AN EVALUATION OF SUSTAINABLE CONSTRUCTION PRACTICES IN THE ZAMBIAN CONSTRUCTION INDUSTRY

by

CHANDA MUSENGA

A DISSERTATION

submitted in fulfilment of the requirements for the degree

MAGISTER TECHNOLOGIAE

in

CONSTRUCTION MANAGEMENT

in the

FACULTY OF ENGINEERING AND THE BUILT ENVIRONMENT

at the

UNIVERSITY OF JOHANNESBURG

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2019

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A DISSERTATION submitted in partial fulfilment of the requirements for the award of the degree Magister Technologiae in Construction Management in the Faculty of Engineering and the Built Environment, Department of Construction Management and Quantity Surveying at the University of Johannesburg, Republic of South Africa.

JOHANNESBURG, NOVEMBER 2019

DECLARATION

I, **CHANDA MUSENGA**, do hereby declare that this thesis is the result of my own investigation and research, except to the extent indicated in the references and by comments included in the body of the report and that it not been presented elsewhere for a similar purpose. It was submitted to the University of Johannesburg (Department of Quantity Surveying and Construction Management), as a requirement to obtain the **MAGISTER TECHNOLOGIAE** degree in **Construction Management**.

19/07/2020

Signature Date

University of Johannesburg,

Doornfontein Campus

ACKNOWLEDGEMENTS

I wish to express my sincere thanks and appreciation to the following people for their assistance, guidance and contribution to this study:

- My Almighty Father for granting me wisdom and strength from above. Without these, I would not have carried out this research effectively.
- My supervisor, Prof. Clinton O. Aigbavboa for his professional and expert guidance throughout the course of this study.
- My co-supervisor, Mr. Olusegun A. Oguntona, for his invaluable guidance throughout the study.
- My co-supervisor, Prof. Wellington D. Thwala, for his expert guidance during the study.
- My family (my parents, John and Joyce Musenga, my siblings, Kaumba and Chitalu Chinyama, and my daughters, Deborah and Kuviuka). Words alone cannot express my gratitude.
- Desiree Khanyisa Mabasa, my eldest daughter, friend and confidant, may the good Lord bless you for always giving me the impetus to keep going.
- Opeoluwa Akinradewo for his invaluable input in the study.
- Joseph Samunete for his timely input in this study.
- All the respondents for sparing the time to complete the questionnaire.
- Finally, I would like to express my sincere gratitude to the Department of Construction Management and Quantity Surveying, University of Johannesburg, South Africa for according me the opportunity to study with them.

DEDICATION

I dedicate this dissertation to the Creator of all things, my Heavenly Father and my family. May this serve as a reminder that we can do all things through Christ who gives us strength.

ABSTRACT

The rapid deterioration of the ecosystem as evidenced in the various occurrences around the world has captured the attention of leaders globally. This has prompted the various sectors around the world to initiate actions to mitigate the gradual extinction of the planet through the implementation of sustainable development principles and Zambia should not be left out. Thus, in order to keep pace with this paradigm shift, this study sought to evaluate the sustainable construction practices (SCPs) in the Zambian construction industry (ZCI)**.**

This study adopted a quantitative approach. A questionnaire survey was conducted on construction professionals (architects, quantity surveyors, civil engineers, construction managers, construction project managers, project managers, mechanical engineers, electrical engineers, land surveyors and town planners). Out of the 150 questionnaires sent out, 122 were received back representing an 81% response rate. The data received from the questionnaires was analysed using descriptive statistics and exploratory factor analysis.

The findings revealed that increased energy consumption, deforestation and climate change are the main adverse impacts of construction activities in Zambia. Despite the low level of awareness, the top three practices that were identified were 3D printing (additive manufacturing), value management and design for the environment. The following were found to be the top barriers to the adoption and implementation of SCP: lack of funds for research and development, corruption within the CI and poor implementation strategy. On the other hand, the benefits of adopting and implementing SCPs are reduced energy consumption, promotion of the use of local sustainable materials, improved site health and safety and improved overall quality of life. The drivers of the adoption and implementation of SCPs are government support, the development of sustainability measurement standards and the training of skilled and unskilled workers in sustainable development.

