reliable AHP analytical stage, licensed Expert choice software was utilised as the main analytical instruments that apply AHP calculation and analysis. Chapter five will consider this in greater length.

Table 3.2: Example of pair-wise comparison

Indoor Environment Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Energy Efficiency
Indoor Environment Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Water Efficiency
Indoor Environment Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Waste Management
Indoor Environment Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Site Quality
Indoor Environment Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Material
Indoor Environment Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Quality of Services
Indoor Environment Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Economic Aspects
Indoor Environment Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Pollution
Indoor Environment Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Management & Innovation
Indoor Environment Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Cultural Aspects

Table 3.3: Nine-point Saaty assessment expression of AHP

A ij	Definition
1	Indicator i and indicator j are of equal importance
3	Indicator i is less important than indicator j
5	Indicator i is more important than indicator j
7	Indicator i is demonstrably more important than indicator j
9	Indicator i is absolutely more important than indicator j
2,4,6,8	Intermediate values between the above pairs of adjacent judgments

3.7 Mathematical and Statistical constructs employed in this research

Delphi Analysis: In the Delphi surveys each round was succeeded by an evaluative phase, within which the responses and opinions of all professionals were given to all members. For example, the medians and IQRs (interquartile ranges) were calculated and used as a quantification of the general extent of agreement (illustrated in Table 3.4) (Geist, 2010). More particularly, IQR (interquartile range) was additionally referred to as the middle fifty and will be calculated as: IQR = Q3 − Q1.

Table 3.4: Statistical Techniques Used for Data Analysis

Statistical Expression	Acronym	Definition
Sum	(Σ)	The accumulated rating answers (Based on Likert scale = 1, 2, 3, 4, 5) for each variable. This is to calculate the mean.
Mean	(M)	The arithmetic average; the sum of the scores divided by the number of scores. Used in F-test calculation.
Median	(MD)	The point that divides a distribution of ordered scores into two equal halves, so that half the scores are above the median and half are below it. Used to determine the mid-point of the ordered responses.
Quartile One	(Q1)	The lower 25% of the ordered responses.
Quartile Three	(Q3)	The upper 25% of the ordered responses.
The Interquartile Range	(IQR)	The middle 50% of the ordered responses.

AHP Analysis: As in the subsequent stage (AHP), all statistical constructs were signified, and designated within the software used to perform the evaluation phase. The key mathematical theories employed in this phase are:

Principal eigen-value λmax;
$Degree of consistency (CI); and$
$Consistency Ratio (CR)$

When undertaking decision-making procedures it is essential to be aware of the dependability and validity of decisions made. Thus, within AHP, the general consistency of the decisions was quantified by using the Consistency Ratio (CR). CR is computed to establish the extent of contradictions within the decisions made by the decision maker. These quantify the consistency of decisions comparative to samples of completely random decisions. To establish CR, the Principal eigen-value is acquired from the summation of products amongst every aspect of the eigen-vector and the total of columns in the reciprocal matrix (Saaty, 1994).

The extent of consistency (CI), may be approximated, as is demonstrated by the subsequent formula.

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{3.1}$$

Consistency ratio (CR) may be computed from the association of the consistency index (CI) and the random consistency index (RI). The value of RI is acquired from Table 3.5, and the value will rely on the value of the magnitude of the proposed matrix.

$$CR = \frac{CI}{RI} \tag{3.2}$$

In line with the AHP model, if CR is above 0.1 the judgments are deemed unreliable as they are too close to randomness, and the exercise has no value or should be repeated. If CR is 10%, the discrepancy is tolerable. If CR 10%, it is essential to amend the subjective judgments. Table 3.5 displays the value of the RI for matrices of the order 1 to 13, as acquired by estimating random indices with the employment of a sample magnitude of 500 (Saaty, 1994).

Table 3.5: Random index RI (Saaty, 1977).

Size of Matrix	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.57	0.9	1.12	1.24	1.32	1.41	1.45	1.49

3.8 Ethical Considerations

There are certain inherent moral principles that guide the research process, from its early stages until completion and publication. ESRS expects a number of key research ethics to be addressed through the execution of research project. This includes ensuring the quality and integrity of research through its design, review and undertaken. It is also important to ensure confidentiality of the information supplied. Research participants must also be informed about the purposes of the research and their participation must be voluntary and the anonymity of respondents must be respected (Liu, 2008). In other words, research needs to be conducted in an ethical fashion; the researcher in this work has therefore complied with the ethical guidelines. Cardiff University has a Research Ethics Committee that deals with the ethical issues of any given research. In compliance with the requirements of this committee, this study has submitted detailed methodological information to the Research Ethics Committee of the Cardiff School of Engineering.

Before commencement of the fieldwork stage of this research study, visits were made to different organizations and expert gatherings (conferences and forums). This was intended to build a network that would support the collection of fair, unbiased data. This stage also facilitated better hypothesis generation and enabled initial acceptance to be gathered for voluntary participation. Invitation letters were subsequently sent to potential participants with further explanation of the research procedures. This stage provided potential participants with detailed information about their role in this work and helped the researcher to identify the most motivated participants who are voluntarily interested and willing to contribute positively to this work. During the data collection stage, questionnaires were sent to the experts who had previously accepted the invitation and who had agreed to participate. An adequate period of time were given to the participants to receive back their responses. Both stages included: (a) the purpose of the questionnaires; (b) examples of how to complete the questions; and (c) a guarantee of anonymity and confidentiality. This means that the participating experts in this study were anonymous to each other throughout. This approach was also followed during the collection of building data (final stage): for instance, the specific location, name of building owner were not disclosed. This commitment to anonymity has been maintained throughout the study, including the data analysis and interpretation stage, in compliance with good ethical practice.

3.9 Summary

This chapter presents the methodology that this study utilised in order to meet the stated research aims. Given that the field of environmental assessment involves the examination of a wide spectrum of criteria, the mixed methodology is the approach that has been selected for this study. This approach comprises four major stages: (a) a theoretical stage, focused on the comparison of well-known methods; (b) consultation with a panel of experts, employing the Delphi technique; (c) using AHP to deliver applicable weighting system of each building assessment category; and (d) testing SEAM by means of the IES building simulation software. The theoretical stage involved a comprehensive review of the environmental building assessment field. This highlighted the complex, stratified nature of this area, and the corresponding need to narrow the focus of this investigation to one specific level, which in this case is the rating system. Following this decision, a number of well-known assessment methods were subjected to comparative analysis with the aim of consolidating building assessment categories and criteria. This stage also involved a review of the most applicable approaches by which new methods can be developed. Critical analysis of the literature, supplemented by reviews of technical manuals, was the method by which this phase was completed. The second stage is a deliberative process, based upon consultation with a panel of experts to seek a consensus on the most applicable building assessment categories and criteria for the built environment in Saudi Arabia. The Delphi technique was instrumental in meeting this objective. This technique involves a systematic process, based upon three successive rounds: (a) brainstorming; (b) revision & narrowing down; and (c) final rating. It was determined that the applicable building categories should have a weighting system, as this is a fundamental component of any assessment method (Chew and Das, 2008, Haapio and Viitaniemi, 2008). Therefore, AHP will be employed to deliver this requirement. This technique is based on a pairwise comparison strategy to priorities each given dimension, with a specially designed AHP-focused Expert-choice programme being used to analyse the outcome from the pairwise comparison.

4

SEAM applicable categories and criteria

4.1 Introduction

The chapter aims to identify applicable sustainable building assessment categories and criteria for the Saudi built environment, and in turn distinguish the difference from the international assessment system such as BREEAM and LEED. Thus this is the chapter that propose to tests the hypothesis that the building assessment categories and criteria- of the leading international environmental and sustainability assessment schemes- are not adapted to the Saudi built environment, with a focus on the residential sector. As building assessment methods involve multi-dimensional criteria, a consensus-based approach is used to conduct the research. Hence, the Delphi technique is selected and conducted in three successive consultation rounds involving world leading experts in the domain of environmental and sustainable assessment schemes, as well as professionals and highly-informed local experts from academia, government and industry. The results reveal that international assessment schemes are not fully applicable to the Saudi built environment, as reflected in the development of a new building environmental and sustainability assessment scheme.

This chapter provides a review of the Delphi technique within the context of the construction industry. Its aim is to demonstrate the relevance of consensus-based approaches in this field of study, as well as to obtain a deeper understanding of the challenges involved, such as the complexity of construction criteria, the composition of the expert panel, and managing expected outcomes. The results of the Delphi stage of this particular study will then be presented, including the approved building assessment categories and criteria, deemed applicable for the specific context of Saudi Arabia. These criteria will be discussed in terms of their relative importance, after which the consensus measurement tool will be provided. Finally, a discussion will be offered on the resultant SEAM criteria and the importance of this assessment method for the Saudi Arabia built environment.

4.2 Delphi technique: review in related field

The Delphi technique has been applied in a large number of studies, across a range of business, industry and academic fields, when these investigations seek a consensus on subjective issues. This application extends to broad subjects as various as public policy, education, health care, human services, environmental studies and also forecasting technological advances and economic and social policy impact. As the current study is concerned with sustainability development, a brief overview of the most recent applications of the Delphi technique in this domain will be presented below.

Chan et al. (2001) investigated the complexity of procurement system selection in construction projects. As this matter is complicated and has an effect on the building delivery method, the Delphi technique was adopted to develop a multi-attribute model. Ten experts participated in this study; four from public organisations, three from the private consultant sector and three academic members from Hong Kong universities. The resultant model consisted of a set of criteria for clients, including: Price competition, Time available, Time predictability, Availability of competent contractors, Clear end users requirements, Complexity, Certainty of cost without fluctuation, Flexibility for changes, Risk management, Responsibility, Familiarity.(Chan et al., 2001).

The Delphi technique was also applied by Schuckmann et al. (2012) during their examination of the role and significance of transport infrastructure, in which they evaluated its influence on globalization, economic and future development. This research was conducted under the Institute for Futures Studies and Knowledge Management (IFK) in Germany to identify and assess the factors affecting transport infrastructure development until 2030. As this study was concerned with examining the topic on a global scale, experts from more than 29 countries participated to ensure adequate diversity in terms of panel composition. The outcomes of this study bridged the research gap on scenario development in the field of global transport infrastructure; four different scenario aspects were proposed: supply and demand, financing, competitiveness, and sustainability (Schuckmann et al., 2012).

Singhal et al. (2013) integrated the Delphi technique with AHP in order to conduct an evaluation of city competitiveness and its role in attracting pioneering businesses. Regeneration and business strategies were shown to play an important role in terms of city competitiveness, the study sought to address the lack of knowledge regarding the links between city competitiveness and regeneration and business strategies. More specifically, a hierarchy model was designed to assess the competitiveness of four British cities (Birmingham, Liverpool, Belfast and Glasgow). The hierarchy model consisted of four tiers starting from City Competitiveness downwards through the lower level that includeed: Physical environment; Social capital, Finance, Development, Investment and Use/Occupiers potential (Singhal et al., 2013).

Carrera and Mack (2010) conducted a Delphi consultation approach to examine the social dimensions of sustainable energy systems. A European committee of energy experts from four different countries (France, Germany, Italy and Switzerland) were gathered and then consulted to evaluate sixteen different energy systems. The overarching dimensions delivered out of this investigation include: security and reliability of energy provision, political stability and legitimacy, social and individual risk (Gallego Carrera and Mack, 2010).

The future of renewable energy technologies in an oil-rich country (Saudi Arabia) also used the Delphi approach (Al-Saleh, 2009). Al-Saleh intended to present a set of renewable energy scenarios, which would be used in the delivery of a systematic framework for the investigation of energy perspectives. In recognition of the large number of energy scenarios developed around the globe, this study attempted to find a consensus on the appropriate energy scenarios for Saudi Arabia. Thirty-two experts, drawn from both academia and industry, participated in three rounds. Overall the outcome of this study demonstrates that the uncertainty and significance of the future of renewable energy in Saudi Arabia lies in the availability of fossil fuels, action on environmental protection in both global and local context, and the positive/negative perception of renewable technology (Al-Saleh, 2009).

The development of a sustainability assessment toolkit for upland estates in Scotland was investigated by Glass et al. (2013). Land uses and upland estate management are increasingly attracting the interest of a wide variety of stakeholders, including biodiversity conservation, renewable energy, agriculture, property and sporting interests, and tourism. In Scotland, these upland areas have a diverse pattern of ownership, the majority are divided into estates that belong to individuals, organisations, public agencies, nongovernmental and even community organisations. Therefore, the Delphi technique was employed to integrate sustainability principles into the complex situation of upland estate management in Scotland. A panel of 19 academic and non-academic stakeholders participated over four stages of development. The resulting toolkit delivered a sustainability framework for stakeholders to assess progress towards practical actions on individual estates (Glass et al., 2013).

Scolozzi et al. (2012) presented an evaluation approach for ecosystem service in spatial planning in Italian landscapes. Their objective was to minimise the consequences of urban sprawl on the local context changes through involving spatial planning in decision making and increased consideration of sustainable landscape management. Given the difficulty in replicating existing ecosystem service assessment, due to reasons such as land use policy and available resources, the adaptation for Italian local conditions was achieved through the Delphi consultation process and focus groups. The assessment approach was developed through the use of land use data and economic valuations, processed by forty-six panellists from ten different research institutions. The role of Delphi panel was to share their vision and to provide reliable inferences about the potential for ecosystem service provisioning by land covers. This consultation produced an original assessment that included ten ecosystem services for Italian provinces, which was also easy to adapt to other European countries (Scolozzi et al., 2012).

Since the construction industry involves multiple, complex stages, the reliable estimation of construction cost is often difficult. For this reason, Jeong et al. (2012) conducted a study to provide a new Life Cycle Cost Breakdown Structure. The key ingredient of addressing the problem was that the Cost Breakdown Structure (CBS) should perform a systematic estimation of Life Cycle Cost (LCC) for each phase of a construction project. The Delphi technique was therefore employed to develop a CBS for more correct LCC estimation of a building structure, which occurred through multiple Delphi rounds. The proposed CBS was divided into four stages (planning and design, construction, maintenance and waste disposal). The cost breakdown factors were restricted to classification for Life Cycle Cost (LCC) estimation (Jeong et al., 2012).

Vatalis et al. (2012) studied project performance indicators (PIs) through project procurement in construction industry. Their research goal was to devise a method to identify and evaluate the procurement process and to examine its role in the environmental performance of construction projects. The emergence of green procurement (previously known as Affirmative Procurement) was recognised as promoting the overall sustainability development. Given that, Delphi techniques were utilised in the Greek context to develop a tool for identifying sustainability perspectives in green public procurement. The resulting evaluation was dependent on Performance Indicators (PIs) that were categorised as follows: Reduction of Waste, Service and Quality, Customer Satisfaction, Education of Personnel Capacity, Utilisation Client Cooperation, and Use of Technology (Vatalis et al., 2012).

Finally, Sookchaiya et al. (2010) investigated the effects of temperature and relative humidity on human health and wellbeing in Thai hospital buildings. They sought to evaluate both the direct and indirect effects of humidity and temperature on human health in air-conditioned buildings in tropical regions. The results could then inform the designing of air-condition systems to support the outcome of better health. The Delphi consultation approach was selected, with a panel of medical experts gathered from both top ranking universities, medical schools and hospitals in Thailand. Given that it is generally believed that air-conditioned rooms without good ventilation systems lead to relative humidity that can boost the spreading of problematic micro-organisms, such as virus, bacteria and fungi, the consultation process aimed to identify the criteria for air conditioning systems, with specific reference to the climate of Thailand (Sookchaiya et al., 2010).

4.3 Proposed SEAM categories and criteria

The main components of the building environmental and sustainable assessment scheme are generally divided into three hierarchical levels: Goal, Categories and Criteria (BRE, 2012, Chang et al., 2007). While the existing methods share almost the same goal, each method is based upon its own philosophy for the allocation of categories and criteria. Since the aim of this study is to establish the most applicable building environmental and sustainable assessment categories and criteria for the Saudi Arabia built environment, many exclusive criteria and new major categories have been developed by this study, as will be discussed below. The main results of this study are presented as follows: the framework of Saudi Arabia sustainable assessment scheme, the applicable criteria for the Saudi Arabia built environment, the overall rating of the sustainable assessment categories, and measurement of consensus. Since the application of the Delphi technique in this study involved three successive rounds. Here, however, the final rating of each of these criteria will be presented, in order to show the level of relative importance. So the criteria set out by the Delphi panellists are illustrated below.

4.3.1 Indoor Environment Quality

The indoor environment quality includes 15 criteria (as illustrated in Fig 4.1) for ensuring the health and wellbeing of the occupant. For example, due to the extreme heat and dust in Saudi Arabia, mechanical ventilation is arguably more important than natural ventilation. Furthermore, the air tightness of building, for the protection of the occupant in the event of a sand storm, was deemed to be the most important criterion.

