DEVELOPING FRAMEWORK FOR A CONCEPTUAL MODEL TOWARDS ASSESSING THE ENVIRONMENTAL COMPLIANCE OF NON-RESIDENTIAL BUILDING IN JORDAN

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UNIVERSITI SAINS MALAYSIA

2019

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by

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Thesis submitted in fulfilment of the requirement
for the degree of
Doctor of Philosophy

May 2019

ACKNOWLEDGEMENT

In the name of ALLAH, the most gracious and the most merciful;

First and foremost, I would like to express my gratitude to ALLAH for the blessing to complete this thesis.

I extend my deepest respect and sincere gratitude to my supervisor Dr. Farid Ezanee Mohamed Ghazali for his constant guidance, support, assistance and cooperation throughout the duration of my study. I appreciate his sincere effort and his precious comments, which enriched the quality of this thesis. I would like to thank my co supervisor Assoc. Prof. Hikmat Ali for his support and guidance. I wish to extend my gratitude to the panel of experts for taking part in surveys and everyone who has contributed directly or indirectly to this research. Special thanks are also extended to Universiti Sains Malaysia (USM) for granting me the chance to pursue my PhD degree.

Also, I would like to take this opportunity to thank my parents for their love, support and prayers. I also extend my thanks to my family members and to my wife for her support and encouragement that gave me the courage to stand all the hardships, trials and challenges I have faced during my study. Thanks go to my daughters Tala, Lana and Ayah. Lastly, I would like to thank my friends Anas Alqudah and Amjad Obeidate.

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
ASHRAE	The American Society of Heating, Refrigerating and Air-Conditioning Engineers
BREEAM	Building Research Establishment Environmental Assessment Method
CASBEE	The Comprehensive Assessment System for Built Environment Efficiency
CCDI	Comprehensive Contribution to Development Index
CM	Construction Management
EA	Energy and Atmosphere Category
EPA	The U.S. Environmental Protection Agency
GBI	Green Building Index
GDP	The gross domestic product
HVAC	Heat, Ventilation and Air Conditioning
IGBC	the Indian Green Building Council
JGBG	Jordan Green Building Guide
JNBC	Jordan National Building Council
LEED	Leadership in Energy and Environmental Design
MCEAI	The Multidimensional Contribution of Energy & Atmosphere Index
MCWEI	The Multidimensional Contribution of Water Efficiency Index
MoPWH	Ministry of Public Works and Housing

RII	Relative Importance Index
SDG	Sustainable Development Goals
UN	United Nations
UNEP	United Nations Environment Programme
UNEP-IETC	United Nations Environment Programme-International Environmental Technology Centre
UN SDGs	United Nations Sustainable Development Goals
USGBC	The United States Green Building Council
WE	Water efficiency category
WGBC	World Green Building Council
WHO	The World Health Organization

MEMBANGUNKAN RANGKA KERJA BAGI MODEL KONSEPSI KE ARAH MENILAI PEMATUHAN PERSEKITARAN BANGUNAN BUKAN KEDIAMAN DI JORDAN

ABSTRAK

Kebayakkan kerajaan di seluruh dunia telah membangunkan strategi untuk mencapai Matlamat Pembangunan Mampan (SDG) Bangsa-Bangsa Bersatu (PBB). Bangunan mampan mempunyai peranan penting ke arah mencapai SDG PBB. Pada masa sekarang, terdapat kekurangan maklumat mengenai subjek ini kerana tiada sistem penilaian bangunan mampan yang menggambarkan hubung kait antara kriteria penilaian mampan dan SDG PBB. Walaupun terdapat usaha ke arah itu, bangunan yang tidak mampan dan kemajuan pembangunan yang perlahan ke arah SDG PBB masih berlaku di Jordan. Oleh itu, penyelidikan ini telah mencapai rangka kerja konsepsi ke arah usaha untuk mengintegrasikan penilaian dan pengurusan bangunan tanpa kediaman yang mampan di Jordan bersama SDG PBB.Terdapat dua persoalan berkenaan dengan bagaimana bangunan mampan dapat menyumbang kepada pencapaian matlamat SDG PBB di Jordan dan bagaimana ianya dapat diperbaiki. Untuk menjawab persoalan-persoalan ini, penyelidikan ini dijalankan melalui dua peringkat utama iaitu mengenalpasti hubungan antara Kepimpinan dalam Rekabentuk Alam Sekitar dan Tenaga (LEED) v2.2 dan SDG PBB yang diterokai dengan menggunakan metodologi deskriptif kuantitatif. Hubungan ini telah dikenalpasti melalui kaji selidik berstruktur iaitu ujian Chi-square dan kekerapan Pearson dimana keputusan menunjukkan hubungan positif antara pra-syarat dan kredit LEED v2.2 dalam kategori WE dan EA dan SDG PBB 6-9, 12-13, dan 15. Peringkat kedua penyelidikan ini pula melibatkan pembentukan rangka kerja baru yang telah mengintegrasikan keperluan PBB SDG ke dalam penilaian dan pengurusan mampan untuk bangunan bukan kediaman di Jordan. Untuk mencapai tujuan ini, selain daripada sistem penarafan bangunan sedia ada yang dikaji semula, kaedah Analisis Hierarki Proses (AHP) dan Indeks Kepentingan Relatif (RII) juga digunakan untuk membangunkan pemberat bersepadu yang inovatif (yang menggabungkan kaedah AHP dan RII) untuk menyelesaikan masalah berkaitan kemampanan bangunan mengikut konteks tertentu negara. Selain daripada itu, tinjauan soal selidik telah dijalankan untuk mengenal pasti tahap integrasi penunjuk penilaian dalam fasa projek dan untuk membina sistem klasifikasi. Hasilnya, rangka kerja dibentuk daripada penyelidikan ini terdiri daripada 12 kategori penilaian termasuk 75 indikator yang telah disahkan oleh pilihan pakar-pakar projek pembinaan di Jordan melalui kaedah perbincangan fokus berkumpulan. Penemuan hasil kajian ini juga berpotensi membantu dalam merumuskan alatan penilaian bangunan dan mencapai SDG PBB di negara-negara selain Jordan.