The adoption and implementation of the various practices that have been identified have the potential to aid and sustain human existence through the protection of the ecosystem, enhanced business opportunities and improved quality of life. This study further recommends that to enable the uptake of sustainability in the ZCI, all platforms should be utilised to disseminate information on the various sustainable practices.

KEYWORDS: Climate change, Construction industry, Environment, Sustainable construction practices, Zambia

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LIST OF ABBREVIATIONS

BIM	Building information modelling
C2C	Cradle-to-cradle design
CE	Construction ecology
DfE	Design for environment
EE	Ecological economics
EF	Ecological footprint
IBS	Industrial Building Systems
IoT	Internet of Things
LC	Lean construction
LCA	Life cycle assessment
LCC	Life cycle costing
MS	Mean item score
NCC	Nation Council for Construction
NT	Nanotechnology
R	Ranking
SACQSP	South African Council for the Quantity Surveying Profession
SC	Sustainable construction
SCPs	Sustainable construction practices
SD	Standard deviation

SD	Sustainable development
VM	Value management
ZCI	Zambia Construction Industry
ZEMA	Zambia Environmental Agency
ZGJP	Zambia Green Jobs Programme

LIST OF PUBLICATIONS

Oke, A., Aghimien, D., Aigbavboa, C. and Musenga, C. (2018). Drivers of sustainable construction practices in the Zambian construction industry. *Proceedings of the 10th International Conference on Applied Energy (ICAE) Hong Kong, China*. (Published)

Aghimien, D., Aigbavboa, C., Oke, A. and Musenga, C. (2018). Barriers to sustainable construction practices in the Zambian construction industry. *Proceedings of the International Conference on Industrial Engineering and Operations Management Paris, France*. (Published)

Musenga, C. and Aigbavboa, C. (2018). Environmental impacts of construction activities: A case of Lusaka, Zambia. *Proceedings of the AHFE 2018 International Conference on Human Factors, Sustainable Urban Planning and Infrastructure, July 21-25, 2018, Loews Sapphire Falls Resort at Universal Studios, Orlando, Florida, USA.* pp. 535-541 (Published)

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

This chapter gives a synopsis of the study and maps out the course that the study followed. The components of the chapter include the research problem, research questions, the objectives of the study, the motivation and the purpose of the study.

1.2 GENERAL BACKGROUND

The Zambian construction industry (ZCI) has continued to drive the economy as can be seen in its steady growth of 17.5% over the past 12 years. This growth has been driven by increased infrastructure development by both the private and public sectors in the form of hospitals, roads, schools, stadia and commercial and residential property (Seventh National Development Plan, 2017:27). In addition, the construction industry (CI) is seen to contribute holistically to the sustainable development (SD) of a nation's economy through the creation of jobs and the vital linkages that it has with other sectors which result in wealth redistribution and generation of income (Durdyev, 2012:883). The industry also plays a key role in meeting basic social needs through the provision of housing and aids the production of consumer goods (Baloi, 2003:289; Durdyev et al., 2018:1).

On the other hand, the industry is also known for its negative contribution to the environment due to its high energy, raw materials and water consumption (Hussin et al., 2013: 15). Studies have found that the traditional construction approach which focuses more on returns and customer satisfaction is responsible for the adverse consequences on society and the environment (Baloi, 2003:1). Evidence of this is in the form of deforestation, desertification, soil erosion, toxic waste, climate change, eutrophication, depletion of fisheries, destruction of the ecosystem, depletion of the ozone layer, as well as water, air and land pollution (Du Plessis, 2002:13-15). Therefore, a section of this study seeks to identify the adverse effects of construction activities in Zambia.