Indoor Environment Quality
1. Noise & Acoustics control
2. View out
3. Glare measure & control
4. Illumination level & control
5. Daylight
6. Natural ventilation
7. Mechanical ventilation
8. Air quality sensors- CO2 Monitoring
9. Volatile organic compounds (VOC)
10. Microbiological contamination level
11. Air tightness of buildings(Prevent Dust)
12. Thermal comfort and control
13. Humidity control
14. Quality of drinking water
15. Internal landscape(Vegetation)

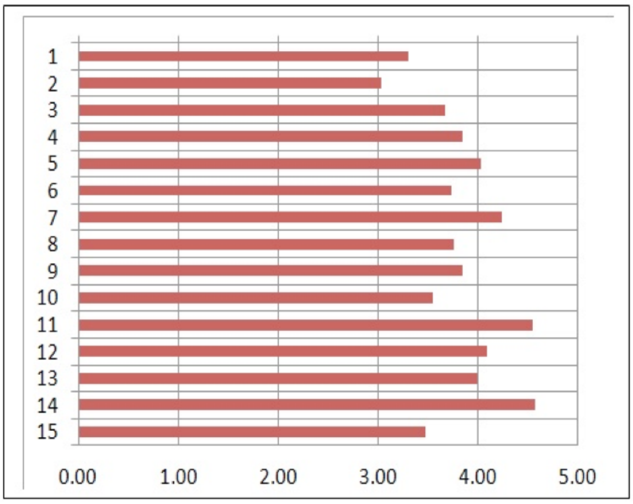

Figure 4.1: Indoor Environment Quality Criteria

4.3.2 Energy Efficiency

The criteria set out below (in Fig 4.2) recognise the importance of taking the advantages from solar radiation while simultaneously delivering protection to ensure the provision of a comfortable and energy efficient building. In this regard, building envelope performance and shading strategies were considered of the highest importance, in addition to the HVAC system and sub-metering of electricity use. Furthermore, renewable energy technology was also a core consideration, promoting the use of greener products such as PV panels.

Energy Efficiency
1. Building envelope performance
2. HVAC System
3. Lighting: internal & external
4. Hot water system
5. Renewable energy technology
6. Shading Strategy
7. Co2 Mitigations strategy
8. Zoning of systems
9. Sub-metering of electricity use
10. Energy management system

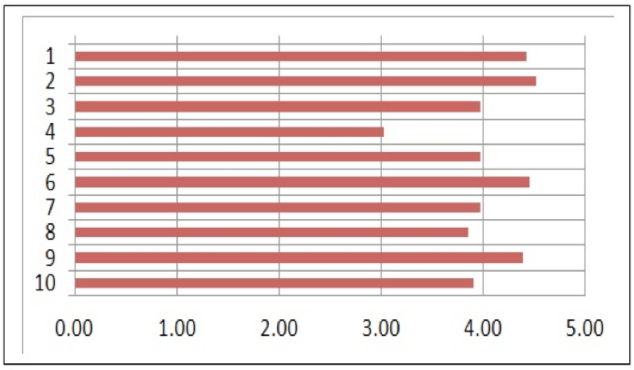

Figure 4.2: Energy Efficiency Criteria

4.3.3 Water Efficiency

It is clear from the water efficiency criteria (Fig 4.3) that water consumption and conservation strategies were deemed to be extremely significant for Saudi context. Furthermore, strategies such as grey water recycling, rain water harvesting and suitability of water restriction level are also viable ways of reducing the overall water consumption.

Water Efficiency
1. Water consumption
2. Grey water recycling
3. Rain water harvesting
4. Water fixture & conservation strategy
5. Irrigation system
6. suitability of water restriction levels

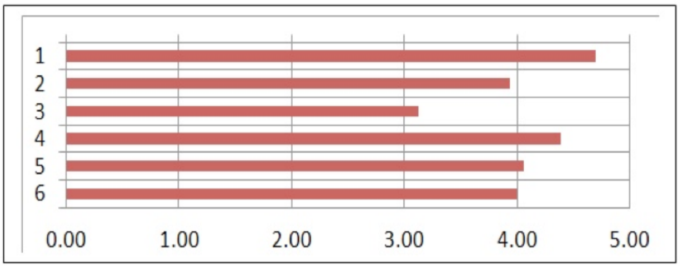

Figure 4.3: Water Efficiency Criteria

4.3.4 Waste Management

The waste management criteria (Fig 4.4) show that modern methods of construction, such as off-site assembly and recycling facilities, can play an important role in waste reduction. Hence, the panellists agreeing that waste management is the most important criterion. In the early stage of this study, one expert suggested considering the principles of designing out waste rather than dealing with waste created, which was later accepted as one of the criteria in this framework.

Waste Management
1. Construction waste management
2. Solid waste treatment
3. Recycling facilities
4. Modern Methods of Construction i.e. off-site assembly
5. Use of recycled and re used materials
6. Principles of designing out waste rather than dealing with waste created

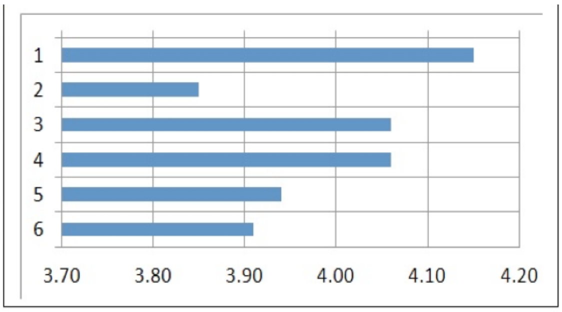

Figure 4.4: Waste Management Criteria

4.3.5 Pollution

It is clear that the 9 criteria related to pollution (Fig 4.5) were all rated as being very important. The most important of these considerations are pollution due to natural disaster, flooding, fire risk and CO_2 emissions. In addition, the Delphi panel agreed that the protection from sand storms is a unique criterion, particularly relevant for building in the Arab peninsula.

Pollution
1. Refrigerant GWP – Building services
2. Night light and noise pollution
3. Preventing refrigerant leaks
4. Heat island effect
5. NOx emissions from heating source
6. CO2 Emissions
7. Fire risk
8. Risk due to natural disaster (Flooding, etc)
9. Protection from sand storm

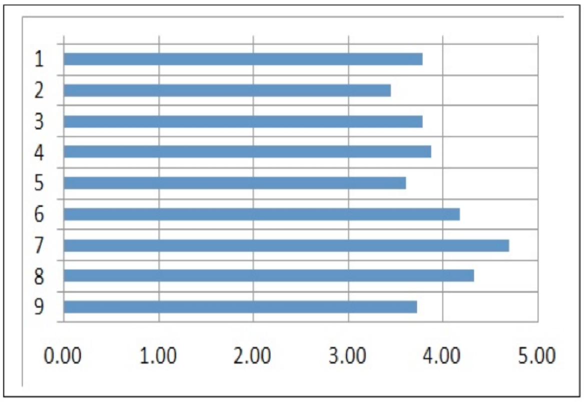

Figure 4.5: Pollution Criteria

4.3.6 Management

A total of 9 criteria (Fig 4.6) for management and innovation were revised and rated by the Delphi panel. The management of the construction process and the integration of services were deemed to be the most important consideration, although innovations in design and construction site impact were given almost the same level of importance.

Management
1. Commissioning & Decommissioning strategy
2. Procurement path
3. Construction process planning
4. Briefing process in construction
5. Considerate stakeholders
6. Supply chain management
7. Construction site impacts
8. Integration of services
9. Innovation in design

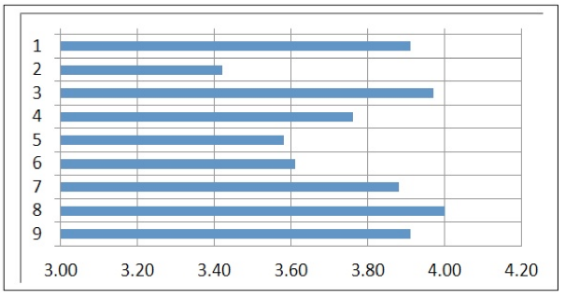

Figure 4.6: Management Criteria

4.3.7 Site Quality

The Delphi panel agreed that the quality of the built area is associated with its surrounding local services, civil construction network and the location of building itself. Hence, the 13 criteria below (Fig 4.7) encourage green and sustainable practices; seeking the potential of Passivity in the selection of a site. They also promote building density development and community connectivity, whilst ensuring that buildings are adequately connected to basic infrastructure and local services.

Site Quality
1. Site selection & potential of passivity
2. Contaminated land
3. Mitigation ecological impact
4. Biodiversity protection
5. Vegetation & Shading
6. Accessibility
7. Density development of buildings
8. Community connectivity
9. Car parking capacity
10. Connection to existing infrastructure
11. Whole community assessment
12. Availability of services
13. Transport links

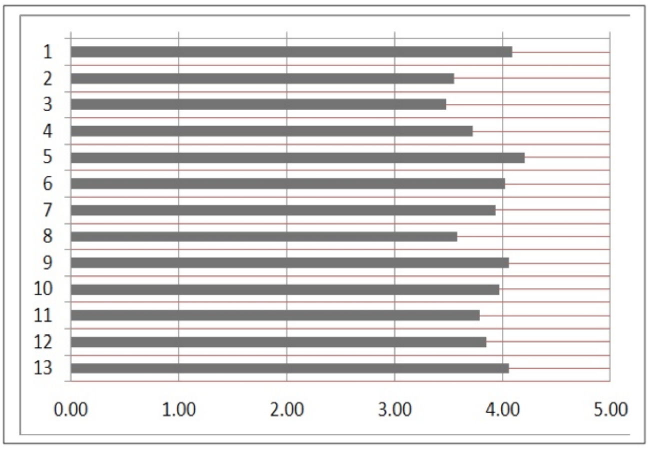

Figure 4.7: Site Quality Criteria

4.3.8 Material

The below figure illustrates (see Fig 4.8) that the choice of materials with low environmental impact along with building fabric components are the most important considerations. The Delphi panel also agreed that the use of materials that are designed to address future climate change issues is a key criterion for Saudi context. The overall objective of these criteria is to avoid harmful practices in building material production as well as to enhance energy efficient design.

Material
1. Material with low environmental impact
2. Local materials
3. Recyclable material
4. Re-use of structural frame materials
5. Building fabric component (Insulation)
6. Responsible source of materials
7. Use of finishing materials
8. Material efficiency over its life cycle (LCA)
9. Use of materials that are designed to deal with future climate change
10. Material with high thermal mass

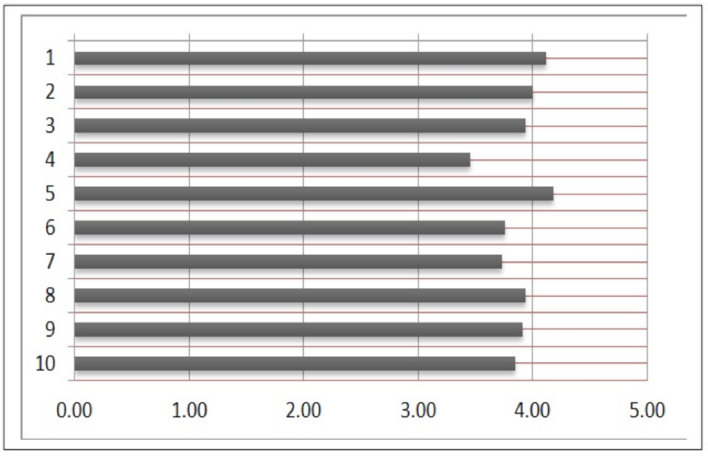

Figure 4.8: Material Criteria

4.3.9 Quality of Services

The quality of services criteria requires the evaluation of key aspects of the buildings performance, such as the degree of its functionality, usability, durability and reliability. The most important consideration was deemed to be efficiency of infrastructure (as illustrated in Fig 4.9).

Quality of Services
1. Functionality and Usability
2. Flexibility and Adaptability for future change
3. Durability and Reliability
4. Maintenance of performance
5. Efficient infrastructure

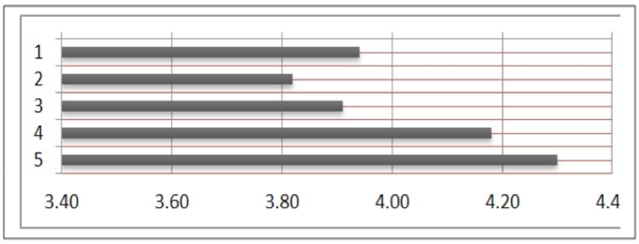

Figure 4.9: Quality of Services Criteria

4.3.10 Economic Aspects

While the economic aspect of a build is a fundamental aspect of sustainable development, the extent to which this is overlooked by leading international schemes is surprising. The results of the deliberation process for this study generated 6 important criteria (see Fig 4.10) for the evaluation of the overall life cycle costs of buildings. Certain of the panel stressed that the use of a whole life costing (WLC) mechanisms is a robust and sustainable practice.

Economic Aspects
1. Construction cost
2. Life cycle cost
3. Operating and Maintenance cost
4. Affordability of residential rental
5. Use of whole life costing mechanism in building choice
6. Recognition of lower running costs in rental levels

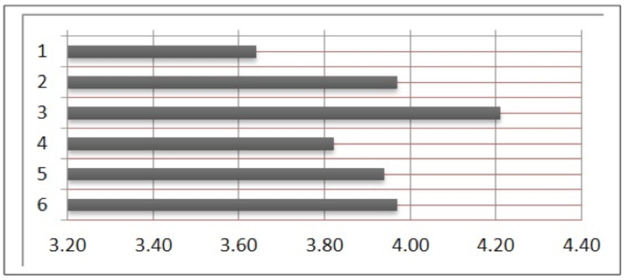

Figure 4.10: Economic Aspects Criteria

4.3.11 Cultural Aspects

The social life of Saudi Arabian people has a remarkable effect on shaping their building designs. Therefore, the 4 criteria shown in (Fig 4.11) are the socio-cultural criteria that identified by this study. These criteria will evaluate certain requirements, from building design, that are required in order to meet the choices and desires of occupants.

Cultural Aspects
1. Heritage & Cultural Identity
2. Male & Female space privacy
3. Habits and custom effects on the built environment
4. Constancy of Islamic faith

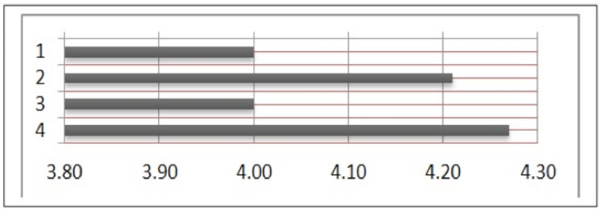

Figure 4.11: Cultural Aspect Criteria

4.4 The SEAM scheme

The framework (Fig 4.12) has been built upon the consensus amongst Delphi panel, with the core of this scheme being the promotion of sustainable development (SD) in the building sector. This framework illustrates three hierarchy levels; the first level includes four major dimensions: environmental, economic, social and management & innovation. The second level includes 11 key categories of building assessment. The third level includes 92 applicable criteria for the assessment of the built environment in Saudi Arabia.

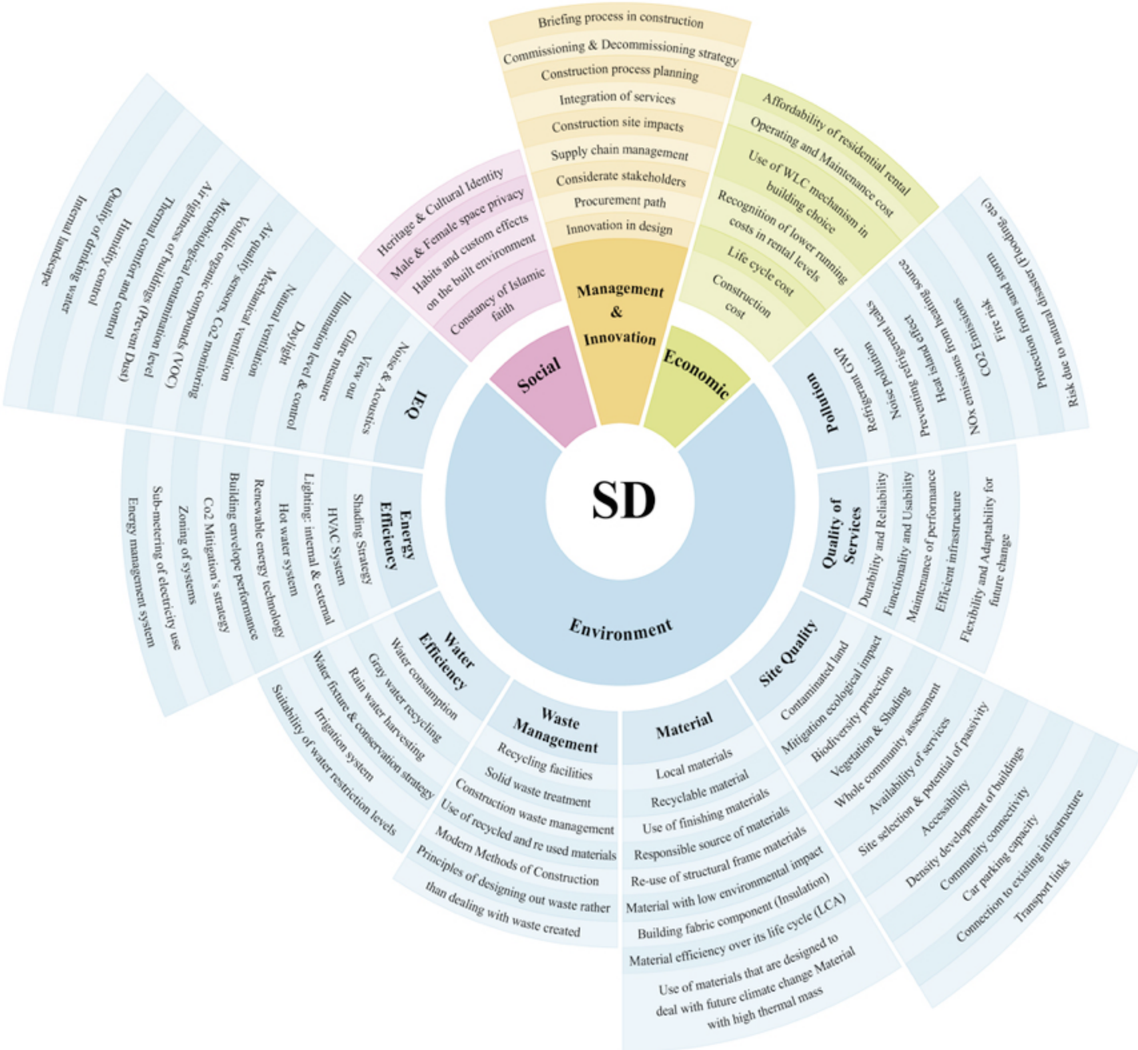

Figure 4.12: SEAM Scheme

4.5 Overall ranking of the assessment categories

All categories illustrated below (see Fig 4.13) are essential, and presented here based on their level of importance. This, in turn, provides a clear picture to the building stakeholders regarding the prioritisation of these categories for Saudi context.