DEVELOPING FRAMEWORK FOR A CONCEPTUAL MODEL TOWARDS ASSESSING THE ENVIRONMENTAL COMPLIANCE OF NON-RESIDENTIAL BUILDING IN JORDAN

ABSTRACT

Governments across the world have developed strategies to achieve United Nations (UN) Sustainable Development Goals (SDG). Sustainable buildings have significant role towards achieving UN SDGs. Currently, there is lack of information on the subject as none of the existing sustainable building assessment systems describe the relationship between its assessment criteria and UN SDGs. Despite the efforts, non-sustainable building and slow progress towards UN SDGs still prevail in Jordan. Therefore, this research achieved conceptual framework towards efforts to integrate the assessment and management of sustainable non-residential buildings in Jordan with UN SDGs.There are two unanswered questions on how sustainable building contributes to achieve UN SDGs in Jordan and how the contributions of sustainable building towards achieving UN SDGs can be improved. To achieve these two research questions, this research conducted into two main stages, in the first stage, the relationships between the Leadership in Energy and Environmental Design (LEED) v2.2 and the UN SDGs were explored using a quantitative descriptive methodology, because at the time of this research, most certified green buildings in Jordan were under new LEED v2.2 construction. Structured questionnaire surveys were conducted. Pearson’s Chi-square and frequency tests were carried out to examine these relationships. The results show a positive relationship between LEED v2.2 prerequisites and credits in both WE and EA categories and the UN SDGs 6−9, 12–13, and 15. In the second main stage of this research, a conceptual framework for integrating UN SDGs into sustainable non-residential building assessment and management in Jordan was developed. For this purpose, previous building rating systems were reviewed, the Delphi technique was applied to identify assessment categories and indicators for sustainable non-residential building in Jordan, the Analytic Hierarchy Process (AHP) and Relative Importance Index (RII) methods were applied to develop a new innovative integrated weight (combination of AHP and RII methods) that can maintain the focus of the sustainable building assessment framework on the UN SDGs while solving building sustainability problems according to a country's specific context. Additionally, questionnaire surveys were conducted to identify the integration of assessment indicators in project phases and to construct a classification system. Finally, the proposed framework, consist of 12 assessment categories include 75 indicators, was validated by focus group discussion method. The findings in this research can potentially assist in formulating building assessment tools and achieving the UN SDGs in countries other than Jordan.

CHAPTER 1

INTRODUCTION

1.1 Background

On September 25, 2015, 193 members of the United Nations (UN) adopted the UN sustainable development goals (UN SDGs), which aim to eliminate discrimination and inequality, poverty, and overcome climate change by 2030 (United Nations, 2018b). Numerous economic and social-developmental concerns such as health, poverty, hunger, education, gender equality, climate change, water, sanitation, environment, energy, and social justice are covered by the 17 UN SDGs (United Nations, 2018a). The construction industry significantly contributes to national socio-economic development. But, this industry uses a considerable amount of natural and energy resources. Therefore, active participation of the construction industry in a country's effort to attain sustainable development is, therefore, essential (UNEP-IETC, 2003).

Worldwide, the building and construction sectors constitute 40% of the total energy use, 40% of waste, 30% of energy-related greenhouse gas emissions, and 12% of water consumption, and employ 10% of the labor force. Many local and global challenges such as demographic shifts, climate change, water, land use, and other resource shortages are significantly affected by the built environment. Fast-growing regions in Asia, Latin America, and Africa are predicted to have additional 2 billion urban residents by 2030. This rapid population increase leads to a higher demand for sustainable construction and buildings (UNEP, 2018a). The society, environment, and economy are three areas that are considerably affected by the built environment. The increasing environmental consideration of the impact of buildings highlights the importance of conducting environmental assessments of buildings in the construction industry (Tatari & Kucukvar, 2011).

The construction industry is vital for social progress, economic growth, and successful environmental protection, which are the three elements of sustainable development (Sev, 2009). "Green building" as defined by the Environmental Protection Agency, is "the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation, and deconstruction. Green building is also known as a sustainable or high-performance building" (EPA, 2018).

Governments worldwide have adopted green building as a key policy to avert energy crises and climate change (Shen, Yan, Fan, Wu, & Zhang, 2017). The World Green Building Council stated that "green buildings can contribute to meeting the sustainable development goals" (World Green Building Council, 2018b). Sustainable development may be achieved through the implementation and application of green-building-assessment tools (Ali & Al Nsairat, 2009). Sustainable construction refers to construction that is economically, socially, and environmentally sustainable (Illankoon, Tam, & Le, 2016).

Survival, economic growth, and human progress require two factors, which are intricately linked: water and energy. Water is essential for production processes of energy sources (including electricity) such as raw-material extraction, cleaning processes, cooling thermal processes, crop cultivation for biofuels, and powering turbines. Energy is necessary to ensure that water resources are available for human consumption (including irrigation) through treatment, pumping, transportation, and desalination. Various resolutions regarding water and energy challenges should be organized into an integrated response because partial responses are bound to fail in the long term despite short-term success (UN, 2018b).