Global discussions on the rapid degradation of the environment resulted in the formation of the term 'sustainable development' (SD). One of the popular definitions of SD is that penned by the Brundtland Report (WCED, 1987) which states that the present needs should be met without compromising the future generations' ability to meet their needs (Kibert 2013:23). This implies that SD has been understood to be the continual development that humans must continue to pursue to attain a state of sustainability. Thus, SD is a continuous process that requires achieving a balance between human demands and what is ecologically possible. In response to calls for a more sustainable CI, the term 'sustainable construction' (SC) was coined as a means of making the industry's processes and activities economically, socially and environmentally responsive (Abidin, 2010:422).

Similarly, Du Plessis's (2002:8) study on developing countries established that SC is an all-inclusive process that purposes to recreate the relationship between built environment and nature. Furthermore, the SC process intends to reaffirm human dignity and enhance economic equity, thus indicating that SC impacts the entire project cycle with emphasis on environmentally orientated design, operation and maintenance procedures. Whilst it is understood that SC is the CI's response to calls for the uptake of SD, application of the principles of SD to the businesses and strategies of the institutions operating within this sector known as sustainable construction practices (SCPs) is unfamiliar territory. SCPs are divided into several areas, namely design and procurement, compliance with sustainability legislation, education and training, technology and innovation, measurement and reporting and organisational structure and process (Tan et al., 2011:228).

Thus, this study focused on enhancing sustainability in the ZCI through sustainable construction practices that fall in the technology and innovation category. The technologies and concepts that have emerged are building information modelling (BIM), biomimicry, construction ecology (CE), cradle-to-cradle design C2C), design for the environment (DfE), ecological footprint (EF), ecological economics (EE), life cycle costing and life cycle assessment (LCA) (Kibert, 2013:7,16-17,43). Other technologies are value engineering (VE), industrialised building system (IBS), lean construction (LC), the Internet of Things (IoT), and 3D printing and blockchain technology (Hussin et al., 2013:21; Kiroglu, 2017:703; Tiastsis et al., 2018:5; Li et al., 2019:80). These innovations have been introduced in some parts of the world and are being improved upon through further research to bring about energy saving, reduced green-house emissions and reduced material consumption.

With the increasing need for sustainability, especially in the CI, it is important for Zambia to keep abreast with this global movement through the adoption of SCPs. Hence, this study accessed the level of awareness of SCPs amongst the professionals in the ZCI. Furthermore, the study investigated the barriers to, and benefits and drivers of adopting and implementing SCPs in the ZCI.

1.3 AIM OF THE STUDY

With the effects of climate change being experienced not only in Zambia but the world over, this study focused on enhancing sustainability in the country's construction industry through sustainable construction practices. This was to be achieved through the identification of level of awareness of the Zambian professionals on the various sustainable construction practices that have been developed. Furthermore, the study examined the barriers, drivers and benefits of adopting sustainable construction practices in the Zambian construction industry.

1.4 PROBLEM STATEMENT

Increased occurrences of natural disasters attributed to high carbon emissions, shortage of resources and alteration of rainfall patterns serve as indicators for the deterioration of the ecosystem. This has prompted various sectors around the world to initiate actions to mitigate the gradual extinction of the planet. SC, which is the CI's response to calls for its implementation of SD principles, has gained momentum globally and Zambia should not be left out. To keep abreast with this phenomenon, stakeholders in the ZCI need to be exposed to SCPs in order to compete favourably on the global market. Seeing that this is a novel concept in the ZCI, this study assessed the level of awareness of SCPs amongst the professionals. This was followed by an investigation of the barriers to, and benefits and drivers of the adoption and implementation of these SCP practices. Additionally, the study established the adverse impacts of construction activities in Zambia.

1.5 RESEARCH QUESTIONS

This part of the study seeks to answer the following research questions:

a. What are the adverse impacts of construction activities in Zambia?
b. What is the level of awareness of sustainable construction practices amongst professionals in the Zambian construction industry?
c. What are the barriers to the adoption and implementation of sustainable construction practices in the Zambian construction industry?

d. What are the benefits of adopting and implementing sustainable construction practices in the Zambian construction industry?
e. What are the drivers of adopting and implementing sustainable construction practices in the Zambian construction industry?