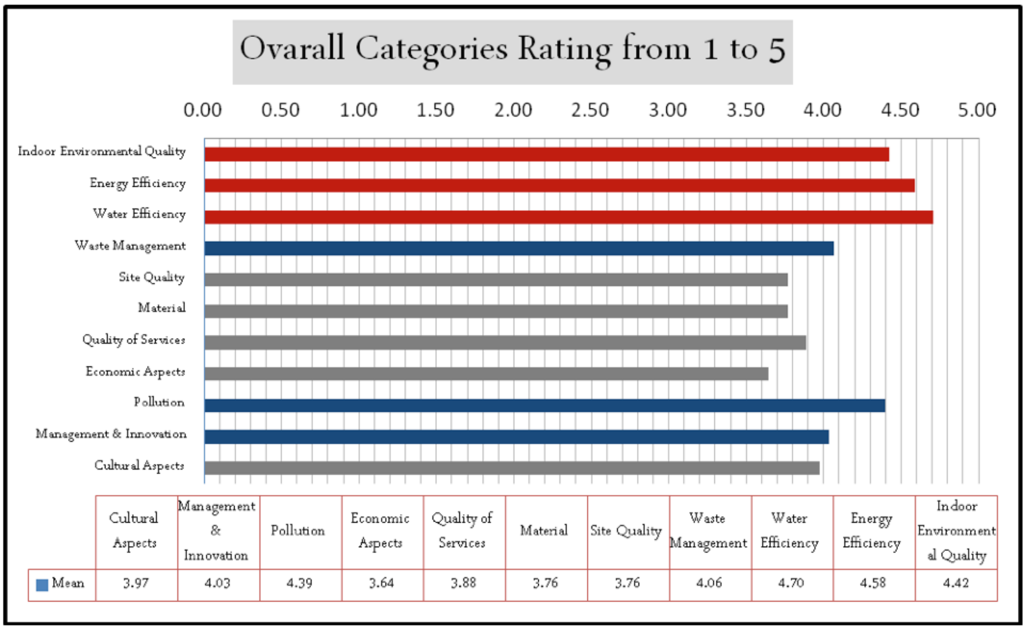

Figure 4.13: Overall ranking of SEAM categories

The judgement of the panel is that water efficiency is the top priority. Subsequently, energy efficiency design and indoor environmental quality are almost at the same level. This agreement by the Delphi panel about the prioritisation of the above three categories are compatible with current concerns in relation to the Saudi Arabian built environment: water use challenges; renewable energy potential (especially solar energy); and poor indoor environmental design (El-Ghonemy, 2012, Hepbasli and Alsuhaibani, 2011, Rahman and Khondaker, 2012). The next most important priorities include waste management, pollution and general management and innovation. These categories are closely linked. For example, the criterion for Recycling facilities from the waste management category can also reduce pollution, as well as reflecting the commissioning and stakeholder strategy of managing the built environment. Eventually, site quality, material, quality of services, economic, and cultural aspects achieved almost the same level of importance. These criteria, as agreed by all panellists, are essential for the creation of a coherent and comprehensive scheme to evaluate the requirements of Saudi Arabias built environment.

4.6 Consensus measurement

The research panel is comprised of professionals from various sectors. It includes Saudi government employees from the municipalities as well as the constitutional centre of affairs development. The key objective of consulting this particular group of experts is to provide up to date criteria, that reflects construction industry trends, as well as the present and forthcoming policy of the Saudi state as regards construction. Policy is of essential significance when establishing sustainable appraisal techniques.

Professionals from the building sector the main members of the Delphi panel, as those from the construction industry have over a decade of experience within the area of construction and environmental development, and more significantly have experience of sustainable assessment systems, such as LEED and/or BREEAM. It was essential to encompass participants who are conscious and conversant with the tactical aims and operation of sustainable assessment techniques.

Experts from Saudi academic institutions participated in the study. These included professors from the domain of sustainable development. They aimed to supply pertinent criteria to encourage the advancement of sustainability, based on their awareness of revolutionary technology and the challenges that could impede the development of sustainable construction within the area. International professionals with experience concerning the strengths and weaknesses of the available techniques for appraisal, and additionally those who have worked closely with such structures were also included. Their role was to address the general and specific limitations of established instruments.

Thus, when viewing the profile of the panel and the collective experience, it is evident that the results from this research are proposed to meet the requirements of individuals from a variety of backgrounds. These include: construction management, water and energy efficiency, urban planning, environmental studies (pollution of building and construction operations), facility management, renewable energy, and building efficiency design. Therefore, their contribution was instrumental in contributing to the existing body of knowledge.

It has been claimed that the four characteristics of the Delphi technique (anonymity; iteration; controlled feedback; and statistical group response) are instrumental in achieving stability and consensus (von der Gracht, 2012). A number of different qualitative analysis methods exist for measuring this consensus; the approach chosen in this study - interquartile range (IQR) - is a descriptive statistical method that examines each mean of consensus (Gnatzy et al., 2011). The value of the IQR is dependent on the unit scales; for example, for 5-unit Likert scales consensus is indicated by values of IQR between 0 and 1(0 IQR 1) (von der Gracht, 2012). Table 4.1 illustrates the status of consensus from the final Delphi round, which clearly demonstrating agreement among the Delphi panel.

Table 4.1: Consensus calculation using interquartile range (IQR)

Categories	**Number of Criteria**	**IQR**	**Status of Consensus**
Indoor Environment Quality	15	0.4500	✓ Achieved
Energy Efficiency	10	0.4875	✓ Achieved
Water Efficiency	6	0.3525	✓ Achieved
Waste Management	6	0.1425	✓ Achieved
Site Quality	13	0.3300	✓ Achieved
Material	9	0.2025	✓ Achieved
Quality of Services	5	0.2700	✓ Achieved
Economic Aspects	6	0.1200	✓ Achieved
Pollution	9	0.4500	✓ Achieved
Management and Innovation	9	0.3000	✓ Achieved
Cultural Aspects	4	0.2250	✓ Achieved

4.7 Discussion

Renewable energy technology provides a solid foundation to promote clean energy generation and hence a more sustainable built environment. Saudi Arabia enjoys as a country wide exposure to solar energy across all its regions. Moreover, the average annual solar energy in Saudi Arabia is in excess of 2200kWh/m2, which can be considered as relatively high when compared to other countries' solar potential (Hepbasli and Alsuhaibani, 2011). Environmentally, for each gigawatt-hour of electricity generated by solar PV, a large amount of hazardous emissions would be prevented, including up to 1000 tons of carbon dioxide, 4 tons of nitrogen oxides, 0.7 tons of particulates and 10 tons of sulphur dioxide (Fthenakis, 2000). Yet some solar PV modules consist of hazardous materials (tellurium, cadmium, lead and selenium). These compounds have severe impacts on wildlife, including Saudi Fauna and flora; also, they may affect humans' health and well-being via the food chain (McDonald and Pearce, 2010). Improving government regulation of those hazards is one major way to tackle this issue. Germanys experience provides standing evidence in this area; it has imposed a set of regulations for recycling electronic waste (McDonald and Pearce, 2010). The regulated decommissioning of PV waste is a key consideration for the Saudi future plan.

In addition, there is potential for alternative sources of renewable energy (other than PV) in Saudi Arabia. Alnatheer (2005) highlights various forms of environmentally and economically competitive energy sources, including solar thermal, wind energy, and geothermal energy. Solar thermal involves different systems of electricity generation, such as power towers, parabolic troughs, and dish/engine. The suns radiation consternated onto a heat absorber produces steam and thereby generates electricity. This technology is used to supply thermal energy for both heating and cooling systems. This, therefore, has the potential to enhance clean energy generation in Saudi Arabia as the country experiences high demands for cooling, representing a major source of overall energy consumption (Taleb and Sharples, 2011). As for wind energy, Al-Abbadi (2005) reveal through their study that the highest average annual wind speed is 5.7 m/s for about 60% of the time. The estimated energy generated from this wind speed can reach up to 1080 MWh.

Saudi Arabia has an interesting potential for geothermal energy. Rehman and Shash (2005), state that Saudi Arabia has ten hot springs discovered in its southern province of the country (Gizan and Al Lith regions). Moreover, a geological inspection was recently carried out as a result of which large volcanic areas were discovered in the

Western region. However, given the economical competitive energy market, geothermal energy remains an untapped source of renewable energy (Taleb, 2009). Out of the above renewable generation sources, PV remains in a short to medium timescale the main viable technology at a domestic level. This is currently enjoying relatively wide acceptance and uptake. Leading schemes, such as BREEAM and LEED, have been critically revised in the development of the assessment scheme for Saudi Arabia. However, regional and cultural variations in Saudi Arabia support the further development of suitable categories and criteria. Throughout the Delphi study, a clear consensus has been reached; that a number of categories and criteria have not been recognised, by leading schemes, as central dimensions for Saudi context. Hence, this study develops a comprehensive framework to assess Saudi Arabias built environment. The following points identify categories and key criteria that have been, to some extent, over-looked by international schemes:

Climatic conditions of Saudi Arabia: The typical climate of Saudi Arabia requires designers and builders to observe certain considerations. As an illustration of this, heavy sandstorms are a common phenomenon in the Arabian Peninsula (Al Saud, 2010), with a severe impact on inhabited cities, causing health problems and communication disruption (Kumar, 2013). Therefore, the Delphi panel recognise the need for criteria that can enhance the quality of the indoor environment, in particular in the context of sandstorms. These criteria include: Air tightness of buildings (as an effective barrier to dust), and Internal landscaping (Vegetation). Another example of the Saudi Arabian situation is that the clear skies and extremely hot arid weather significantly increase building exposure to bright sunlight, meaning that shading strategies should be used to protect building envelopes and occupants from solar radiation. The shading strategy can also play an important role in energy saving and enhancing the comfort of the indoor environment (Chan, 2012, Alzoubi and Al-Zoubi, 2010). In addition, due to climate change and global warming indicators in the middle east (Lelieveld et al., 2012, Rahman and Khondaker, 2012), the panellists agreed that the degree of building adaptability for future change is significant, especially given evidence that predicts the temperature of Saudi Arabia will rise by approximately 2.02.75 C in the next 30 years (Almazroui et al., 2012).

Natural resources (Energy, Water, and Material): It is estimated that about two-thirds of the electricity generated in Saudi Arabia is used in buildings. Current practices involve burning fossil fuel to produce heavily subsidised electricity and water, resulting in a lack of awareness about environmental concerns. This, in turn, create a barrier to the widespread adoption of sustainable architecture in Saudi Arabia (Taleb and Sharples, 2011). In recognition of sustainable energy being one of the objectives of the Saudi Arabian building assessment framework, the panel recommend the promotion of one of the highest potential renewable energy sources, solar energy application, coupled with relevant building fabric and shape design.

As the Kingdom is not densely populated, electrification and desalination plants, along with other basic networks have been expanded over thousands of kilometres to cover the most populated cities (Alnaser and Alnaser, 2011). However, certain rural and remote areas are not yet connected to the network, and connecting them will require an additional increase in power generation (Obaid, 2008). Therefore, various criteria were recommended to manage this expansion, including: Renewable energy technology and, Sub-metering of electricity use.

Saudi Arabia has poor water resources and is heavily dependent on non-renewable resources such as groundwater and sea water treatment (desalination) (El-Ghonemy, 2012, Taleb and Sharples, 2011). This study ranked water as the top priority category, with the aim of raising awareness amongst utility customers regarding water scarcity. Therefore, the panellists recommended encouraging innovative strategy of water conservatives and Ensuring that the restriction level of water supply should not lead to unsustainable practices.

Building material requires large amount of embodied energy that also put intensive pressure on the natural environment (Ortiz et al., 2009). However, The Delphi panel add that buildings should be designed to deal with future climate change, using environmentally friendly material with high thermal mass that can cope with the environmental and climatic conditions of Saudi Arabia.

Infrastructure (building services): The evaluation of building performance alone is not an efficient way of realising sustainable development goals, as building operations depend on various networks and infrastructures. However, international assessment schemes assume the existence of a coherent infrastructure, such as water, sewage, drainage systems and transportation networks. The reality for developing countries is that these basic infrastructure and services are incomplete or insufficient. Therefore the panel have highlighted the importance of promoting efficiency in infrastructure and connecting the building to it, thereby not only improving the quality of the building sector but also nearby communities.

Furthermore, torrential rainfall in Saudi Arabia is a dramatic phenomena that causes massive flooding, pollution, and even loss of life and property (e.g. Jeddah flooding, 2009) (Al Saud, 2010). For this reason, Pollution and risk due to flooding are considered as key criteria in the assessment of Saudis built environment, with the aim of recognising these threats and creating built environments that can thrive without external risks.

Economic aspects: Financial considerations are essential in sustainability development in both developed and developing countries. Developed countries are concerned with the reduction of environmental impact while maintaining standards of living (Cole, 2005) , while in developing countries economic and social issues are often as important as environmental considerations (Libovich., 2005). However, neither BREEAM nor LEED consider financial aspects in their evaluative framework, this arguably contradicting the ultimate principle of sustainable development, as financial returns are essential for all projects, with environmentally friendly projects potentially being very expensive to build (Ding, 2008). Therefore, this scheme has incorporated economic criteria that play an important role in Saudi Arabias built environment, including Use of whole life costing mechanism in building choice (WLC), Affordability of residential rental, and constructions cost & pay back.

Cultural aspects: Residential buildings in Saudi Arabia are greatly influenced by cultural considerations. Typical Saudi families are large and dynamic, keeping strong ties with even distant relatives and neighbours. Therefore, buildings need to be designed and built to accommodate social events and needs. This issue was raised by various local experts in the consultation rounds. A consensus was reached by the Delphi panel in the subsequent rounds. The required criteria for the assessment of residential buildings include: Male and Female space privacy; Heritage and Cultural Identity; Habits and custom effects on the built environment and; Constancy of Islamic faith. These issues are completely overlooked by the leading international schemes, which also contradict sustainable development principles.

Construction Management: There are many manageable parameters that can indirectly impact upon the quality of the built environment. For this reason, BREEAM stipulates the fundamental criteria for sustainable management principles (BRE, 2013). However, a number of additional criteria have been incorporated into the Saudi scheme; in order to take supply chain management into account, as well as the briefing process in construction and the integration of services. The application of these aspects will boost the adoption of best practices and sustainable development principles in the building sector in Saudi Arabia.

4.8 Summary

In this chapter, an overarching hypothesis has been set to meet this objective, namely that the leading international sustainable assessment schemes, such as BREEAM and LEED, are unsuitable for the Saudi Arabia built environment. This hypothesis was tested using the Delphi technique, over a four month period. Thirty three Delphi panellists have reached a consensus on the applicable categories and criteria for a sustainable building assessment scheme in Saudi Arabia. The findings of this consultation process strongly suggest that international schemes such as BREEAM and LEED are inapplicable for the Saudi context. Hence, there is a need to develop further categories and criteria for the assessment of the built environment in Saudi Arabia. Expert consensus converge in that building environmental and sustainable assessment categories should include: indoor environmental quality, energy efficiency, water efficiency, waste management, site quality, material, pollution, quality of services, economic aspects Cultural aspects and Management and Innovation. Each of the above categories includes a list of related criteria (shows in Fig. 4.12 in the proposed SEAM scheme), creating a 92 item list of criteria for sustainable residential building assessment in Saudi Arabia. Due to the absence of a non-subjective approach for the development of new weighting systems for sustainable assessment schemes, the use of Analytical Hierarchy Process (AHP) considers a viable alternative (Pohekar and Ramachandran, 2004, Ali and Al Nsairat, 2009). This constitutes follow on next chapter which will deliver a weighting system for the generated categories and criteria, identified and approved with the use of the Delphi technique.