The importance of utilizing a novel sustainability approach in Jordan is reinforced by rapid urbanization, continuing of non-sustainable building development and low progress in achieving UN SDGs. The new approach should integrate the UN SDGs into the assessment and management of sustainable building in Jordan to assist in guiding the implementation of UN SDGs in the Jordanian construction sector. The contributions of sustainable buildings to achieve UN SDGs in Jordan have not been assessed before.

1.2 Jordan

The UN has classified Jordan as a lower-middle-income nation. The gross domestic product (GDP) per capita of Jordan was USD 4087.9 in 2016. The population of Jordan increased from 5,597,000 in 2004 to 9,798,000 in 2016, with over 80% of residents in urban areas. In 2016, the construction sector of Jordan contributed 4.4% to the GDP, which is equal to an additional 1,195.8 million Jordan Dinars. This sector employed approximately 6.1% of the total Jordanian labor force. In the same year, the number of buildings with permits reached 7,576 (Department of Statistics, 2017a). Water scarcity is a serious concern in Jordan. It is a problem that affects every industry that requires water to sustain its production activities and achieve success (Ministry of Water & Irrigation, 2016b). The overdependence of Jordan on imported energy and its escalating energy demand have become serious challenges to Jordan's ability to secure a stable energy supply (Ministry of Energy & Mineral Resources, 2016).

Jordan has embarked on implementing the 2030 Agenda for Sustainable Development and achieving the Sustainable Development Goals (SDGs) despite numerous challenges Jordan is currently facing (UN, 2018a). Jordan has ranked the 80th country worldwide according to Sustainable Development Goals (SDG) Index and Dashboards Report (2017) by the Sustainable Development Solutions Network. This network analyzes SDGs performance of a total of 157 countries from a total of 193 UN member states (Sachs, Schmidt-Traub, Kroll, Durand-Delacre, & Teksoz, 2017) as shown in figure 1.1. Jordan Green Building Guide (JGBG) was issued in 2013 by the Ministry of Public Works and Housing (MoPWH) - Jordan National Building Council (JNBC) division, which is responsible for the development of the Building Codes in Jordan (Jordan National Building Council, 2013). An incentive program for the adoption of green buildings in Jordan based on the JGBG rating system was approved in 2015 and it was launched on September 3, 2015 (Amman Greater Municipality, 2018). The number of building permits in Jordan is 78,518 during the period from 2009 until 2016 (Department of Statistics, 2012, 2013, 2014, 2015, 2016, 2017a, 2017b) as shown in table 1.1. However, only four certified sustainable/green buildings under LEED certification were executed in Jordan in the same period (US Green Building Council, 2018e, 2018b, 2018a, 2018d). There are several challenges that are related to the implementation of sustainable construction technologies and practices in Jordan. A strategic framework is, therefore, needed for sustainable construction in Jordan (Alsubeh, 2013).

Table 1.1 Number of Permits for new buildings and certified green/sustainable buildings in Jordan

Year	Total Number of Building Permits	Certified Green/Sustainable buildings in Jordan
2009	11,739	The number of certified green/sustainable buildings in Jordan from 2009 to 2016 is only four certified LEED buildings in Jordan based on data available on the USGBC website: 1) World Health Organization Building, LEED BD+C: New Construction v2 – LEED 2.2, a certification awarded in December 2011. 2) Dutch Embassy in Amman, LEED BD+C: New Construction v2 - LEED 2.2, a certification awarded in October 2010. 3) Middle East Insurance Building, LEED BD+C: New Construction v3 - LEED 2009, certification awarded in March 2014. 4) ATG Head Quarter, LEED ID+C: Commercial Interiors v3 - LEED 2009, certification awarded in September 2015.
2010	9,410	
2011	9,873	
2012	9,960	
2013	10,822	
2014	10,304	
2015	8,169	
2016	8,241	
Total = 78,518		

Source: Jordan Department of Statistics (Department of Statistics, 2012, 2013, 2014, 2015, 2016, 2017a, 2017b) and USGBC (US Green Building Council, 2018e, 2018b, 2018d, 2018a)

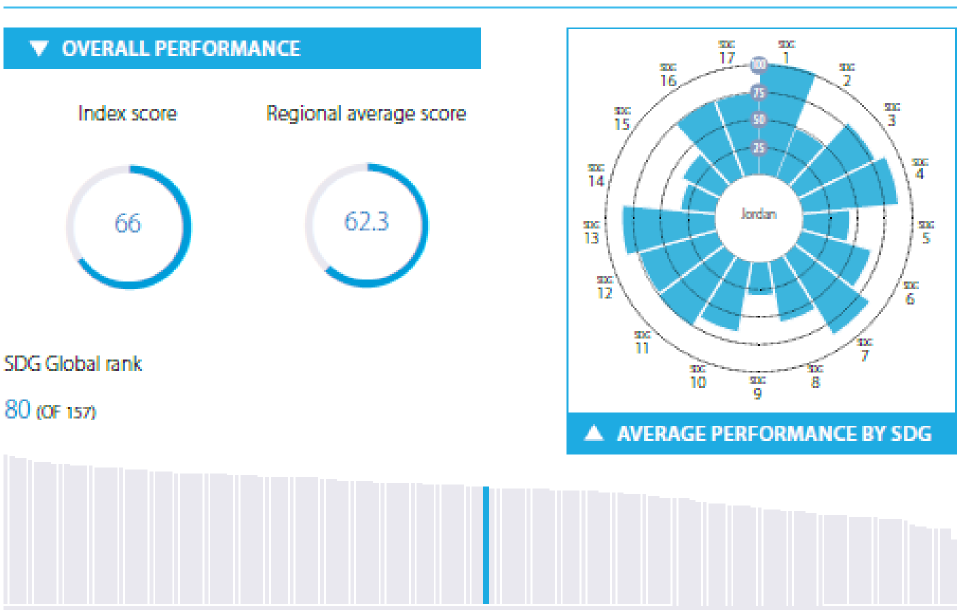

Figure 1.1 Jordan average performance by SDG

Source: (Sachs et al., 2017)