1.6 OBJECTIVES OF THE STUDY

With reference to the research problem statement and the afore mentioned research questions, the objectives of the study were as follows:

a. To identify the adverse impacts of construction activities in the Zambian construction industry;
b. To assess the level of awareness of sustainable construction practices amongst the professionals in the Zambian construction industry;
c. To identify the barriers to the adoption and implementation of sustainable construction practices in the Zambian construction industry;
d. To determine the benefits of adopting and implementing sustainable construction practices in the Zambian construction industry; and
e. To identify the drivers of adopting and implementing sustainable construction practices in the Zambian construction industry.

1.7 MOTIVATION OF THE STUDY

The inspiration behind carrying out this study was to expand the knowledge base of SCPs in the ZCI. The results obtained from this study will contribute meaningfully towards a better understanding of the practices that can enhance sustainability in the ZCI. In addition, this study will provide Zambian construction professionals with information on the benefits of adopting the various SC practices, the barriers that are deterring the process of adoption and the measures that can be implemented in order to hasten the adoption process.

1.8 PURPOSE OF THE STUDY

The CI has been identified as a major contributor to global greenhouse gas emissions, the depletion of natural resources, high energy consumption, air pollution, and high waste generation: these cannot be ignored. Therefore, the aim of this study was to identify the various SC practices that can aid sustainability in the ZCI and determine the construction professionals' level of knowledge about these SC practices. Through the data collected, the study established the barriers to, and drivers and benefits of adopting and implementing these practices.

1.9 RESEARCH METHODOLOGY AND DESIGN

1.9.1 Research Methodology

A research methodology outlines the process by which the research will be carried out. It also paves the way for the researcher to make several choices concerning the environment in which the research is to occur (South African Council Quantity Surveying Profession, Mod.18: 25). The section outlines the geographical area in which the study was conducted, the design the study adopted and the data collection method that was used.

1.9.2 Research Approach and Design

For this study, the quantitative approach was adopted. A quantitative approach is known to be scientific and deductive in nature. This is because it simplifies situations to a point where they can be measured, tested and examined. In addition, this study adopted a descriptive survey design. In line with this, a questionnaire was prepared based on the literature reviewed and was used as a tool for collecting data from the respondents.

1.9.3 Research Area and Targeted Respondents

This study was carried out in Zambia and the targeted respondents were professionals practising in the various provinces. These professionals were architects, civil engineers, construction managers, quantity surveyors, construction project managers, project managers, mechanical engineers, electrical engineers, land surveyors and town planners.

1.9.4 Sampling and Data Collection

For this study, convenience sampling was used to obtain a more scientific representation to be used to evaluate the SCPs in Zambia. A questionnaire prepared based on the literature reviewed was used as a tool for collecting data from the respondents.

1.9.5 Limitations

This research was centred on the ZCI. The respondents were the various professionals in the ZCI. This research only explored the adverse impacts of construction activities and identified the various SCPs that have been developed. In addition, the study analysed the level of adoption of SC practices amongst the construction professionals. Furthermore, the study determined the drivers of, barriers to and benefits of adopting SCPs.

1.9.6 Ethical Consideration

This research took into consideration the professionals in the industry who have contributed to the literature by ensuring that their works were properly cited and recognised. Secondly, the study sought to protect the interests of the respondents by ensuring that they were well informed about the purpose of the study and the basis for their selection. The respondents were not coaxed into completing the questionnaire and were assured that the information obtained would be used for academic purposes only.

1.10 OUTLINE OF CHAPTERS

Chapter One Introduction

The chapter presents a synopsis of the study. This includes the problem that is being investigated and the research questions and objectives that helped to address it. Furthermore, the section provides an outline of the course of action that was adopted for the completion of the study.

Chapter Two Overview of the Construction Industry

This chapter reviewed literature on the CI's contribution to economic development and also interrogated the adverse impacts of its activities.