5

SEAM applicable weighting system

5.1 Introduction

Sustainability development is a board concept, that can be measured through various dimensions (Cole, 1998; Cooper, 1999; Crawley and Aho, 1999; Wong and Abe, 2014). A weighting system is one best option and a viable strategy to priorities those dimensions (Chang et al., 2007; Chew and Das, 2008). Yet, the weighting system of well-known methods (e.g. BREEAM, LEED, SBTool, and CASBEE) has not originally been designed to suit developing countries (including Saudi Arabia). This chapter proposes to customize an adapted weighting system that prioritizes Saudi Environmental Assessment Method (SEAM) categories. The research methodology involves the use of analytic hierarchy process (AHP). Expert choice software was the main tool analyse the input data. This research instrument involves the participation of a number of leading, global experts in the field of environmental and sustainable development, as well as professionals and highly-informed local experts from government, academia, and industry. The results reveal that the weighting systems of well-known environmental assessment methods are not fully applicable to the Saudi Arabia built environment, as reflected in the resulting categories, criteria and weighting system of SEAM. This chapter will begin by illustrating the current AHP applications in the construction industry, commenting on the robustness of this analytical tool for the delivery of a reliable weighting system. A presentation will then be provided of the resultant SEAM weighting system, which includes: the weight of each category, the credit allocation strategy, the chosen rating formula, and SEAMs benchmarking expression. This presentation will conclude with a discussion of the approved weighting system for the Saudi context, along with its distinguished aspects from international systems, and also will discuss the adaptation of SEAM in different climatic conditions within the KSA.

5.2 Development of an environmental weighting system

Given the existing socio-cultural and regional variations, it is difficult and impractical to impose a single environmental assessment scheme worldwide. Hence, an adapted assessment scheme is essentially required to suit specific environment, economy and cultural aspects. This section seeks to shed light on the process of adapting the proposed assessment method, more specifically its weighting system, to the particular requirements of Saudi Arabia (Chandratilake and Dias, 2013). Grace (2008) argues that sustainable assessment methods involve a spectrum of criteria; using a singledimension approach is not the most practicable method of meeting the desired objective of sustainable development principles. Instead, a multi-dimensional approach involving the participation of key stakeholders and decision-makers offers a more robust methodology, which would produce both quantitative and qualitative building assessment criteria (Ding, 2008). The development of well-known assessment methods was established on the basis of consultation processes amongst a panel of experts, with the aim of reaching the most reliable consensus on applicable building assessment criteria (Sam, 2010; BRE, 2008).

The strategy employed for a worldwide adaptation process of the weighting system, in both BREEAM and LEED, lacks overall transparency. On the other hand, SBTool (international) follows a systematic approach towards its customization in different counties, and this tool has enhanced its quality so as to overcome some of the environmental and regional variations. In this regard, Chang et al. (2007) conducted a study of SBTools adaptation in Taiwan. The research instrument utilized was the analytical hierarchy process (AHP), which aimed to prioritize the environmental and regional dimensions to suit the local conditions of Taiwan territory (Chang et al., 2007). Furthermore, Lee and Burnett (2006) state that in Hong Kong there has been increasing public demand for the development of sustainable buildings. As SBTool was deemed the most comprehensive assessment method, it has been customized for the Hong Kong context; a survey and in-depth interviews was the method selected to bridge the gap between the Hong Kong context and the philosophy of SBTool (Lee and Burnett, 2006).

According to most recent publications (Burdov and Vilekov, 2012; Chandratilake and Dias, 2013; Raslanas et al., 2013) a panel of experts participation is still the key ingredient for the adaptation of an environmental assessment method and its weighting system. A case in point, the development of Slovakias method (Burdov and Vilekov, 2012) involved the participation of eleven experts to determine the level of intensity of its main categories, which include: building site and project planning, building construction, indoor environment, energy performance, water management and waste management. Overall, there are essential steps which ensure the correct handling of the complex sustainable assessment method for certain regions. These steps include (a) identification of applicable multiple criteria through a reliable instrument; (b) establishing a valid weighting system, by which regional and cultural aspects may be prioritized. The use of (applicable criteria and weighting system), therefore, will greatly simplify the evaluation of sustainable development, thereby making a constructive contribution to the identification of best practices in design and operational strategy.

5.3 Application of Analytical Hierarchy Process (AHP)

AHP has been used in research fields as diverse as health care, education, and the construction industry. Given that this study is concerned with the development of the building sector in general and sustainable building assessment methods in particular, this section presents a selection of important studies utilizing AHP in related fields.

Wong and Li (2008) identified and evaluated the criteria that affect the performance of intelligent building systems (IB), which they achieved through the use of a general survey followed by the AHP method. Since previous IB projects tended to lack a systemic method to enhance the evaluation of building technology, they proposed to lay the foundation for the selection of intelligent building systems (IB). The general observation of IB in this study includes main criteria: work efficiency; cost effectiveness; user comfort; safety; operating and maintenance costs and reliability. AHP was the main instrument used to prioritise these dimensions (Wong and Li, 2008).

Zheng et al. (2009) recognised that the remarkable growth in the global building sector has serious consequences on the environment. This led them to study life cycle assessment (LCA) in an attempt to mitigate environmental pollution caused by intensive consumption of energy in the construction field. Zheng et al. formed a LCA model combined with extenics theory in building energy conservation, as well as providing a scientific tool for the assessment of building energy conservation. The life cycle of the construction include: Design stage, construction stage, use stage, and decommissioning stage. AHP played a major role in determining the weighting system for the proposed model (Zheng et al., 2009).

Pohekar and Ramachandran (2004) reviewed multi-criteria decision making (MCDM) techniques in the domain of sustainable energy management. This field embraces a spectrum of subject matter, including: allocation of energy resource, renewable energy planning, building energy management, management of transportation energy, planning for energy projects, and planning electric utility. In recognition of this diversity, more than 90 published papers were analysed to determine the most popular and applicable techniques in this field. The surveyed literature showed that AHP is the most popular method, followed by outranking technique (Pohekar and Ramachandran, 2004).

Zayed et al. (2008) studied the assessment of risks and uncertainties in Chinese highway projects, at both macro and micro levels. In this context, the macro level is associated with the company: financial, political, and cultural and market risk; in contrast, the micro level is associated with the project itself: technology usage, contracts and legal issues, resources, design, quality, construction and other areas. A model was designed to determine the risk index (R-index), with AHP being used as the main instrumental tool to deliver that model (Zayed et al., 2008).

Ying et al. (2007) combined a geographical information system (GIS) with the AHP technique to study regional eco-environmental evaluation. The GIS capability of spatial analysis was supported by the effectiveness of AHP in dealing with the complexity of the eco-environment characteristics. This resulted in the creation of an integrated assessment system for eco-environmental evaluation that covers environmental pollution, natural environment, eco-environment disaster and social economy (Ying et al., 2007). In addition, Bunruamkaew and Murayama (2011) used (GIS) and AHP technique to evaluate site suitability for ecotourism. Professional experts identified the most important criteria as: visibility, reservation/protection, land use/cover, species diversity, elevation, proximity to cultural sites, slope, and distance from roads and settlement size. The AHP technique provided the crucial role of deriving a relative weight value for each criterion (Bunruamkaew and Murayam, 2011).

Al-Harbi (2001) employed the AHP technique in project management, in order to model the contractor prequalification problem in order to create an effective means to evaluate contractor competence and ability during a project bid. This selection requires various criteria to be examined, many of which depend on a degree of subjective judgment. Therefore, this study established a hierarchy model comprising three levels: goal, criteria and possible alternative contractors. The main criteria that determine the best potential contractor were shown to be financial stability, experience, quality performance, manpower resources, equipment resources and current work load. Furthermore, there are many factors that affect the choice of project delivery method (Al-Harbi, 2001).

Kanagaraj and Mahalingam (2011) examined building energy efficiency during the design stage. This study claims that the building design process requires multiple stages in securing approval for a proposed design, with many approaches in this domain that lack practical solutions. The authors attempted to bridge this gap by establishing inclusive design process named the Integrated Energy-Efficient Building Design Process (IEBDP). The AHP technique was used resolve the controversial and conflict decisions among the varied design goals that they discussed (Kanagaraj and Mahalingam, 2011).

Teo and Ling (2006) assessed the effectiveness of safety management systems (SMS) in construction companies in order to reduce the probability of risk occurrence in construction sites. A framework including more than 500 factors and sub-factors was established and AHP technique used to process this data into a weighting system. As a result, their study enables a Construction Safety Index (CSI) to be calculated to evaluate the safety management system (SMS) in construction companies (Ai Lin Teo and Yean Yng Ling, 2006).

Hsueh and Yan (2011) developed an evaluation model to enhance sustainable community development in construction. This model sought to promote the effectiveness of energy-saving polices and to thereby help communities to mitigate their carbon footprint. The AHP technique was integrated with the Delphi method and fuzzy logic in order to create a proposed model for use by governments to evaluate the performance of low-carbon community construction projects. The domain of sustainable community development criteria in this initiative include: Natural environment, Energy efficient design, Planting, Renovation benefits, Development convenience, Living environment, Disrupted facilities, Community attractions, Local cultural attractions, Community participation community organizations (Hsueh and Yan, 2011).

5.4 Proposed SEAM weighting system

Building assessment categories and criteria are the basis of any assessment method; SEAM has been developed on a consensus basis, informed by local and international experts. Since the development of a coherent and comprehensive framework was deemed to be complex issue, this, however, has been overcoming by systematic consultation with informed experts. The illustration of SEAM categories and criteria has comprehensively presented in chapter four (Alyami et al., 2013); and here is the followed part which is the proposed weighting system of that delivered SEAM categories and criteria.

5.4.1 Weighting system

The weighting system is a viable strategy in which local environmental conditions may be prioritized; it is also considered the heart of any environmental assessment scheme (Cole, 2005). SEAM categories were therefore subjected to the use of AHP. A hierarchy model was built relying on the consensus of 35 experts. A pair-wise comparison was conducted so as to prioritize these categories, based on the Saudi Arabia local context. Fig 5.1 shows the combined pair-wise comparison (Reciprocal Matrix = 11x11).

	Indoor Env	Energy Effi	Water Effic	Waste Mar	Site Quality	Material	Quality of S	Economic A	Pollution	Manageme	Cultural As
Indoor Environment Quality		1.07341	2.11332	1.25896	1.73589	2.06533	3.78902	3.50061	1.25451	3.12977	4.00848
Energy Efficiency			1.11916	2.55322	4.14267	4.21698	3.99252	3.83565	2.63785	4.26052	4.51075
Water Efficiency				5.66386	6.20986	4.84784	4.47702	4.57165	3.73854	5.57422	6.36466
Waste Management					1.85304	1.5999	2.44959	1.36189	1.46452	1.65963	3.52687
Site Quality						1.01991	1.37345	1.38907	1.1184	1.12738	1.992
Material							2.98881	1.42508	1.39764	1.65627	3.31676
Quality of Services								1.11863	1.35368	1.49102	2.47141
Economic Aspects									1.06975	1.18912	2.3593
Pollution										1.84547	2.83175
Management & Innovation											2.56646
Cultural Aspects		Incon: 0.02									

Figure 5.1: Combined pair-wise comparison matrix (generated from Expert-Choice)

Expert choice software was the main tool used in implementing AHP concepts (Ali and Al Nsairat, 2009). Therefore, the outcome calculations conducted by this software show reliable judgments. This is clearly presented by the calculation of consistence ratio CR (which equals 0.02 in this study). The synthesis of the pair-wise comparison revealed that "water efficiency" and "energy efficiency" are of top priority to the Saudi Arabia built environment (see Fig 5.2). Furthermore, the categories were arranged in descending order, as shown in Fig 5.2, in order to provide a clear indication of SEAM prioritized categories.

Moreover, in some water scarce regions, water is equally allocated the highest weight amongst environmental assessment categories. For instance, Ali and Al Nsaira 2009 have adapted a rating system for Jordon and the resulted weighting are: (a) Site selection 10.3%; (2) Energy efficiency 23.0%; (3) Water efficiency 27.7%; (4) Materials and resources 10.3%; (5) Indoor environmental quality 11.8%; (6) Waste and pollution 6.4%; (7) Economics 10.0%. It is clear here that the water efficiency has the highest weight, and this is compatible with the current concerns about water scarcity in most of the Middle East countries (Ali and Al Nsairat, 2009).

On the other hand, energy efficiency is often the dominant weight for many developed environmental assessment methods. According to the most recent development, Lithuania adopted BREEAM for its built environment and the energy efficiency weighting is the first prioritised category (Raslanas et al., 2013). Furthermore, the development of Sri Lanka rating method has included six main environmental assessment categories (Site, Energy efficiency, Water efficiency, Materials, Indoor environmental quality and Waste & Pollution). The weight of Site category is allocated as the highest domain; this study also compared its weightings with eight other rating systems in different countries. This comparative analysis revealed that "energy efficiency is the top ranked weighting in those surveyed systems (Chandratilake and Dias, 2013).

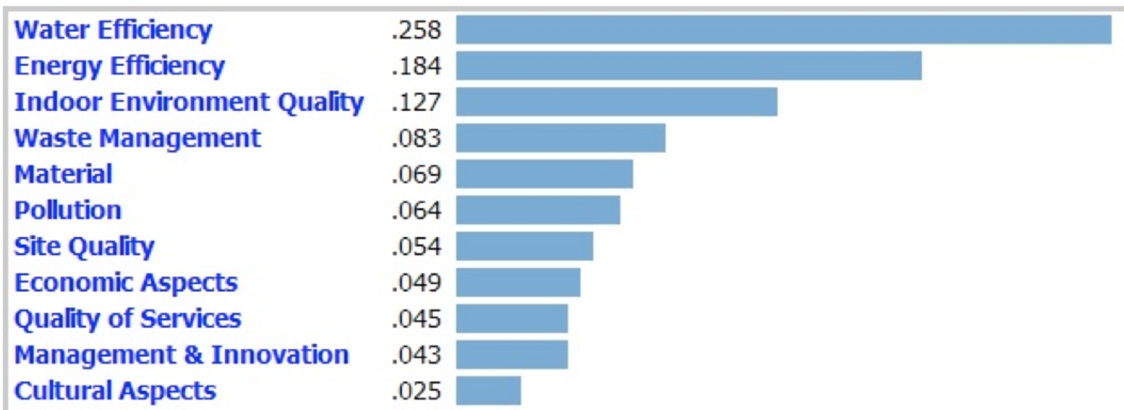

Figure 5.2: Priorities of building assessment categories, derived from pair-wise comparison (generated from Expert-Choice)

Table 5.1: SEAM Weighting System

Categories	Available Credits	Weighting Coefficient
Water Efficiency	12	0.258
Energy Efficiency	20	0.184
Indoor Environment Quality	30	0.127
Pollution	18	0.083
Waste Management	12	0.068
Material	18	0.064
Site Quality	26	0.054
Management and Innovation	17	0.049
Quality of services	10	0.045
Economic Aspects	12	0.043
Cultural Aspects	8	0.025
		∑ 1.000

5.4.2 Credits allocation

Given that the Delphi panel has reached consensus on the criterias relative importance, SEAM credits will inform on ways to distinguish between these criteria. As an example of this, (Fig 5.3) 22 illustrates Indoor Environment Criteria (IEQ) credits allocation. This example is one amongst 11 categories. The criteria that exceed 50% or 2.5/5 are considered applicable to the Saudi built environment, as this indication is commonly used in Delphi studies (Okoli and Pawlowski, 2004). In order to differentiate between these criteria, therefore, a three-level credit allocation has been proposed. In other words, criteria rated more than 2.5/5 can award one credit; criteria rated more than 3.5/5 can award two credits; and criteria rated more than 4.5/5 can award three credits. This strategy will emphasize more compliance on higher rated criteria. Therefore, In Fig 5.3, two criteria are worth 2 credits; 10 criteria are worth 20 credits; and two criteria are worth 6 credits. The total available criteria of IEQ are 30 credits, (which are presented in Table 5.1, The weight of SEAM categories).