1.3 Statement of the Problem

Jordan faces challenges regarding the availability and the utilization of its natural resources. These challenges are generated by the scarcity of both, water and fossil energy resources along with their increasing demand (Al-Bajjali & Shamayleh, 2018; Al-Omary, Kaltschmitt, & Becker, 2018; Hadadin, Qaqish, Akawwi, & Bdour, 2010; Jaber, Elkarmi, Alasis, & Kostas, 2015; Ministry of Energy & Mineral Resources, 2016; Ministry of Water & Irrigation, 2016a, 2016b). Globally, the construction and building sectors represent 40% of the energy use and waste, 30% of gas emissions from energy-related greenhouses, 12% of water consumption and 10% of labour (UNEP, 2010). "The building and construction sector is one of the most important areas of intervention and provides opportunities to limit environmental impact as well as contribute to the achievement of Sustainable Development Goals" (UNEP, 2018b).

Governments across the world have developed strategies to meet UN SDGs and sustainable building has an important role to play in this respect. Sustainable building has a critical role towards achieving UN SDGs (World Green Building Council, 2018b). Presently, there is a lack of information and understanding of this important subject as none of the existing sustainable buildings assessment tools describes the relationship between its criteria and UN SDGs. This study aims to address these issues. Therefore, the problem statement of this study is summarized as follows: Despite the efforts that have been implemented to promote sustainable building and towards achieving UN SDGs, non-sustainable building development and slow progress towards UN SDGs are still prevail in Jordan. There is no clear framework for integrating UN SDGs into assessing and managing sustainable building in

Jordan. Therefore, there is a need for developing a framework to integrate UN SDGs into the assessment and management of sustainable building in Jordan.

1.4 Research Questions

This study aims to develop a framework for integrating United Nations (UN) Sustainable Development Goals (SDGs) into the assessment and management of sustainable non-residential building in Jordan. To achieve this aim, this study answers the following research questions:

1) What are the contributions of certified sustainable building (particularly water and energy efficiency in certified LEED 2.2 building) to achieve UN SDGs in Jordan?
2) What are the most significant assessment categories and indicators for sustainable non-residential building in Jordan?
3) What are the weights for the assessment indicators of sustainable non-residential building based on the Jordanian significance of sustainability issues and contributions to achieve UN SDGs?
4) What is the appropriate classification system for sustainable non-residential building in Jordan?
5) How should the assessment indicators be integrated into building project phases?
6) How should the framework for integrating UN SDGs into assessing and managing sustainable non-residential building in Jordan be validated?

1.5 Research Objectives

To achieve the main aim of this study, developing a framework for integrating United Nations (UN) Sustainable Development Goals (SDGs) into the assessment and management of sustainable non-residential building in Jordan, the following objectives are addressed:

1) To identify the contributions of the implementation of LEED v2.2 prerequisites and credits in water and energy and atmosphere categories to achieve the UN SDGs in Jordan and develop an integrated index to assess these contributions and validate the proposed index.
2) To identify the appropriate categories and indicators for the assessment and management of sustainable non-residential building in Jordan.
3) To develop an integrated weighting system for the assessment indicators of sustainable non-residential building based on the Jordanian significance of sustainability issues and contributions to achieve UN SDGs.
4) To propose a rating and classification system for sustainable non-residential building in Jordan.
5) To identify the integration of the assessment indicators in the project phases.
6) To propose and validate the framework for integrating UN SDGs into assessing and managing sustainable non-residential building in Jordan.

1.6 Research Hypotheses

Sustainable building has an important role to play in achieving United Nations (UN) Sustainable Development Goals (SDGs). None of the existing sustainable building assessment tools describes the relationship between its assessment indicators and UN SDGs. Therefore, there are two main hypotheses that are postulated in this study.

Hypothesis One for the first part of this research: there is a significant relationship between UN SDGs and LEED v2.2 prerequisites and credits in water efficiency and energy and atmosphere categories.

Hypothesis Two for the second part of this research: a comprehensive framework for integrating UN SDGs into assessing and managing sustainable non-residential in Jordan can assist in improving the development of sustainable non-residential building and the achievement of UN SDGs.

1.7 Research Scope

The scope of this study is confined to non-residential building in all areas of Jordan (buildings that are commercial, institutional and industrial in nature: offices, hospitals, universities, colleges, hotels, shopping complexes and factories). The average number of permits for non-residential building in Jordan reached 1,007 per year from 2009 to 2016 (Department of Statistics, 2012, 2013, 2014, 2015, 2016, 2017a, 2017b). Most of certified green/sustainable buildings in Jordan are non-residential buildings including : office buildings, embassy, and schools under LEED certification system (US Green Building Council, 2018e, 2018b, 2018d, 2018a). According to the American Environmental Protection Agency (EPA), office buildings, schools, hotels, hospitals, restaurants, as well as other commercial and institutional facilities use considerable amounts of water and energy in their daily operations. The owners and managers of these facilities are increasingly aware of the need to use water more efficiently to minimize the water shortage risk and the increasing costs. There is a vital business case to be made for water efficiency (US Environmental Protection Agency, 2018). Also, EPA stated that 30% of the average energy that is consumed in commercial buildings is wasted. The rising energy prices, as well as climate change concerns encourage the owners of commercial buildings to reduce the soaring energy bills along with their huge impact on the environment (US Department of Energy, 2018). This indicates that there is a growth potential in the construction of sustainable non-residential building in Jordan. The research consists of two main parts. The first part is the identification of the contributions of water and energy efficiency in sustainable building towards achieving UN SDGs in Jordan. The second part of the study is the development of a framework for integrating UN SDGs into assessing and managing sustainable non-residential building in Jordan.