Chapter Three Overview of Sustainable Construction

This chapter reviewed among others published articles, books, dissertations, and journals on the evolution of sustainable development and how it is being implemented in the CI. This was done to aid the identification of the various innovations that can be adopted for the purpose of enhancing sustainable practices in the CI. Furthermore, this section considered the barriers, benefits and drivers to the adoption and implementation of sustainable practices in the ZCI.

Chapter Four Performance of the Zambian Construction Industry

Through a literature review, this chapter interrogated the Zambian CI from three angles. Firstly, the industry's contribution to the economy was analysed followed by the impact of the industry's activities. Lastly, the section explored the measures being implemented by the industry to enhance sustainability.

Chapter Five Research Methodology

The method and approach adopted by the researcher are presented in this chapter. This section commenced with an outline of the research design, followed by a brief outline of the geographical area in which the study was centred. The chapter ended with the data collection and analysis procedures that were applied by the researcher to effectively communicate the research findings.

Chapter Six Data Analysis and Interpretation

This chapter highlights how the data collected from the respondents using the descriptive survey was analysed using appropriate analytical procedures. This study adopted statistical techniques for analysis of the data collected. The results obtained from the analysed data provided feedback on the formulated questions.

Chapter Seven Discussion of Findings

The results presented in the previous chapter are discussed based on the literature reviewed. This was done for the purpose of ensuring that the research questions were answered, and the research objectives were achieved.

Chapter Eight Conclusion and Recommendations

This chapter reviewed the discussion from the previous chapter to ascertain that the research objectives have been met. The subsequent section in this chapter is the conclusion of the study and recommendations are made in relation to the evaluation of SCPs in the ZCI.

1.11 CONCLUSION

This chapter introduced the various components of the study including the research problem that the study seeks to resolve. In addition, the chapter gave an overview of how the study was conducted as a means of achieving its objectives. The next chapter reviews the contributions of the construction industry.

CHAPTER TWO

AN OVERVIEW OF SUSTAINABLE CONSTRUCTION

2.1 INTRODUCTION

This section reviews the construction industry's contribution to economic and social development. Furthermore, this section seeks to bring to light the adverse impacts of construction activities.

2.2 THE CONSTRUCTION INDUSTRY

The construction industry (CI) can be described as one which produces infrastructure that supports development (Du Plessis, 2002:4). On the other hand, Alagidede and Mensah (2016:1) posited that construction is a term that includes but is not limited to visible structures in different forms that are used as inputs in the production of goods and services by the various industries. This description encompasses residential and commercial buildings. What constitutes the construction sector further extends to a myriad of activities from the design phase to the engineering, procurement and the execution of small, medium and large-scale infrastructure projects. Other activities that fall under the construction sector include alterations, maintenance and repairing of infrastructure. The output of construction activities are airports, railways, highways, bridges, sewage treatment plants, tunnels, and commercial and residential buildings, among others, (Osman et al., 2012:1). The CI in comparison with other sectors has unusual characteristics such as many stakeholders with varying interests, complex projects and extended production durations. Increased activity in this industry has been motivated by decades of population growth and urbanisation (Du Plessis, 2002:23).

The CI is an essential element for a country's economy. Durdyev and Ismail (2012:2) established that with its strong links to output, the CI serves as a major indicator of the economy's health. Other contributions of the CI are the provision of employment to about 110 million people globally. A large proportion of those employed work for firms that are categorised as small and medium-sized enterprises (SMEs) (Balogun et al., 2016:49). Scholars further established that the CI in several countries is the largest employer and its activities have a high multiplier effect (Djokoto, 2014:134; UNEP, 2003:1). In addition to employment, the industry makes a sizeable contribution to the world's gross domestic product (GDP). This percentage is greater in developing countries than in developed ones. This is illustrated in the contribution of 7% to 10% for highly developed economies and around 3% to 6% for underdeveloped economies (Wibowo, 2009:279).