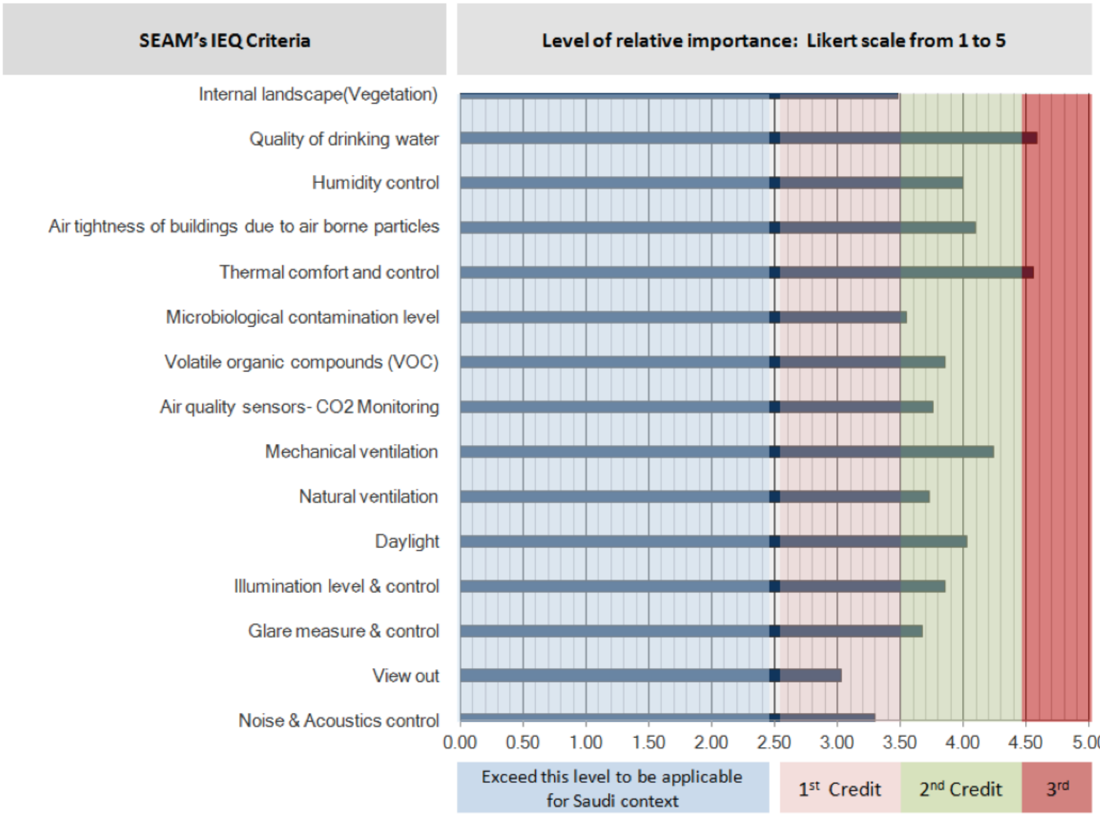

Figure 5.3: Credits allocation based on the intensity importance

5.4.3 Rating formulas

According to the weighting system (Table 5.1) derived from AHP, the SEAM will be able to provide a single score, which will reflect the level of sustainability in the Saudi built environment. This can be achieved by means of the following procedure: (a) determine the rate of each building environmental category (as shown in Equation 1); SEAM has 11 categories: this will result in 11 different rating scores; (b) determine the summation of these 11 rating scores (as shown in Equation 2), which will provide the overall rating within a maximum of 100 credits available.

$$BEC = \frac{CA}{AC} \times W \times 100 \tag{5.1}$$

Where:
BEC: Building Environmental Category
CA: Credits Achieved
AC: Available Credits
W: Weighting Coefficient

$$OverallRating = \sum_{n=1}^{n} BECn \quad (5.2)$$

5.4.4 Rating benchmarks

Since the appearance of the first environmental assessment method (BREEAM), the result of building assessment process is converted into a single ranking expression. Follow on environmental assessment methods (e.g. LEED, SBtool and CASBEE) have adopted the same strategy, with some variations. For example, in BREEAM and LEED the score is calculated out of 100 percent and then converted into a single expression. In SBtool, the assessment is provided using a linear scale from -2 to +5. CASBEE was influenced by SBtool and follows a liner scale from 0 to 3. Using a similar approach to LEED and BREEAM, SEAM advocates the use of a percentage-based scale (as illustrated in Fig 5.4), including 6 different levels of certification. Therefore, in SEAM, buildings rated below 35 will be considered "UNCLASSIFIED" because this is the starting level of meeting primary criteria; buildings rated between 35 and 45 will be considered "PASS"; buildings rated between 45 and 55 will be considered "BRONZE"; buildings rated between 55 and 75 will be considered "SILVER"; buildings rated between 75 and 85 will be considered "GOLD"; and finally, buildings rated over 85 will be considered "DIAMOND" (Five stars) as this is the level of reaching innovative solutions and meeting the majority of SEAM criteria.

5.5 The significance of SEAMs wighting system

. SEAM will play a major role in promoting sustainable products and services within the Saudi built environment. It has therefore been subjected to a multi-stage process in order to obtain reliable customization. The derived assessment categories and criteria have resulted from three deliberative rounds; so as to enable key building stakeholders to evaluate the Saudi Arabia built environment in accordance with adapted sustainable development criteria. Each assessment category has been given a weight, by which the Saudis sustainable objectives may be prioritized. In most recent publication, the significance of SEAM categories and criteria has been discussed in detail (Alyami et al., 2013). It is therefore important to discuss here the relevance of the customized weighting system for the Saudi context, and its divergence from the international system.

Figure 5.4: SEAM rating benchmark

Water use: Currently, LEED is the only assessment method deployed in Saudi Arabia, of all international methods. This choice is not based on the most applicable assessment system accurately measuring the level of sustainability; instead, it is based on some political and market-based preferences. To prove this argument, one could assert that the weighting system is the heart of any building assessment method. However, LEED has been criticized for the absence of its adaptable weighting system (Haapio and Viitaniemi, 2008). As it makes use of simple 1 for 1 additive credits. Another important consideration is that Saudi Arabia has one of hottest and most arid climates, having neither lakes nor rivers. It was also identified as one of the countries having the highest water consumption - the third-largest per capita water use worldwide (Kajenthira et al., 2012). Therefore, when looking to the Saudi Arabia environment, water use is the most challenging issue requiring to be recognized as a top priority category. International systems (e.g. LEED), however, consider water efficiency less important than other sustainable categories, such as energy and sustainable sites.

In other words, LEED allocates 35 possible credits for energy, 26 credits for sustainable site, and 14 credits for materials; whereas water efficiency provides only 10 possible credits. This indicates that buildings may be awarded many credits regardless of its water efficiency. SEAM, however, took this factor into account; hence, the consensus of the panel of experts indicates that water efficiency is the top priority category for the Saudi built environment (with the weighting coefficient equal to 25.8 %).

Energy efficiency: Although Saudi climatic conditions make this vast land difficult for comfortable habitation, SEAM will nevertheless support building professionals who focus on green building principles. Accordingly, taking full advantage and efficient use of (energy and material) can significantly enhance the level of sustainability. This is because of its high potential of reducing environmental impact. The energy efficiency category is given almost the highest rating among international assessment methods. In SEAM this category is also the second-top priority with the weighting coefficient equal to 18.4%. SEAM also allocates higher credits to various criteria compatible with current concerns of developing the Saudi built environment (El-Ghonemy, 2012, Hepbasli and Alsuhaibani, 2011, Al Saud, 2010). Neither LEED nor BREEAM covered those key sustainable criteria. For instance, buildings and associated facilities in Saudi Arabia are exposed to the burning sunlight during day time. The SEAM panel strongly advises using shading strategies as key criteria, whereas there is no consideration of such techniques by the international systems.

Another key issue is the government subsidy of electricity. It has been argued that it is better to subsidize the solar industry and technology in Saudi Arabia instead of subsidizing the cost of electricity consumption. This approach had positive effects in countries such as Japan and Germany. High solar irradiation is not experienced in either Germany or Japan, and yet these countries have, by dint of subsidies, expanded and augmented their solar industries. Two kinds of government subsidy are worth highlighting: mandates and incentives, or the stick and carrot approaches. Negative incentives, or the stick types, apply to mandates, as they do to carbon cap-and-trade schemes; equally to RPS or renewable portfolio standards. The carrot types, or positive incentives, provide financial motivation for using sources of renewable energy, as found in tax credits, feed-in tariff, or installer subsidies (KICP, 2009). In this context, SEAM can play the significant role of evaluating the level of energy saving. This, in turn, will provide policy and decision-makers with the most accurate input indications

As the environmental assessment method seeks to stimulate the market demand on sustainable practice, the world has witnessed some pioneering projects. A case in point, The Fujisawa Sustainable Smart Town (Fujisawa, Japan,) is predicted to be one of the most highly developed eco-towns in the world. The desired objective, for this town community, is to reduce CO_2 emissions by 70%, while cutting water consumption by 30%. This town comprises 1000 homes; several stores; a nursing home; health-care services; and public parks. The project is designed to be more energy efficient than a conventional town. Each home has installed a solar PV, which can afford approximately 70% of the total household energy consumption (To and Fernndez, 2012).

Some could argue that Japan has particular climatic conditions which allow for the building of such green and eco-built environment. However, the Arab peninsula is also witnessing an advance in green and sustainable development, as illustrated by Masdar Eco City (Abu Dhabi, United Arab Emirates) (Masdarcity, 2013). The city under construction is located on the heart of the Arab Emirates desert. It will rely entirely on renewable energy sources such as solar energy, geothermal power, hydrogen power, and wind energy. This city is a paradigm, making the statement that humans are capable of adapting themselves to extreme uninhabited environments. Thus, Masdar City will exhibit zero-carbon and zero-waste ecology. In addition, about 80% of the water used will be recycled, and fed into its irrigation system. This shows that an applicable evaluative scheme has great potential for promoting a sustainable built environment for the Saudi context.

Pollution & risk and site quality: The location of the built environment is of vital importance when it comes to sustainable development (USGBC, 2013), because there are several factors which can cause a severely negative impact on this environment. In other words, pollution and natural disasters (e.g. flooding, earthquake, etc.) would be extremely destructive to the inhabited site. Hence, environmental assessment methods deal with this issue differently. BREEAM, for residential buildings allocate 10% weighting value for this category. It takes into account relevant issues such as food risk, which may be considered in assessing of the Saudi context. In LEED, a lack of weighted criteria in this regard is observable. Over the last decade, the Saudi built environment has experienced regular flooding, which have caused massive damage to buildings and associated services (Al Saud, 2010). Even LEED platinum rated buildings suffered from a lack of efficient infrastructure which would protect both citizens and the built environment. Therefore, the weighting system of SEAM considers this and other pollution risks as a major priority, by giving a relevant weighting of 8.3 %.

The quality of sustainable site is taken in great consideration by both LEED and BREEAM. LEED allocates 26 possible credits for a sustainable site with more attention to the Development Density and Community Connectivity and Public Transportation

Access. BREEAM also has two different categories that evaluate the site, which are land use & ecology; and transport. Land use and ecology weigh equal to 10%; transport weighs equal to 8%. By contrast, SEAM allocates 26 available credits which form 5.4 % from the overall weighting. SEAM, therefore, shows no great difference in this regard; however, it also evaluates a key criterion which is assessing the linkage of building with fundamental infrastructures and services. While the developed world is concerned with the quality of the site, most developing countries still suffer from the lack of fundamental infrastructure. For this reason, SEAM provides sufficient indicators for building professionals to allocate proper weight to fundamental infrastructure.

Economic and cultural aspects: The environmentally friendly building still costs more than a conventional building; this conflicts with the ultimate principles of sustainable development (Ding, 2008). LEED has a clear shortcoming in dealing with financial considerations; where there is no such category or such weighted criteria to deal with this issue. BREEAM also places a higher weight for energy efficiency, CO_2 mitigation and indoor environment quality. The weighting system, however, lacks a balance of these dimensions with economic aspects which comply with the desired objective of sustainability. These systems (BREEAM and LEED) seem to reflect the developed countries concern with overcoming financial considerations of vital importance in the developing countries. However, SEAM has customized a major category (Economic Aspect), giving a weight equal to 4.3 %, which will evaluate building and its associated economic aspects in Saudis built environment.

Socio-cultural aspects can also influence building design and operation in Saudi Arabia (Alyami et al., 2013). These aspects have not been given any weight by international assessment methods. The SEAM panel has, however, reached consensus on a weighting coefficient equal to 2.5 % by which the influence of cultural and social aspects can be recognized.

Quality of services: The functionality and reliability of building services and products are the main aspects on which buildings can be assessed. On examining the well-known assessment methods, BREEAM and LEED do not give reasonable weight or even few credits in acknowledgement of these aspects. On the other hand, SBTool and CASBEE offer a better evaluation framework, by giving these aspects relatively adequate attention, as represented on their weighting systems. This was therefore a viable learnt lesson to SEAM. The SEAM panel agreed on the significance of these dimensions, allocating 10 possible credits for the quality of services, with overall weighting equal to 4.5%.

5.6 SEAM adaptation in different climatic conditions within the KSA

Although there is a growing number of environmental assessment method across the globe, the adaptation of environmental assessment methods for specific regions is becoming significant for a reliable evaluation of certain built environments (Gou and Lau, 2014, Seinre et al., 2014, Wong and Abe, 2014). Specific factors such as regional climatic conditions may hinder the direct application of any environmental assessment method (Todd et al., 2001, Haapio and Viitaniemi, 2008). Therefore, it is imperative when developing a new environmental assessment method to examine the influence of the specific, local climatic conditions on a buildings energy performance, on the one hand and devise customized building assessment categories, criteria and an applicable weighting system suitable for that particular climatic zone, on the other. As presented in the previous publications (Alyami and Rezgui, 2012; Alyami et al., 2013; Alyami et al., 2014) SEAM has been through multiple stages of development to build an adapted scheme for the Saudi context.

The discussion here focuses on the identification of distinct regional climatic zones within Saudi Arabia and their potential influence on the adaptation of SEAM, specifically building energy performance. It suggests that further investigation of a customised EAM would be relevant, in a way, to determine the degree to which the use of a particular sustainability measure - energy efficiency and CO_2 mitigation - has different building performance effects in different Saudi Arabian climatic zones. This investigation can then be used to propose a mathematical factor or coefficient (in matrix form), by which SEAM can make a more accurate assessment when it is used across Saudi territories.

5.6.1 Saudi Arabia climatic zones

The built environment in Saudi Arabia is experiencing extreme climatic conditions across its geographical regions (Al-Homoud, 2009). According to an updated environmental data report - maintained and published by Saudi Presidency of Meteorology & Environment - Saudi Arabia can be subdivided into three climatic zones. The most significant Saudi climatic conditions can be presented by looking at three different regions (CDSI, 2014): (a) hot arid climate (b) hot humid climate (c) mild hot mountainous climate.

Hot-arid climate: This site is typified by Riyadh, and covers the central regions of Saudi Arabia with its hot-dry climate. This region experiences extreme hot and dry conditions in summer, with clear skies most of the year. This makes the situation very challengeable for building designers to overcome the harsh overheating conditions. In winters, the temperature drops significantly, with large diurnal temperature ranges and moderate cold.

Hot-humid climate: This site is typified by Jeddah, and covers the coastal regions of Saudi Arabia, which is hot-humid climate. The humidity coupled with high temperature is the dominant conditions during summers. On the other hand, winters are short and mild with very small diurnal temperature ranges. The humid and hot conditions are very important factors that need to be taken into account by building designers and developers. Mild hot mountainous climate: This site is typified by Al-Bah, and covers the mountainous and high region of Saudi Arabia, which is characterized by a mild hot climate. This region experiences moderate temperatures in summers and cold weather in winter.

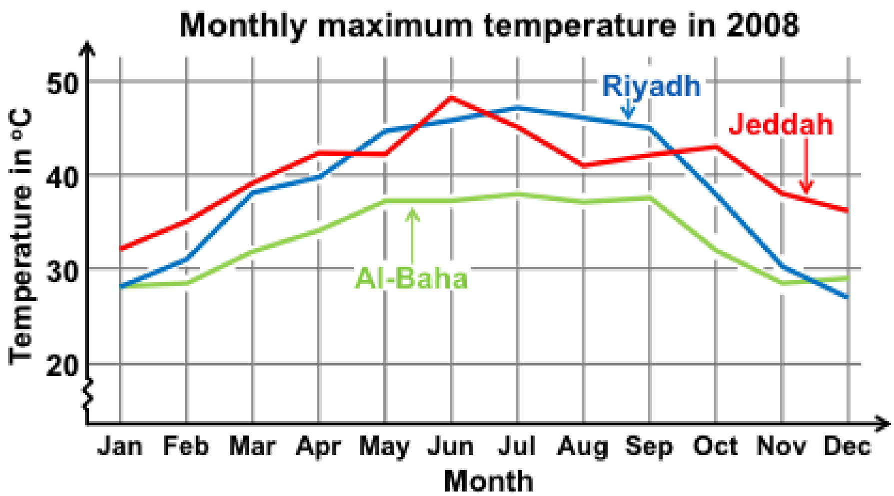

Figure 5.5: Temperature degree during 2008 for: Riyadh, Jeddah and Al-Baha (Source: Central Department of Statistic & Information, 2014).