1.8 Thesis Outline

This thesis is divided into six chapters, a summary of each chapter is provided in this section.

Chapter 1 presents the background of the study, the research objectives, the research questions, the statement of the problem, the research scope and limitation, and the structure of the thesis.

Chapter 2 reviews previous studies that are related to the subject of this study. The chapter reviews the current situation in Jordan regarding non-residential buildings, sustainable building, United Nations Sustainable Development Goals, benefits of sustainable building, barriers and drivers for sustainable building, management of sustainable building, well-known building assessment systems, as well as recent studies in the development of green building assessment tools. The chapter discusses the relationship between water and energy efficiency in green building and UN SDGs.

Chapter 3 presents the methodology that is used in both parts of the study. The chapter introduces various research methodologies and, particularly, discusses the applied methodology in detail. Data collection techniques, data analysis procedures, and validation methods are presented and discussed in this chapter including the questionnaire survey, Delphi technique, the Analytic Hierarchy Process (AHP), Relative Importance Index, and Focus Group Discussion.

Chapter 4 reports and discusses the results of the data analysis of both parts of the study. The analysis and results of the first part of the study include the identified relationships between LEED v2.2 prerequisites and credits in both WE and EA categories and the UN SDGs (Chi-square tests), and the proposed Comprehensive Contribution to Development Index (CCDI) to assess the contributions of the implementation of LEED v2.2 WE and EA to achieve the UN SDGs. The results of the second part of the study include the identified assessment categories and indicators for sustainable non-residential building in Jordan based on the consensus of the Delphi panel, weights of assessment categories and indicators based on Jordan significance of sustainability issues (AHP weights), weights of assessment indicators according to their contributions to achieve the UN SDGs (RII values), the integrated Weighting system (AHP and RII weights), the rating and classification system of sustainable non-residential building in Jordan, and the identified integrations of assessments indicators in project phases (Gantt chart) .

Chapter 5 discusses the validation of the results of the two parts of the study. It is conducted through a focus-group discussion.

Chapter 6 provides the overall achievements and contributions of this study, conclusions, and recommendations for future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Global Impact of Construction and Building Sector

The construction industry is defined as all who produce, develop, plan, design, build, alter, or maintain the built environment, and includes building material suppliers and manufacturers as well as clients, end users and occupiers (Du Plesis, 2001). The construction industry is generally divided into three sub-sectors: (1) the construction of buildings; (2) road, highway, bridges and other infrastructure construction; and (3) special trade works comprises of activities such as metal works, electrical works, refrigeration and air-conditioning works.

Generally, the process of construction can be classified into pre-construction, construction, and post-construction activities. However, the basic process in a typical construction project includes: conception; inception; feasibility; outline of proposal; scheme design; detailed design; production information; tender action; project planning; site operation; completion; handling over and feedback; operation and usage; demolition and re-use. (Oke and Aigbavaboa , 2017). Construction management is the process of planning, coordinating and providing monitoring of construction project during design, pre-construction, procurement, built and owner occupancy. Clients, consultants, contractors and project managers are examples of major stakeholders in most of construction projects. There are numerous stakeholders involved in a construction project such as: owners, managers and users of facilities, project managers, designers, shareholders, legal authorities, employees, sub-contractors, suppliers, service providers, competitors, financial establishments, insurance companies, media organizations, neighbors and community representatives, the general public, government establishments, visitors (Chinyio and Olomolaiye, 2009). These stakeholders can be categorized as internal or external. Project owners or clients are an internal stakeholder while local communities, government, potential users, regulators, environment groups and the media are external stakeholders (Ward and Chapman , 2008).The client sector in the construction industry can be classified as the public and the private (Jaafar & Nuruddin ,2012). Public construction projects consist of projects that provide services and improvement to government owned property, while private construction projects include construction on properties that are owned by private owners. Procurement is an important process of all construction projects to provide materials, services, goods and consultancy and to achieve the objectives of construction projects (Ruparathna and Hewage, 2015). There are six basic activities associated with procurement processes: establish what is to be procured, decide on procurement strategies, solicit tender offers, evaluate tender offers, award contracts, administer contracts and confirm compliance with requirement (Watermeyer and TC59WG, 2011). Procurement systems can be classified as: traditional (separated: the design work is separated from construction, consultants are appointed for design and cost control, and the contractor is responsible for executing the works.); design and construct (integrated: contractor accepts responsibility for some or all of the design and the is responsible for executing the works); management (packaged: include several variants of management procurement forms such as management contracting, construction management and design and manage) (Davis, Love, & Baccarini, 2008).

The construction and buildings sector account for 40% of annual energy consumption, up to 30% of all energy-related greenhouse gas emissions, and 12% of all freshwater usage; moreover, it produces up to 40% of annual solid waste. Many local and global challenges such as demographic shifts, climate change, water, land use, and other resource shortages are significantly affected by the built environment (UNEP, 2018b).

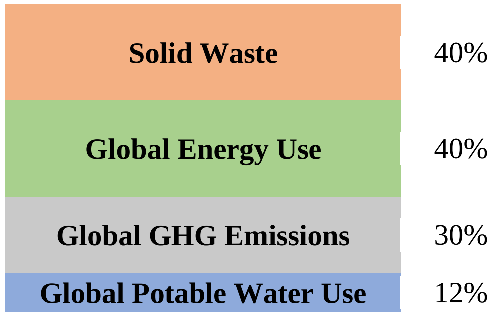

Figure 2.1**:** The contribution of buildings to global energy use, waste, potable water use and GHG emissions.

Source: (UNEP, 2018b).

2.1 United Nations Sustainable Development Goals

With the aim of eliminating discrimination, inequality, and poverty as well as overcome climate change by 2030, the 193 member states of the United Nations (UN) formulated the Sustainable Development Goals (SDGs) on September 25, 2015 (United Nations,2018a, 2018b). The 17 UN SDGs encompassed numerous economic and social–developmental problems, such as health, poverty, hunger, education, gender equality, climate change, water, sanitation, environment, energy, and social justice as shown in Table 2.1 (United Nations,2018a, 2018b).

Table 2.1: United Nations Sustainable Development Goals

SDG#1	End poverty in all its forms everywhere.
SDG#2	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.
SDG#3	Ensure healthy lives and promote well-being for all at all ages.
SDG#4	Ensure inclusive and equitable quality education and promote life-long learning opportunities for all.
SDG#5	Achieve gender equality and empower all women and girls.
SDG#6	Ensure availability and sustainable management of water and sanitation for all.
SDG#7	Ensure access to affordable, reliable, sustainable, and modern energy for all.
SDG#8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
SDG#9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.
SDG#10	Reduce inequality within and among countries.
SDG#11	Make cities and human settlements inclusive, safe, resilient and sustainable.
SDG#12	Ensure sustainable consumption and production patterns.
SDG#13	Take urgent action to combat climate change and its impacts.
SDG#14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
SDG#15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
SDG#16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
SDG#17	Strengthen the means of implementation and revitalize the global partnership for sustainable development.

2.2 Sustainable Construction

According to the International Council for Research and Innovation in Building and Construction (CIB), sustainable construction is defined as ‘the sustainable production, use, maintenance, demolition, and reuse of buildings and constructions or their components’ (CIB, 2004, p.02). Du Plessis, (2002) defined sustainable construction as ‘a holistic process aiming to restore and maintain harmony between the natural and the built environments and create settlements that affirm human dignity and encourage economic equity'.

A distinction is commonly made between the term sustainable construction (the process) and sustainable buildings (the outcome). 'Sustainable construction' is also often used as a general term to describe all types of building including civil and industrial structures. However, it is most helpful to think of sustainable building or sustainable construction as a process of continual improvement in the building sector from unsustainable practices to positive ones (Graham & Booth, 2010).

The society, environment, and economy are three areas that are considerably affected by the built environment. The construction industry is important for three elements of sustainable development, namely :social progress, economic growth, and successful environmental protection (Sev, 2009). As a results of the increasing environmental consideration of the impact of buildings, the importance of conducting environmental assessments of buildings in the construction industry is highlighted (Tatari & Kucukvar, 2011). Many scholars have used many terms for assessment the building system such as framework, scheme, tool and method (Kamaruzzaman, Lou, Wong, Wood, and Che-Ani, 2018; Alyami, Rezgui, and Kwan, 2015; Ali and Al Nsairat, 2009; Banani, Vahdati, Shahrestani, and Clements-Croome, 2016; Yu, Li, Yang, and Wang, 2015). In this research, the term of "framework" is adopted.

In literature, two terminologies are often used to describe sustainable buildings namely 'sustainable building' and 'green building'. According to the Environmental Protection Agency (EPA) "Green building" is defined as "the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation, and deconstruction Green building is also known as a sustainable or high-performance building"(EPA, 2018). Sustainable building is about the integration of sustainable development considerations throughout the whole life of building process (Yudelson, 2009). The Conseil International du Bâtiment for sustainable building (2010) identified the principle of sustainable building as shown in Table 2.2. (CIB, 2010). Berardi (2013), conducted a study to clarify the new definition of sustainable building and to identify the differences between green and sustainable building as shown in Table 2.3.

Table 2.2: Principles of the Conseil International du Bâtiment for sustainable building.
Source: (CIB, 2010).

Principles for sustainable building (CIB, 2010)	
1.	Apply the general principles of sustainability, and hence, promote continual improvement, equity, global thinking and local action, a holistic approach, long-term consideration of precaution and risk responsibility, and transparency.
2.	Involve all interested parties through a collaborative approach, so that it can meet occupants' needs individually and collectively, be respectful consistent with collective social needs through partnership in design, construction, and maintenance processes.
3.	Be completely integrated into the relevant local plans and infrastructure, and connect into the existing services, networks, urban and suburban grids, in order to improve stakeholder satisfaction.
4.	Be designed from a life-cycle perspective, covering planning, design, construction, operation and maintenance, renovation and end of life, considering all other phases during the evaluation of performance at each phase.
5.	Have its environmental impact minimized over the (estimated o remaining) service life. This takes into consideration regional and global requirements, resource efficiency together with waste and emissions reduction.
6.	Deliver economic value over time, taking into account future life-cycle costs of operation, maintenance, refurbishment and disposal.
7.	Provide social and cultural value over time and for all the people. A sustainable building must provide a sense of place for its occupants, be seen as a means of work status improvement for the workers, and should be related and integrated into the local culture.
8.	Be healthy, comfortable, safe and accessible for all. Health criteria include

Principles for sustainable building (CIB, 2010)	
	indoor air quality whereas comfort criteria include acoustic, thermal, visual and olfactory comfort. It must allow safe working conditions during its construction and service life, and full accessibility to everyone in the use of building facilities.
9.	Be user-friendly, simple and cost effective in operation, with measurable performances over time. Operation and maintenance rules must be available for both operators and occupants at any time. People should understand the philosophy and the strategies included in the building and should be incentivized to behave sustainably.
10	Be adaptable throughout the service life and with an end-of-life strategy. The building has to allow adaptation by changing performance and functionality requirements, in accordance with new constraints.