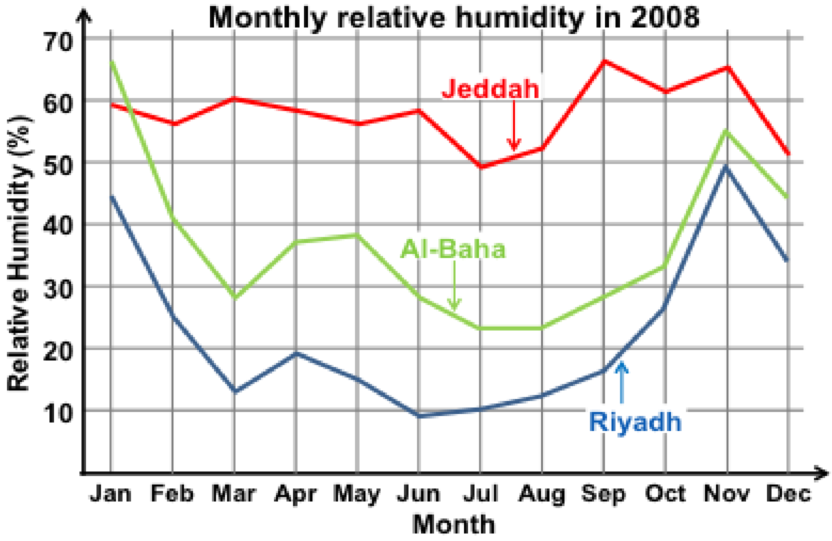

Figure 5.6: Relative humidity during 2008 for: Riyadh, Jeddah and Al-Baha.(Source: Central Department of Statistic & Information, 2014)

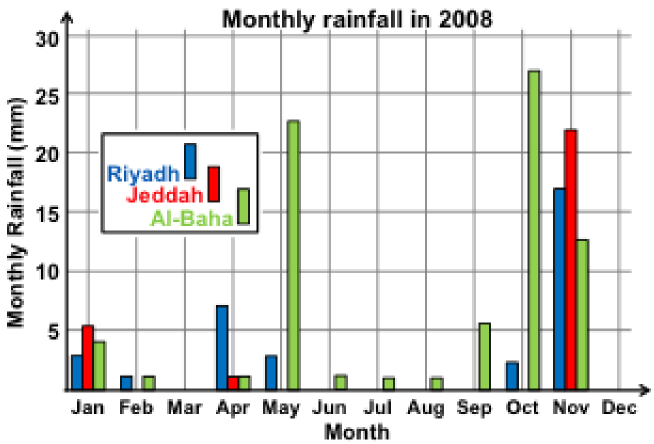

Figure 5.7: Annual rainfall during 2008 for: Riyadh, Jeddah and Al-Baha.(Source: Central Department of Statistic & Information, 2014)

It is clear from Figures 5.5, 5.6 and 5.7 that when comparing these three different cities both Riyadh and Jeddah experience overall high temperate levels. The mild hot climate, however, presents notable differences, in contrast with the temperature of these two zones; the difference in temperature ranges between 11 and 12 from June to July. As for the relative humidity, the recorded data show that Jeddah has the highest and relative constant humidity level during the year. In addition, the precipitation rate shows fluctuated and very low rainfall levels in all these zones. However, the recorded data indicate that in November 2008, these cities experienced torrential rains, which have in many instances resulted in localized flooding (CDSI, 2014). Primarily looking to these zones, there are some challenges, but also some benefits that can be taken from these weather conditions, a case in point, the clear skies during the year which can be exploited for renewable energy generation (e.g. the effective use of solar radiations).

5.6.2 Proposed method of enhancing SEAM

Saudi Arabia is a large country incorporating different climatic zones. As a result the effectiveness of an assessment method will depend on: (a) Ensureing the appropriateness of the SEAM development process and its potential role in meeting sustainable development (b) Distinguishing the climatic conditions of Saudi Arabia and its impact on the built environment (c) Promoting nergy efficiency design and the potential benefits that can be obtained from energy efficiency and CO_2 reduction. The investigation and analysis of a built environment is significantly affected by its climatic conditions. There is a unique condition in every city, a micro climate, the description of which , for any location in the world, is to some degree complex (Al-Homoud, 2009). However, there is a number of different ways to categorize climatic zones; this depends on various criteria or variables (Yang et al., 2008).

For the purpose of enhancing SEAM accuracy, the weather data of Saudi Arabian cities (feasibly include : Riyadh, Jeddah and Al-Baha) should be analysed. The reason of suggesting the investigation on these three cities, because they represent the most critical three climatic zones, demanding varying energy consumption and carbon emission rates, in Saudi Arabia. The analysis and comparative testing of these climates can play a significant part in verifying SEAM use in different climatic conditions within the same level of economic development and social activity. Therefore, some of the published weather data, along with the building simulation tools weather data profile, for these three cities, would be used to provide relevant background information about these sites (Ryan and Campbell, 2012).

5.6.3 Potential development & benefits

Environmental assessment methods have been justifiably criticised for being used in widely differing climatic conditions without appropriate adjustment for local variation in conditions. This necessarily influences the accuracy of assessments being made (Ding, 2008, Haapio and Viitaniemi, 2008, Todd et al., 2001). Therefore, depending on where they are being utilised, the effectiveness of well-known environmental assessment methods may potentially be limited. The absence of adaptable assessment systems, that acknowledge the ways in which climatic conditions affect building performance, is causing severe criticism. However, the building simulation tools can play a significant role in acknowledging the influences of climatic conditions on building performance, helping to improve overall environmental assessment methods. These building simulation tools can produce quantitative data, enabling mathematical analysis that identifies the best possible values for given climatic variations. Such an approach could improve the overall accuracy of existing assessment methods, like BREEAM for example, when they are used in different, regional climatic zones. In the present study, this approach was used in relation to SEAM and produced the SEAM Climatic Zone Matrix.

The question here is that what SEAM Climatic Zone Matrix can do to make fair judgments and what is the overall benefit from this outcome? The answer is that the significance of such matrix is to allow greater specificity in the assessment of building performance. Let us assume that three buildings of similar design and operation activities -but located in three different climatic conditions- needs to be assessed. Building A: located in hot arid climate; Building B: located in hot humid climate; and Building C: located in mild hot and mountainous climate. It seems rational that those buildings should be awarded similar credits because they incorporate exactly the same specifications. However, in SEAM a coefficient are proposed, to be included in the calculation process, taking into consideration the impact of the climatic conditions, not just being entirely dependent on building design and function. Thus, this matrix recognises the actual contribution of building design & operation and most importantly the impact of climatic conditions on building energy performance.

In addition, the matrix can identify the effects of climatic conditions, potentially leading to as much as 15% energy saved. From a financial perspective these savings could be profound. Given that Saudi Arabia is burning 2.9 millions barrels of crude oil per day to generate electricity (eia, 2014) half of which (approximately 1.45 Million barrels per day) is consumed by residential buildings (Al-Ajlan et al., 2006). As the price of one oil barrel is almost \$85 (Oil-Price, 2014), this means that residences in Saudi Arabia cost about (\$85 X 1.45 Million barrels per day=\$123.25 per day) \$123.25 million per day to run, and so a 15% saving from wide-scale adoption of more efficient housing could account for a reduction around \$18.5 million per day.(As 15% saving is the highest potential marks of climatic differences among Saudi territories, Which occurs when comparing: Hot humid climate against Mild Mountainous climate , For this case, it is taken above to show how significant small proportion of energy saving).

Energy Efficiency Significance

Energy efficiency is the driving force of implementing environmental assessment methods; this is due to the fact that the building industry worldwide is putting high pressure on natural resources, embodied in the tremendous demand for electricity. This high demand as mentioned earlier is behind the raise of CO_2 emissions as the burning of fossil fuel is the dominant way of generating the electricity especially in the developing world.For instance, in the GCC countries the demand for energy has far exceeded the global average over the last few years; Qader (Qader, 2009) points out that the reasons behind this high consumption of energy in the GCC countries is high economic growth, reflected by the increase in GDPs, with the GCC experiencing tremendous development in services and infrastructure, as seen in KSA and the UAE. As mentioned earlier, electricity demand is increasing at a record level; and it is expected that the next 2030 years will witness higher rates worldwide. The future electricity demand in the GCC countries is expected to be 80% higher in 2015 than the current demand (Qader, 2009). It is unlikely that the major source of electricity generation in GCC countries will still be the combustion of fossil fuels, as this being recognised a harmful effect on the environment (Lelieveld et al., 2012).

The building sector is the dominant sector for energy consumption; building environmental assessment methods seek to comply with sustainability principles. However, building environmental assessment methods are comparatively new and still evolving as a field of investigation. This is, in order, to prompt worldwide adaptation. The existing assessment methods are heavily criticised for the absence of integrating regional variations (Haapio and Viitaniemi, 2008). Thus, it is of vital importance for policy makers and other building professionals (assessors) to detect how much environmental and economic benefit can be gained from the implementation of sustainability measures. It is exactly this degree of specificity that this study attempts to add to assessment methods by focusing on regional climate conditions.

It can be argued that environmental assessment methods designed in the manner described above can bring about a new appreciation of climate influence on the built environment. They can provide decision makers with a robust strategy aiming to classify regional climates and in turn direct the growth and potential building boom to these provinces. This approach can also be a good strategy for detecting efficient locations with high level of passivity, which can, in turn, facilitate a high standard of sustainable development. Hence, the mild hot and mountainous area in Saudi Arabia occupies massive regions. This province is still under development and is not as densely populated as Jeddah or Riyadh. Al-Baha city was taken to represent those regions, which is located in southwest Saudi Arabia. Therefore, if the government take this point into consideration by, taking serious steps to direct the countrys regional building development, it can play a crucial role in saving energy, with huge economic and environmental benefits.

According to IEA 2012 the benefits of energy efficiency can go beyond energy savings and CO_2 reduction. It can also be a good strategy for economic growth and social development. This statement was further explained in a report by IEA; it has categorised these multiple benefits into: individual; sectoral; national and international levels. (a) Individual level benefits include: health and wellbeing; poverty alleviation (energy affordability and access); and increased disposable income (b) Sectoral level benefits include: industrial productivity and competitiveness; energy provider and infrastructure benefits; and increased asset values. (c) National level benefits include: job creation; reduced energy related public expenditures; energy security; and macroeconomic effects. (c) International level include: reduced GHG emissions; moderating energy prices; natural resource management; and meeting development goals (Ryan and Campbell, 2012).

Since energy efficiency can be a key contributor to many benefits at different levels, it would be furthering for SEAM to examine the impact of climatic conditions on a buildings energy efficiency. This examination can aid building professionals to recognise the impact of factors beyond human control (such as climate). Furthermore, taking into consideration local climatic conditions can lead to a more accurate judgement when comparing building performance in different climatic zones within Saudi Arabia and determining how much sustainable development would achieve aside from the environmental benefits. SEAM can then provide key stakeholders (policy makers, building professionals building assessor etc) with (distinguished sensitive coefficient factors) when comparing buildings energy performance across Saudi Arabia.

This in turn can direct building professionals effort and produce innovative solutions. Through the approach presented here, building professionals would be aware that achieving a high standard of building performance is not as hard or costly in the mild, hot climate of Al-Baha as in the extreme hot, arid climate of Riyadh. Therefore, the coefficient is important if building assessors and policy makers need to detect the distinctions between how much effort and innovation are required when comparing building design and operation.

5.7 Summary

The need of stimulating the market demand for sustainable practices in the built environment requires the large scale adoption of adapted environmental building assessment methods. While western countries have widely engaged in this avenue, developing economies such as Saudi Arabia are still trialling different environmental assessment schemes developed for other contexts. Also, Saudi Arabia presents a great potential for renewable energy while still heavily relying on fossil fuels. Hence, it becomes imperative to design and put into operation a benchmark scheme which will assess the principles of sustainable building construction. This will foster the recognition of green building principles with the extensive adoption of sustainable energy. Therefore, the research hypothesis formulated earlier in this chapter is set to promote the adaptation of such a scheme in Saudi Arabia. It was tested using AHP method; Expert choice software was the main tool that analyses the input data of pair wise comparison. The results of the AHP study strongly suggest that the weighting system of well-known environmental assessment methods such as BREEAM and LEED are inapplicable for the Saudi context. SEAM categories have been prioritized in this study, by means of AHP (Fig 5.2), with the aim of reflecting the most accurate sustainable measures of the Saudi Arabia built environment. As Saudi Arabia is experiencing water scarcity, water efficiency came at the top of SEAM weighting system. Saudi Arabia has an alternative and abundant natural resource (i.e. solar energy), which can be used to deliver a more sustainable built environment. For this reason, energy efficiency emerged as the second top priority. (Table. 20) provides a full illustration of the weightings system for all SEAM categories, in line with the first research question. As the strategy of an environmental building assessment method is to provide a single score, this chapter combines AHP with Delphi to devise credits allocation for SEAM criteria and rating formula, and this, in turn, closes the circle of a completed SEAM weighting system. Yet, through the discussion and deliberation around SEAM potential modification in Saudi Arabia, it is suggested enhancing SEAM by investigating the influence of different climatic conditions on the built environment performance. Therefore, SEAM would subject to a sensitivity analysis with the objective of conducting comparative testing of three different climate zones: hot arid climate (Riyadh); hot humid climate (Jeddah) and mild hot mountainous climate (Al-Baha). This investigation would play important role to detect the distinction between these different climate conditions within the Saudi context, and its impact on a buildings energy efficiency and carbon emission reduction. Building simulation tool (e.g IES-VE) is suggested to be used as research instrument to collect and analysis relevant data.

6 Conclusion

6.1 Motivation

In recent years, Saudi Arabia has embarked on an ambitious development programme in all sectors, including rapid evolution of the building sector (Ali and Alfalah, 2010). The widespread transformation from traditional buildings to modern, reinforced concrete structures is evident. This change has been facilitated by the availability of fossil fuel, which enable and enhance the built environment through the use of diverse building components and appliances (KACST, 2002; Taleb and Sharples, 2011; Bahammam, 1998). This dramatic shift in building strategies has put enormous pressure on construction material, energy, water supply and other services; this is because of its ultimate reliance on conventional way of building design and operational practices. As a consequence of this reliance, the building sector in Saudi Arabia is placing intensive pressure on national reserves of natural resources, with an estimated two-thirds of all electric energy generated in the Kingdom of Saudi Arabia being used by the building industry (Al-Sanea et al., 2012). The current practices of the construction industry severely impact on the environment, with the most widespread building design and operation approaches dramatically exacerbating the situation. To illustrate this, in 1975 the total peak electricity load was 300 MW. By 2007 it had increased to 34,953 MW. According to projections, total peak electricity is set to reach 57,808 MW by 2023, all of which is forecast to still come from burning fossil fuels, the major source of CO_2 (Obaid, 2008). This demonstrates that the need for sustainable practices and innovative solutions has become essential. There should therefore be greater concern and meaningful action from all sectors toward the design and adoption of environmentally friendly practices. The importance of this issue has led to this research study and its stated goals of searching for ways to promote sustainable development in Saudi Arabia.

From a wider perspective, the early 1990s saw a real attempt to obligate the building sector to comply with certain building codes and standards of sustainability development. This primarily focused upon the ways in which buildings were designed and operated, aiming to reduce their operational implications and the associated potential environmental impact. For instance, Crawley and Aho (1999) state that measuring tools should be used to assess the design and operation of buildings with regards to their effect on the environment. Developed countries have put significant effort into the creation and refinement of such systems. As an example of this, the foremost international environmental assessment methods BREEAM and LEED are widely used in countries around the world, despite having been designed to suit a specific environment. Indeed, the evidence suggests that many existing environmental assessment methods were developed for different, local purposes, and are therefore not universally applicable to all regions (Cole, 1998; Cooper, 1999; Crawley and Aho, 1999; Kohler, 1999). More specifically, the direct use of existing assessment tools may be hindered by environmental factors including climatic conditions; potential for renewable energy gain; resource consumption; construction materials; and techniques used.

The main aim of this study is therefore to customise a building environmental assessment scheme to stimulate the demand for sustainable buildings and services in Saudi Arabia. This will come in the form of developing a sustainable building assessment method for Saudi Arabias built environment. The research goal is therefore to provide a credible environmental label for buildings, enabling them to be recognised and evaluated according to their environmental characteristics. This will hopefully contribute to the popularity of potential renewable resources (e.g. solar energy) in the KSA. A number of key objectives must be met in the delivery of this method: (a) consolidation of sustainable building assessment categories and criteria through the comparative analysis of a selection of important assessment methods (BREEAM, LEED, SBTool and CASBEE); (b) the assembly of a panel of experts in the field of sustainable built environmental, who will participate in the deliberation process; (c) investigation of the consensus by the panel of experts on the applicable categories and criteria for Saudi Arabia built environment; (d) and delivery of a tailored weighting system for the chosen building assessment categories.

6.2 Answering the defined research questions

The overarching hypothesis of this study is that the leading environmental assessment models currently in use, such as BREEAM and LEED, have not been properly adapted to the political, environmental, and social specificities and context of the Saudi built environment. This encompasses recognition of regional variations, including the constraints of available resources, local architecture, specific environmental conditions, and other economic and socio-cultural factors. A mixed methodology approach was used to investigate these research questions (see the theoretical model presented in Fig). The strategy chosen to answer the first of these (What is the applicable theoretical model to promote robust development and to provide a roadmap that supports the customization of an environmental assessment method?) was a theoretical study, involving comprehensive review of the building assessment field. This led to recognition of the need to develop a new scheme based upon a comparative analysis of well-known building assessment methods. This stage also identified the main requirements for the adaptation of such a scheme in different built environments. This included expert consensus on applicable building assessment categories and criteria, in addition to the requisite weighting system. A comparative analysis of well-known systems (BREEAM, LEED, SBTool and CASBEE) was instrumental in providing a solid basis upon which the subsequent stage of adaptation, namely the deliberation process, The detailed answer to the first research question can be seen on the spiral model that breaks down the process of the development of new system which answer research question one.