Table 2.3: Major issues in green and sustainable buildings.

Source: (Berardi, 2013).

Major issues of the building performances	Green building	Sustainable building
Consumption of non-renewable resources	x	x
Water consumption	x	x
Materials consumption	x	x
Land use	x	x
Impacts on site ecology	x	x
Urban and planning issues inspiration	x	x
Greenhouse gas emissions	(x)	x
Solid waste and liquid effluents	x	x
Indoor well-being: air quality, lighting, acoustics	x	x
Longevity, adaptability, flexibility	(x)	x
Operations and maintenance		x
Facilities management		x
Social issues (access, education, inclusion, cohesion)		x
Economic considerations		x
Cultural perception and		x

Worldwide, green buildings are adopted as a key policy by governments to minimize energy crises and climate change (Shen et al., 2017). According to the World Green Building Council "green buildings can contribute to achieve UN SDGs the sustainable development goals" (World Green Building Council, 2018b).

Implementation and application of green-building-assessment tools contribute to achieve sustainable development (Ali & Al Nsairat, 2009). Sustainable construction refers to the construction that is economically, socially, and environmentally sustainable (Illankoon et al., 2016). According to Huovila and Koskela (1998), sustainable construction is the response of the building sector to the challenge of sustainable development as shown in Figure 2.2. The evolution and challenges of the sustainable construction concept in a global context are outlined in Figure 2.3 (Huovila & Koskela, 1998).

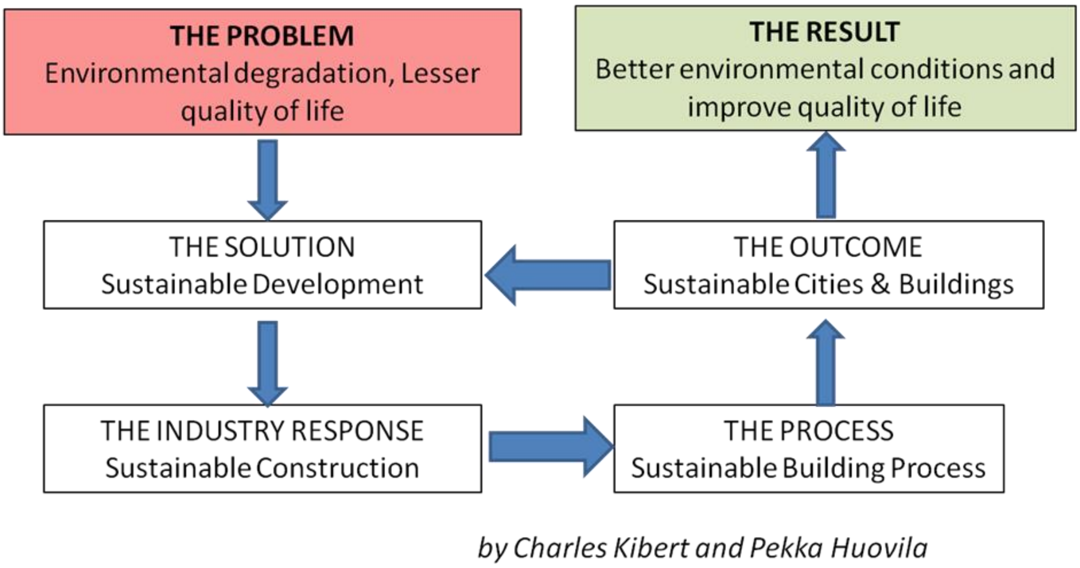

Figure 2.2: A simplified roadmap for sustainable construction

Source: (Bourdeau, 1999)

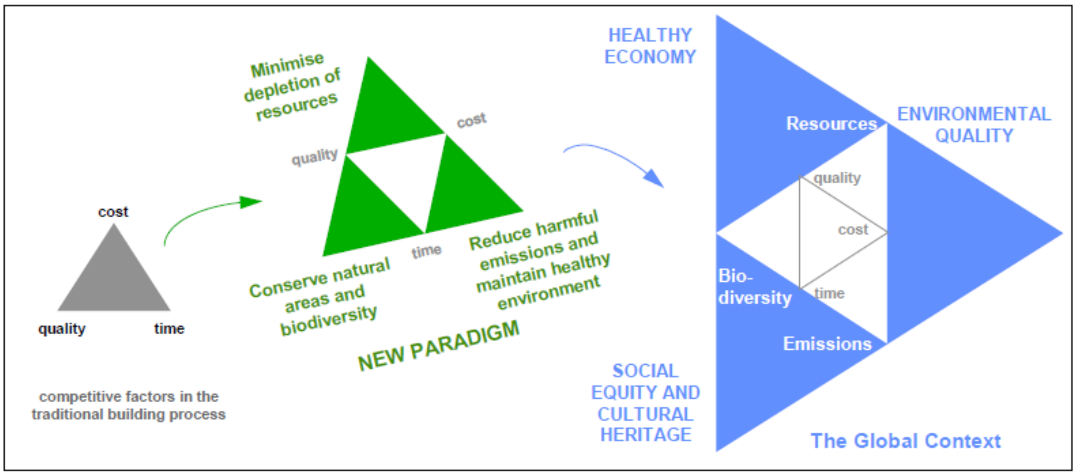

Figure 2.3: Challenges of sustainable construction in a global context
Source: (Huovila & Koskela, 1998)