The second research question sought to answer, what are the categories and criteria required to form the best sustainable assessment method for the Saudi Arabian built environment? In order to answer this question, an empirical study was conducted using the Delphi method. The goal of the Delphi technique was to obtain the most reliable consensus of opinion of a group of experts by a series of intensive questionnaires interspersed with controlled opinion feedback (Linstone et al., 1975). This study utilised the Delphi technique to gain an insight from the consensus of a panel of experts on applicable building assessment categories and criteria. Three successive rounds of a structured consultation were conducted, which resulted in the development of the SEAM scheme (categories and criteria): the first round involved brainstorming to identify potential categories and criteria suitable to Saudi Arabia built environment; the second round concentrated on revision of and narrowing down; and the third round involved a final rating on the agreed building assessment categories and criteria. The next stage sought to develop a customised weighting system for SEAM through the use of AHP, which is the answer to the third research question: What are the applicable weighting systems, rating formulas and benchmarking expressions that reflect the most accurate appraisal of the Saudi Arabian context?. AHP was originally developed in the 1970s by Thomas Saaty. AHP supports a multi-criteria decision-making approach and allows decision makers to model a complex problem in a hierarchical structure (Saaty, 1994). In the context of this research, AHP provided a vital service through conversion of the subjectivity of the research problem into a mathematical form.

6.3 Achievements during the building of this thesis

Reviewing the EAM resulted in several benefits arising from this research. First, by understanding emerging and rapidly growing areas of research a comprehensive and critical review of the specific domain Rating System for the sustainable assessment method led to the identification of weaknesses in existing and leading well-established methods (LEED and BREEAM). More importantly, this led to the proposal of a theoretical model on which to develop new and customised method, that will potentially overcome this weakness. The value of the proposed theoretical model has been confirmed, and approved for publication in the Sustainable Cities and Society Journal (Elsevier). It includes multiple stages of development that seek to identify the most applicable method to suit regional and local contexts, socioeconomic aspects, and has also been adapted to match accessible and potential natural resources.

- One of the key components when carrying out the SEAMs multi-stage development was the panel composition. Therefore, during the fieldwork, satisfactory knowledge was attained regarding the KSAs current movement towards sustainable development. This follows on from an extended informal interview with key and leading experts in the field. Some points in this regard were discussed in the KSA context section. Likewise, the main objective Composing a Panel of Experts was met at this stage, which is an essential phase prior to the research rounds.

- The overall findings of the empirical study strongly suggest that predominant international schemes, such as BREEAM and LEED, are not applicable for the assessment of Saudi Arabias built environment. There is therefore a need to develop customised categories and criteria tailored for use within Saudi Arabias built environment. Expert consensus holds that building environmental and sustainable assessment categories should include: 1. Indoor environmental quality; 2. Energy efficiency; 3. Water efficiency; 4. Waste management; 5. Site quality; 6. Material; 7. Pollution; 8. Quality of services; 9. Economic aspects; 10. Cultural aspects; and 11. Management and Innovation. Each of the above categories includes a list of related criteria (shows in Fig.3 in the proposed scheme), creating a 92-item list for sustainable building assessment in Saudi Arabia.

- The prioritisation of sustainable categories was derived from AHP. This process contributed to the establishment of a customised weighting system reflecting the significance of each category, with water and energy efficiency being accorded top priority in the Saudi context. The percentage weight accorded to each category is as follows: water efficiency (25.8 %), energy efficiency (18.4%), indoor environmental quality (12.7%), pollution (8.3%), waste management (6.8%), materials (6.4%), site quality (5.4%), management and innovation (4.9 %), quality of services (4.5 %), economic aspects (4.3%), and cultural aspects (2.5 %). For greater explanation and a discussion of the weighting system and associated aspects, see Chapter five.

6.4 The adaptation process: Justification

The major motivation for launching and operating environmental assessment methods is to promote energy efficiency and to reduce carbon emissions (Lee & Burnett 2008). For example, both BREEAM and LEED focus on these two factors (BRE 2013; USGBC 2013). This is probably attributable to the fact that the consumption of fossil fuels contributes to numerous negative environmental phenomena, such as pollution, acid rain, erosion and elevated GHE concentration in the atmosphere (Field et al., 2014). Therefore, this issue has been given the top priority in the area of sustainable development and green building principles (Berardi, 2012, Cole and Jose Valdebenito, 2013). However, EAM include a number of different dimensions that are considered mixed criteria (Kajikawa et al., 2011). As a result, the development of such systems should necessarily involve a consensus-based approach to create a comprehensive and coherent scheme (Haapio and Viitaniemi, 2008). For this reason, the development of SEAM has involved constant and approved approaches towards building coherent categories, criteria and weighting systems. While there was a lack of clear guidance for the development of new environmental assessment methods, a number of experts recommended that a consensus-based approach could be a viable option (Chew & Das 2008; Grace K.C 2008; Haapio & Viitaniemi 2008; Ali & Al Nsairat 2009; Lee & Burnett 2006; Cole 2005). In addition, the synthesis of research papers has contributed to the building of consistent stages (theoretical models) (Alyami & Rezgui 2012) for the development of a new scheme. The evaluation of well-known environmental assessment methods (BREEAM, LEED, SBTool and CASBEE) contributed to the initial development of SEAM, with the foundations and even guiding philosophy of these recognised methods informing the creation of the new SEAM scheme. However, certain essential factors required customisation to suit the Saudi Arabian context, including: (a) the adaptation of building assessment categories and criteria; (b) the development of an applicable weighting system. The multiple consultation stages of the Delphi technique were crucial in verifying the applicability of selected building assessment categories and criteria (Alyami et al. 2013). This consultation process was a powerful method to engage with the built environment, as the complexity of this field cannot be consolidated by the use of a single tool. Expertise contribution, using the human capability for synthesising various factors on common ground, is therefore the only method of forming a comprehensive and coherent assessment system. Human judgement can also be converted into mathematical form and used more accurately in the evaluation of certain specific circumstances through the use of AHP. Therefore, the development of SEAM has used this technique in the delivery of an applicable weighting system, which is at the core of correct functioning of the assessment method.

6.5 Recommendations

- Almost all well-known building assessment methods are updated and revised either annually or every two years. Therefore, it is recommended that SEAM be subjected to regular review, which will inform required development and updating.

- The building assessor should take a comprehensive course and have a solid background in sustainability development. This will make the building assessment process more reliable, reflecting the real performance of the Saudi Arabian built environment.

- This SEAM scheme is particularly suitable for use with residential buildings and so it is therefore recommended that similar schemes should be developed for use within the urban development, such as with schools and hospitals etc.

- Key Delphi panel experts recommend that SEAM should not initially impose prerequisite criteria, in order to prompt the first launch and operation of SEAM. However, key building professionals should eventually reach an agreement on the prerequisite criteria for SEAM, after it has been extensively used in the Saudi context.

- As the testing and simulation process of SEAM applicability within the context of Saudi Arabia has been limited to a sample of typical houses, it is recommended that the assessment method be tested on different sizes and types of buildings.

6.6 Future work

There are a number of certain environmental assessment criteria that require compliance with building standards and codes (e.g. ISO, CIBSE and ASHRIA). As these codes were originally designed in developed countries, the government of Saudi Arabia is now in the process of developing and enforcing its own building standards. Therefore, the comparison of local and international standards is an important area for further investigation, particularly from the perspective of offering support to the criteria of SEAM. For this case, it is worth studying the appropriateness of international standards and codes in contrast with the nascent Saudi Arabia building standards. Another important consideration arises from the assumption that environmentally friendly buildings are more financially expensive than conventional buildings, meaning that it is important to investigate any environmental economic aspects that may hinder the movement towards adoption of these more environmentally friendly buildings.

6.7 Summary

This chapter presents the main motivation for this study, namely the rapid growth and development in Saudi Arabia and the consequent pressure that the construction industry experiences . This growth needs to be carefully operated and monitored in order to reduce the strain on the environment. Therefore, this study proposes a customised sustainable building assessment scheme to contribute to sustainable development of the KSA. In order to meet this objective, a number of research questions have been answered, with the answer to each having been presented and explained above. Validation statements are also made in this section, as well as recommendations for future research.

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Appendix A: Invitation letter

Dear Sir/Madam ....

Date...............................

A research study is being conducted to customize sustainable building assessment tool in which sustainable development can be met in Saudi Arabia built environment. Therefore, sustainable building criteria have been consolidated from well-known assessment tools at the aim of open-ended solicitation of ideas to create a list of applicable criteria for Saudi Arabia built environment. The residential building is the target for this study. The study utilizes Delphi technique and Analytical hierarchy process (AHP) as a research instruments for data collection. The primary purpose of using these methods is to obtain consensus of experts' opinion on the applicability of building assessment criteria and it's weighting system for Saudi Arabia residential building.

Your contribution to this research is very important to the success of this study. Therefore, I am inviting you to participate in this study. If you agree to participate in this study, you will be kindly required to respond to approximately four rounds of questionnaires. Each round will take about less than 30 minutes to complete *(A detailed information about Delphi and AHP will be provided with the questionnaire)*. All information submitted from the participants will be treated as confidential and will be used for research purposes only. Participants' names and details will not be disclosed to anybody or organization, only summarized information will be reported.

Your willingness to contribute in this study is highly appreciated

Sincerely yours,

Saleh Alyami
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Mobil: 00447715586979

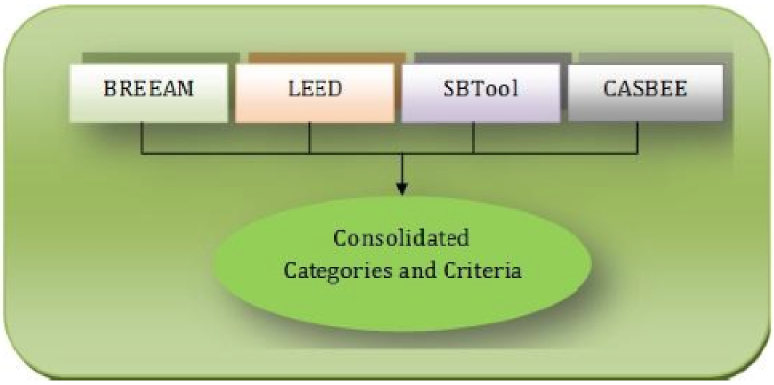
Appendix B: Delphi Survey

Customize Building Environmental Assessment Method for Saudi Arabia

Dear Expert,

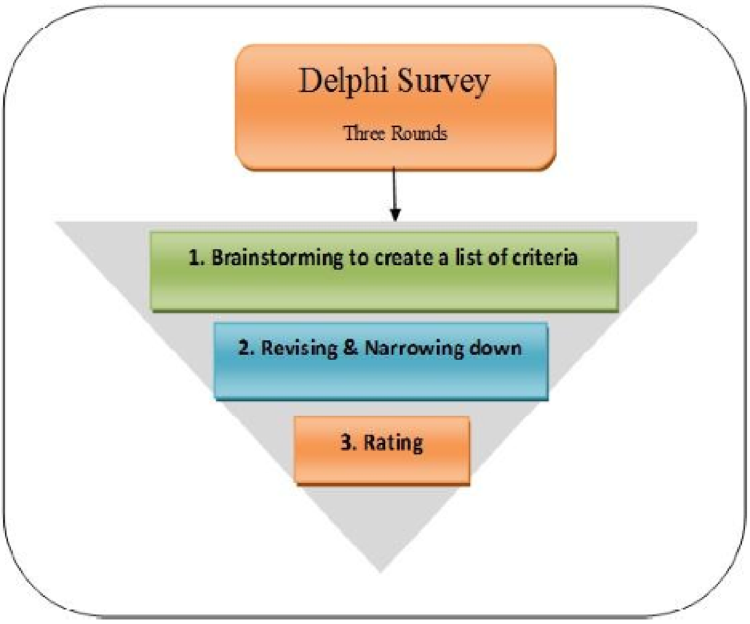
A research study is being conducted to customize building environmental assessment tool in which sustainable development can be met in Saudi Arabia built environment. Therefore, sustainable building criteria have been consolidated from Well-known assessment tools (as shown in Fig.1) at the aim of open-ended solicitation of ideas to create a list of applicable criteria for Saudi Arabia built environment. The residential building is the target for this study.

Figure 1 Well known Assessment Tools



The study utilizes Delphi technique as a research instrument for data collection which consists of three rounds (as shown in Fig.2). The primary purpose of using Delphi survey is to obtain consensus of experts' opinion on the applicability of building assessment criteria for Saudi Arabia residential building.

Figure.2 Delphi Rounds



Customize Building Environmental Assessment Method for Saudi Arabia

Personal Information

***1. Please type down your contact details.**

Name:

Organisation:

Country:

Phone Number:

Customize Building Environmental Assessment Method for Saudi Arabia

1. Indoor Environment Quality

The assessment systems assess Indoor Environment Quality with regard to an appropriate healthy level such as Lighting & Illumination, Noise & Acoustics, Ventilation rate and Thermal comfort, as well as protecting the occupants from microbiological contamination or any hazardous substances that might be emitted from the indoor materials.

***2. Please indicate the level of importance of the assessment criteria for Saudi Arabia built environment.**

	1.Not Applicable	2.Not Important	3.Somewhat Important	4.Moderate Important	5.Very Important
Noise & Acoustics control	○	○	○	○	○
View out	○	○	○	○	○
Glare measure & control	○	○	○	○	○
Illumination level	○	○	○	○	○
Daylight	○	○	○	○	○
Natural ventilation	○	○	○	○	○
Mechanical ventilation	○	○	○	○	○
Air quality sensors- CO2 Monitoring	○	○	○	○	○
Volatile organic compounds (VOC)	○	○	○	○	○
Microbiological contamination level	○	○	○	○	○
Thermal comfort and control	○	○	○	○	○

If you indicate Not Applicable for any criterion above, Please justify briefly your opinion

3. Please list further criteria of Indoor Environment Quality which not covered above that consider important for Saudi Arabia built environment.

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Customize Building Environmental Assessment Method for Saudi Arabia

2. Energy Efficiency

Assessment systems therefore place vital importance on energy efficiency design, renewable energy strategies, energy conservation and monitoring. Aiming of efficient use of green resources and taking care of surrounding atmosphere.

***4. Please indicate the level of importance of the assessment criteria for Saudi Arabia built environment.**

	1.Not Applicable	2.Not Important	3.Somewhat Important	4.Moderate Important	5.Very Important
Building envelope performance	○	○	○	○	○
HVAC System	○	○	○	○	○
Lighting: internal & external	○	○	○	○	○
Hot water system	○	○	○	○	○
Renewable energy technology	○	○	○	○	○
Shading Strategy	○	○	○	○	○
Energy monitoring	○	○	○	○	○
Co2 Mitigations strategy	○	○	○	○	○

If you indicate Not Applicable for any criterion above, Please justify briefly your opinion

5. Please list further criteria of Energy Efficiency which not covered above that consider important for Saudi Arabia built environment.

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Customize Building Environmental Assessment Method for Saudi Arabia

3. Water Efficiency

In recognition of water being a limited and therefore valuable resource, the assessment systems seek effectively to determine best practice of water use.

***6. Please indicate the level of importance of the assessment criteria for Saudi Arabia built environment.**

	1.Not Applicable	2.Not Important	3.Somewhat Important	4.Moderate Important	5.Very Important
Water consumption	○	○	○	○	○
Rain water harvesting	○	○	○	○	○
Grey water recycling	○	○	○	○	○
Water fixture & conservation strategy	○	○	○	○	○
Irrigation system	○	○	○	○	○

If you indicate Not Applicable for any criterion above, Please justify briefly your opinion

7. Please list further criteria of Water Efficiency which not covered above that consider important for Saudi Arabia built environment.

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Customize Building Environmental Assessment Method for Saudi Arabia

4. Waste Management

Waste treatment and recycling facilities used in parallel with sophisticated waste management have the potential to insulate humans and their surrounding environment from the consequences of waste risk, and also attain the advantages of treatment and recycling.

***8. Please indicate the level of importance of the assessment criteria for Saudi Arabia built environment.**

	1.Not Applicable	2.Not Important	3.Somewhat Important	4.Moderate Important	5.Very Important
Construction waste management	○	○	○	○	○
Solid waste treatment	○	○	○	○	○
Recycling facilities	○	○	○	○	○

If you indicate Not Applicable for any criterion above, Please justify briefly your opinion

9. Please list further criteria of Waste Management which not covered above that consider important for Saudi Arabia built environment.

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Customize Building Environmental Assessment Method for Saudi Arabia

5. Site & Location Quality

This category also aims to deliver a number of important issues such as density development of building, infrastructure efficiency, and public communication through easy access to public services and relevant facilities as well as outdoor amenity.

***10. Please indicate the level of importance of the assessment criteria for Saudi Arabia built environment.**

	1.Not Applicable	2.Not Important	3.Somewhat Important	4.Moderate Important	5.Very Important
Site selection	○	○	○	○	○
Contaminated land	○	○	○	○	○
Mitigation ecological impact	○	○	○	○	○
Biodiversity protection	○	○	○	○	○
Vegetation & Shading	○	○	○	○	○
Accessibility	○	○	○	○	○
Density development of buildings	○	○	○	○	○
Community connectivity	○	○	○	○	○
Pedestrian & Cyclist safety	○	○	○	○	○
Car parking capacity	○	○	○	○	○

If you indicate Not Applicable for any criterion above, Please justify briefly your opinion

11. Please list further criteria of Site & Location quality which not covered above that consider important for Saudi Arabia built environment.