2.3 Benefits of Sustainable Building

World Green Building Council (WGBC) states that evidence is increasing that green building brings about multiple benefits. It is an effective means to achieve many global goals. Green building aims to address climate change, creates sustainable, thriving communities. It also derives economic growth (World Green Building Council, 2018a). A systematically carried review is conducted by Darko, Chan, Owusu, and Antwi-Afari (2018). They selected scholarly publications in journals of construction management (CM). The publications' date covered the period from 2000 until 2014 (years inclusive). The researchers concluded that lower life cycle costs, as well as energy saving, improved occupants' health and comfort, better productivity, in addition to environmental protection, represent the most described benefits and advantages in the related literature. In accordance with WGBC, the green buildings' benefits are classified into three categories including the environmental benefits, the economic benefits, and finally the social benefits (World Green Building Council, 2018a).

2.3.1 Environmental Benefits

Green buildings provide great benefits to the climate of the earth, as well as the earth's natural environment. Green buildings reduce or remove negative effects on the environment using fewer amounts of water and energy or untreated resources. Also, they bring about positive effects on our environment (at buildings or city scales) through their energy-generating aspect or biodiversity increase (World Green Building Council, 2018a).

The construction sector exhibits a very high potential to significantly reduce the amounts of the greenhouses' gas emissions in comparison with the most important emitting sectors (UNEP, 2009). A potential of gas emissions' savings is expected to amount approximately about 84 gigatonnes of CO_2 ($GtCO_2$) by 2050. This can be carried out via direct measures in buildings like energy efficiency and fuel switching in addition to renewable energy use (Dean, Dulac, Petrichenko, & Graham, 2016). The construction sector possesses a great potential to produce a total of 50% energy savings or even more by 2050 to support the limitation of the global temperature to 2°C (above pre-industrial levels) (Dean et al., 2016).

Turner and Frankel (2008) measured the performance of energy for 121 LEED buildings. They compared these buildings with various national benchmarks. It was found that 25–30% less energy was consumed by green buildings compared with the national average (Turner & Frankel, 2008).

Green buildings, as stated by WGBC (World Green Building Council, 2018a), which achieved the Australian Green Star certificate, produced less greenhouse gas emissions at 62% than average. Less potable water at 51% than average can be provided in case the buildings were built to fulfill the least industry requirements. Green buildings, which are certified by the Indian Green Building Council (IGBC) provided 40-50% energy savings, as well as 20-30% water savings in comparison with the Indian conventional buildings. In South Africa, Green buildings, which achieved the Green Star certificate, saved 30-40% energy, carbon emissions, and 20-30% potable water on a yearly basis in comparison with the norms in the industry. In the USA and other world countries, green buildings, which achieved LEED certificate, consumed 25% less energy in addition to 11% less water than the consumed energy and water in non-green buildings (US Green Building Council, 2018c).

2.3.2 Economic Benefits

Ries, Bilec, Gokhan, and Needy (2006) reported that green construction results in substantial economic savings through the enhancement of the employees' productivity. Also, green construction results in considerable benefits based on health improvements and safety enhancements to achieve savings of energy, maintenance, as well as operational costs.

Green construction yields economic and/or financial benefits pertaining to different people's groups. The obtained benefits include utility bills' cost savings (through energy, as well as water efficiency). They also involve lower costs of construction and higher values of property for the construction sector developers. Moreover, they increase the occupancy rates and the building owners' operating costs. They can yield considerable benefits pertaining to job creation (World Green Building Council, 2013). An estimated €280 to €410 billion energy spending savings can be obtained through global energy efficiency measures (equivalent savings to approximately double the savings of the US yearly electricity consumption) (European Commission, 2015), (Molenbroek et al., 2015).

In Canada, $23.45 billion in GDP is generated by the green building industry. This represents approximately of 300,000 full-time occupations in 2014 (Canada Green Building Council, 2018). Green building is expected to create over 3.3 million US occupations by 2018 (World Green Building Council, 2018a). Building owners indicated that green construction, including new buildings or renovated ones, provide a 7% increase in an asset value in comparison with traditional buildings (Buckley & Logan, 2016).

Kats (2003), in an earlier study, collected data about 33 LEED building projects in California with an estimated 2% average cost premium including all the studied buildings (with values that range between 0.5% for LEED Certified buildings and 7% for LEED Platinum buildings). An extra 2% investment in the costs of construction resulted in 20% savings in costs that are long-term. Kats (2006) studied 30 green schools in the US. The findings revealed that the cost of these green schools is less than 2% compared with the conventional schools. They provided 20 times benefits over 20 years. Moreover, cost savings in health, as well as productivity were achieved owing to the people's increased earnings, a noticeable reduction in breathing diseases in addition to the higher retention of employees, which made up to 85% of the total savings of whole life costs. This includes savings in energy, water, as well as waste, which made up the remaining savings of 15% (Kats, 2006).

Bradshaw, Connelly, Cook, Goldstein, and Pauly (2005) studied and analyzed sixteen buildings. It was found that lower levels of water and energy costs in all buildings, excluding one project, were achieved in sustainable construction as