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Customize Building Environmental Assessment Method for Saudi Arabia

6. Material & Vernacular Architectural Principles

The assessment systems aim to mitigate the potential consequences of resource consumption, by taking into account many issues such as, future generation needs, effective use of local materials, and encouraging the use of recyclable and environmentally friendly material.

***12. Please indicate the level of importance of the assessment criteria for Saudi Arabia built environment.**

	1.Not Applicable	2.Not Important	3.Somewhat Important	4.Moderate Important	5.Very Important
Material with low environmental impact	○	○	○	○	○
Local materials	○	○	○	○	○
Recyclable material	○	○	○	○	○
Re-use of structural frame materials	○	○	○	○	○
Building fabric component (Insulation)	○	○	○	○	○
Responsible source of materials	○	○	○	○	○
Use of finishing materials	○	○	○	○	○
Material efficiency over its life cycle (LCA)	○	○	○	○	○

If you indicate Not Applicable for any criterion above, Please justify briefly your opinion

13. Please list further criteria of Material & Vernacular Architectural Principles which not covered above that consider important for Saudi Arabia built environment.

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Customize Building Environmental Assessment Method for Saudi Arabia

7. Quality of Services

There are a number of building characteristics that facilitate both a higher quality of operation and attendant services. These have indirect but significant effects on resource use, environmental loadings and indoor environmental quality.

***14. Please indicate the level of importance of the assessment criteria for Saudi Arabia built environment.**

	1.Not Applicable	2.Not Important	3.Somewhat Important	4.Moderate Important	5.Very Important
Functionality and Usability	○	○	○	○	○
Flexibility and Adaptability	○	○	○	○	○
Durability and Reliability	○	○	○	○	○
Maintenance of performance	○	○	○	○	○

If you indicate Not Applicable for any criterion above, Please justify briefly your opinion

15. Please list further criteria of Quality of Service which not covered above that consider important for Saudi Arabia built environment.

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Customize Building Environmental Assessment Method for Saudi Arabia

8. Economic Aspects

Attaining superiority in the construction industry is the goal that attracts the interest of most key stakeholders and therefore sustainable principles must be built upon a careful consideration of the financial aspect. Thus to meet best practice, environmental assessment systems are concerned with the management of life cycle cost, construction cost, and operating maintenance cost in a sustainable manner.

***16. Please indicate the level of importance of the assessment criteria for Saudi Arabia built environment.**

	1.Not Applicable	2.Not Important	3.Somewhat Important	4.Moderate Important	5.Very Important
Construction cost	○	○	○	○	○
Life cycle cost	○	○	○	○	○
Operating and Maintenance cost	○	○	○	○	○
Affordability of residential rental	○	○	○	○	○

If you indicate Not Applicable for any criterion above, Please justify briefly your opinion

17. Please list further criteria of Economic Aspects which not covered above that consider important for Saudi Arabia built environment.

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Customize Building Environmental Assessment Method for Saudi Arabia

9. Pollution And Risk

Due to the global warming and climate change the likelihood of natural disaster and pollution are steadily raised. For this reason, assessment systems take into consideration certain criteria when assessing built environment.

***18. Please indicate the level of importance of the assessment criteria for Saudi Arabia built environment.**

	1.Not Applicable	2.Not Important	3.Somewhat Important	4.Moderate Important	5.Very Important
Refrigerant GWP – Building services	○	○	○	○	○
Night light and noise pollution	○	○	○	○	○
Preventing refrigerant leaks	○	○	○	○	○
Strategic Prevention from sand storm (Dust Impact)	○	○	○	○	○
Heat island effect	○	○	○	○	○
NOx emissions from heating source	○	○	○	○	○
CO2 Emissions	○	○	○	○	○
Fire risk	○	○	○	○	○
Natural disaster (Flooding, Hurricanes. etc)	○	○	○	○	○

If you indicate Not Applicable for any criterion above, Please justify briefly your opinion

19. Please list further criteria of Pollution & Risk which not covered above that consider important for Saudi Arabia built environment.

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Customize Building Environmental Assessment Method for Saudi Arabia

10. General Management

There are a number of manageable criteria that assessment systems evaluate, with the goal of ensuring the protection of both social and environment features as well as attaining superiority in economic aspects.

***20. Please indicate the level of importance of the assessment criteria for Saudi Arabia built environment.**

	1.Not Applicable	2.Not Important	3.Somewhat Important	4.Moderate Important	5.Very Important
Commissioning	○	○	○	○	○
Construction process planning	○	○	○	○	○
Consultation	○	○	○	○	○
Considerate constructors	○	○	○	○	○
Construction site impacts	○	○	○	○	○

If you indicate Not Applicable for any criterion above, Please justify briefly your opinion

21. Please list further criteria of General Management which not covered above that consider important for Saudi Arabia built environment.

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Customize Building Environmental Assessment Method for Saudi Arabia

Conclusion

The summary of the consolidated Categories for Saudi Arabia (Environmental& Sustainable Assessment Scheme)

24. Please indicate the level of importance for the below categories.

	1.Not Important	2.Somewhat Important	3.Moderate Important	5.Very Important	5.Extremely Important
Indoor Environment Quality	○	○	○	○	○
Energy Efficiency	○	○	○	○	○
Water Efficiency	○	○	○	○	○
Waste Management	○	○	○	○	○
Site& Location Quality	○	○	○	○	○
Materials & Vernacular Architectural Principles	○	○	○	○	○
Quality Of Services	○	○	○	○	○
Economic Aspects	○	○	○	○	○
Pollution &Risk	○	○	○	○	○
General Management	○	○	○	○	○
Cultural & Social Aspects	○	○	○	○	○

Comment

Appendix C: Pairwise comparison: AHP

Dear Expert,

I would like to inform you that the result of three rounds "Delphi survey" presents the consensus on the applicable ***Building Assessment Categories*** for Saudi Arabia built environment which include 11 key categories *as shown below in Fig.1*. Therefore, a Pair-wise comparison approach will be carried out in this round to priorities these dimensions for the conditions of Saudi Arabia built environment. Thereby, the results of this comparisons process will be analyse using Analytical Hierarchy Process (AHP) to determine the weighting system for the sustainable assessment method for Saudi Arabia residential building.

Questionnaires: Pair-wise Comparisons

In this questionnaire, you will be asked to perform relative comparison of importance of the applicable categories for Saudi Arabia residential buildings. Each row in the relative comparison tables includes two categories and their rating boxes at the middle. In each row, please circle the appropriate number using pair-wise comparison scale (1-9 scale) as shown below:

Scale	Categories Scale
1	Equal importance of both element
3	Moderate importance of one category over anther
5	Strong importance of one category over anther
7	Very strong importance of one category over anther
9	Extreme importance of one category over anther
2,4,6,8	Intermediate values

Please can you type your name?

Name	

Examples:
The objective of this concept is to determine the weighting for each category by conducting pair-wise comparison.

If your decision is that the weight of "A" is moderate important than "B", then your response will be:

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
A							✓											**B**

If your decision is that the weight of "B" is extremely important than "A", then your response will be:

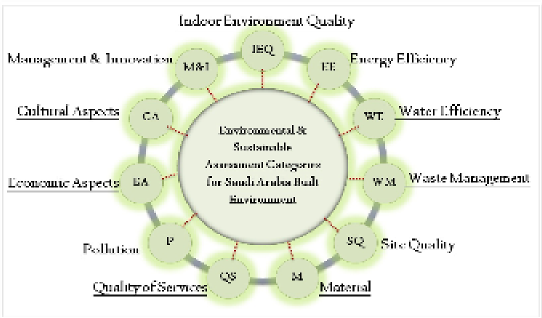
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
A																	✓	**B**

If your decision is that the weight of "A" is equal to "B", then your response will be:

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
A									✓									**B**

Part 2: Sustainable Building Assessment Categories

Below Fig shows the approved Sustainable Building Assessment Categories for Saudi context.



Could you please perform the followings **pair-wise comparison**, to determine the applicable weighting system for Saudi context?

1. **Please perform pair-wise Comparisons of Indoor Environment Quality**

[1 = Equal 3 = Moderate 5 = Strong 7 = Very strong 9 = Extreme]

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Indoor Environment Quality																		Energy Efficiency
Indoor Environment Quality																		Water Efficiency
Indoor Environment Quality																		Waste Management
Indoor Environment Quality																		Site Quality
Indoor Environment Quality																		Material
Indoor Environment Quality																		Quality of Services
Indoor Environment Quality																		Economic Aspects
Indoor Environment Quality																		Pollution
Indoor Environment Quality																		Management & Innovation
Indoor Environment Quality																		Cultural Aspects

2. **Please perform pair-wise Comparisons of Energy Efficiency**

[1 = Equal 3 = Moderate 5 = Strong 7 = Very strong 9 = Extreme]

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Energy Efficiency																		Water Efficiency
Energy Efficiency																		Waste Management
Energy Efficiency																		Site Quality
Energy Efficiency																		Material
Energy Efficiency																		Quality of Services
Energy Efficiency																		Economic Aspects
Energy Efficiency																		Pollution
Energy Efficiency																		Management & Innovation
Energy Efficiency																		Cultural Aspects

4. Please perform pair-wise Comparisons of Waste Management

[1 = Equal   3 = Moderate   5 = Strong   7 = Very strong   9 = Extreme]

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Waste Management																		Site Quality
Waste Management																		Material
Waste Management																		Quality of Services
Waste Management																		Economic Aspects
Waste Management																		Pollution
Waste Management																		Management & Innovation
Waste Management																		Cultural Aspects

3. Please perform pair-wise Comparisons of Water Efficiency

[1 = Equal   3 = Moderate   5 = Strong   7 = Very strong   9 = Extreme]

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Water Efficiency																		Waste Management
Water Efficiency																		Site Quality
Water Efficiency																		Material
Water Efficiency																		Quality of Services
Water Efficiency																		Economic Aspects
Water Efficiency																		Pollution
Water Efficiency																		Management & Innovation
Water Efficiency																		Cultural Aspects

1. Please perform pair-wise Comparisons of Indoor Environment Quality

[1 = Equal 3 = Moderate 5 = Strong 7 = Very strong 9 = Extreme]

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Indoor Environment Quality																		Energy Efficiency
Indoor Environment Quality																		Water Efficiency
Indoor Environment Quality																		Waste Management
Indoor Environment Quality																		Site Quality
Indoor Environment Quality																		Material
Indoor Environment Quality																		Quality of Services
Indoor Environment Quality																		Economic Aspects
Indoor Environment Quality																		Pollution
Indoor Environment Quality																		Management & Innovation
Indoor Environment Quality																		Cultural Aspects

2. Please perform pair-wise Comparisons of Energy Efficiency

[1 = Equal 3 = Moderate 5 = Strong 7 = Very strong 9 = Extreme]

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Energy Efficiency																		Water Efficiency
Energy Efficiency																		Waste Management
Energy Efficiency																		Site Quality
Energy Efficiency																		Material
Energy Efficiency																		Quality of Services
Energy Efficiency																		Economic Aspects
Energy Efficiency																		Pollution
Energy Efficiency																		Management & Innovation
Energy Efficiency																		Cultural Aspects

4. **Please perform pair-wise Comparisons of Waste Management**

[1 = Equal   3 = Moderate   5 = Strong   7 = Very strong   9 = Extreme]

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Waste Management																		Site Quality
Waste Management																		Material
Waste Management																		Quality of Services
Waste Management																		Economic Aspects
Waste Management																		Pollution
Waste Management																		Management & Innovation
Waste Management																		Cultural Aspects

3. **Please perform pair-wise Comparisons of Water Efficiency**

[1 = Equal   3 = Moderate   5 = Strong   7 = Very strong   9 = Extreme]

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Water Efficiency																		Waste Management
Water Efficiency																		Site Quality
Water Efficiency																		Material
Water Efficiency																		Quality of Services
Water Efficiency																		Economic Aspects
Water Efficiency																		Pollution
Water Efficiency																		Management & Innovation
Water Efficiency																		Cultural Aspects

5. **Please perform pair-wise Comparisons of Site Quality**

[1 = Equal 3 = Moderate 5 = Strong 7 = Very strong 9 = Extreme]

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Site Quality																		Material
Site Quality																		Quality of Services
Site Quality																		Economic Aspects
Site Quality																		Pollution
Site Quality																		Management & Innovation
Site Quality																		Cultural Aspects

6. **Please perform pair-wise Comparisons of Material**

[1 = Equal 3 = Moderate 5 = Strong 7 = Very strong 9 = Extreme]

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Material																		Quality of Services
Material																		Economic Aspects
Material																		Pollution
Material																		Management & Innovation
Material																		Cultural Aspects

7. **Please perform pair-wise Comparisons of Quality of Services**

[1 = Equal 3 = Moderate 5 = Strong 7 = Very strong 9 = Extreme]

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Quality of Services																		Economic Aspects
Quality of Services																		Pollution
Quality of Services																		Management & Innovation
Quality of Services																		Cultural Aspects

8. Please perform pair-wise Comparisons of Economic Aspects

[1 = Equal 3 = Moderate 5 = Strong 7 = Very strong 9 = Extreme]

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Economic Aspects																		Pollution
Economic Aspects																		Management & Innovation
Economic Aspects																		Cultural Aspects

9. Please perform pair-wise Comparisons of Pollution

[1 = Equal 3 = Moderate 5 = Strong 7 = Very strong 9 = Extreme]

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Pollution																		Management & Innovation
Pollution																		Cultural Aspects

10. Please perform pair-wise Comparisons of Management & Innovation

[1 = Equal 3 = Moderate 5 = Strong 7 = Very strong 9 = Extreme]

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Management & Innovation																		Cultural Aspects

Appendix D: Training Courses and Certificates

BREEAM®

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Certificate of Attendance

This is to certify that

Saleh Alyami

of

Cardiff University

Attended the

BREEAM New Construction Assessor Training Course

On

19 February 2013

Terence Beckett
Training and Events Manager
BRE Global

21 February 2013

Date

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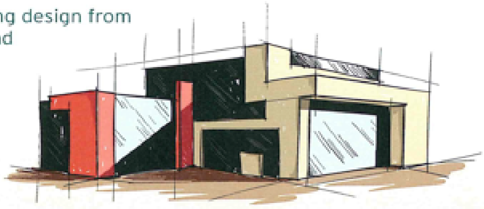

This is to certify that

Saleh Alyami

of **University of Cardiff**

attended and completed face-to-face training

in the following **Virtual Environment** software:

IES VE Product	Date Attended
ModelIT, SunCast	**19th November 2013**
ApacheSim, MacroFlo	**20th November 2013**
Part L2/EPCs via DSM and SBEM	**21st November 2013**

Integrated Environmental Solutions Ltd

Hans Dhargalkar
Training Manager

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SAUDI ENVIRONMENTAL SOCIETY

شهادة حضور

تشهد جمعية البيئة السعودية بأن سعادة الأستاذ/ **صالح هامل اليامي** قد حضر المنتدى الدولي للبنية التحتية وتأثيرها على البيئة والذي أقيم بتاريخ ٢١-١٤٣٣/٢/٢٣هـ الموافق ١٥-٢٠١٢/١/١٧م برعاية خادم الحرمين الشريفين في فندق بارك حياة- جدة والتي كان لها اكبر الأثر في النجاح المميز لهذا الحدث.

نواف بن ناصر بن عبد العزيز

المدير التنفيذي

المملكة العربية السعودية - رقم التسجيل [illegible]
صندوق بريد [illegible] | هاتف [illegible] | فاكس [illegible]

Mr Saleh Alyami
Cardiff University
School of Engineering
Queen's Buildings – The Parade
UK-Cardiff CF 24 3AA
Wales

Lausanne, 29 April 2013

CISBAT 2013 International Conference
Cleantech for Smart Buildings & Cities – From Nano to Urban Scale
Letter of Invitation

Dear Mr Alyami,

As stated in our email message of 20 March 2013, it is with pleasure that we invite you to present your paper

A consensus-based approach to test the applicability of international sustainable assessment schemes for Saudi Arabia context
Alyami S., Rezgui Y.

in the framework of the CISBAT 2013 Conference, which will take place from 4 to 6 September 2013 at the Ecole Polytechnique Fédérale in Lausanne, Switzerland.

The conference website http://www.cisbat.org will help you plan travel and accommodation. Under the same URL, you will also find the preliminary conference programme.

We recommend that the Swiss Embassy issue a visa to you. Your contribution will clearly be of interest for the participants CISBAT 2013 and the topics of the conference are highly relevant to your work.

Please do not hesitate to contact us for additional information or if anything is unclear. We look forward to welcoming you in Lausanne.

Yours sincerely

Professor Jean-Louis Scartezzini
Conference Chair

CISBAT

UF | Distance & Continuing Education
Conference Department
UNIVERSITY *of* FLORIDA

Presents this certificate of attendance to:

Saleh Alyami

For Completion of the

15th International Conference on Computing in Civil and Building Engineering (ICCCBE)

June 23-25, 2014
Orlando, Florida