Furthermore, the industry either directly or indirectly provides basic social needs by meeting accommodation and consumer needs (Ofori, 2007:2; Durdyev et al., 2018:1; Serpel, 2013:273). Similarly, Celik et al. (2017:78) posited that construction enables humankind to meet one of its basic needs in the form of shelter which protects them from the elements. In addition, the infrastructure serves as a means of providing the needs and wants of humans which in turn result in improved livelihoods.

From the assessment of the contributions of the CI, it can be deduced that it has strong ties with SD in the form of economic growth and social improvement. Despite its positive contributions to sustainable development, an assessment of the CI would not be complete without interrogating its adverse impacts.

2.3 ADVERSE IMPACTS OF THE CONSTRUCTION INDUSTRY

Studies have shown that the bulk of human activities that negatively impact the environment and society can be traced back to the CI. This is often attributed to the fragmented state of the industry and its unique and complex by-products, most of them with a long-life span (Du Plessis, 2002:13; Hussin et al., 2013:31). Studies on the environmental impacts of road construction have identified that there are direct, indirect and unpredictable impacts. Direct impacts are borne from the construction of the structure such as the removal of vegetation, loss of farmland and redirection of roads and streams. These impacts are easier to quantify and control whilst indirect impacts, on the other hand, are more difficult to quantify and tend to affect a larger geographical area. Examples of these are deforestation borne from the quest to obtain simpler transportation routes, soil erosion brought about by extraction of raw materials for building activities which in turn causes pollution of surface and underground water. Lastly, there are unpredictable impacts and these are presented in the form of landslides and climate change (Tsunokawa & Hoban, 1997:61-62; Muhwezi et al., 2012:942-944).

Other adverse impacts on society and the environment that can be traced back to poor planning or unsustainable urban development are the disappearance of green areas and recharge areas for groundwater resources. In addition, pollution of surface and groundwater as a result of the construction of onsite sanitation, changes to drainage patterns, damage to sensitive eco-systems, soil erosion, interference with wildlife movement, loss of valuable agricultural lands, displacement of people, demographic changes and accelerated urbanisation were identified to be impacts affecting not only the environment but also society (EIA Guidelines for the Construction Sector in Zambia, 2016:2). Similarly, Kibert (2016:52) established that the effects of construction activities are deforestation, desertification, soil erosion, toxic waste, climate change, eutrophication, depletion of fisheries, destruction of the ecosystem, depletion of the ozone layer, and water, air and land pollution. Additionally, other adverse impacts were found to be unfair labour practices, high energy use and associated emissions of greenhouse gases, extraction and consumption of non-renewable and renewable natural resources, abundant corruption opportunities, disruption of communities and animal habitation through inappropriate design and materials (Du Plessis, 2002:13-15; UNEP,2003).

2.3.1 Depletion of Non-Renewable Energy Resources

The CI consumes massive quantities of natural resources These natural resources are categorised into renewable and nonrenewable. In addition, the manufacture of construction products and the subsequent operation and maintenance of buildings consume excessive amounts of energy (Son et al., 2011:337; Ametepey & Ansah, 2014:937).Similarly, Sterner (2002:22) found that the CI is a huge consumer of energy-producing resources. This is linked to the change in lifestyle as humans spend more time indoors; therefore, energy is required for heating and cooling purposes. These resources contribute significantly to the carbon dioxide that is emitted and in turn accelerates the rate of global warming. In some places around the world, the main sources of this energy are non-renewable resources, such as coal and oil products. Furthermore, statistics indicate that 45-50% of the total energy produced, 50% of all water available, 60% of all raw materials, 80% of all agricultural land lost and 30-40% of all solid wastes and emissions of 35-40% of CO2 are as a result of the CI (Baloi, 2003:337).

2.3.2 Pollution

The major causes of land, air and water pollution have been found to be through the mining of raw materials and the manufacturing of components for construction activities. The mining of raw materials often leads to the disturbance of the ecosystem and land degradation. Through the emissions of toxic gases and effluents in the air and in water – bodies that affect aquatic and marine life – construction activities contribute to increased energy consumption and atmospheric and water pollution. This occurs through the processing of raw materials and the transportation of the finished products. These emissions often contain toxic substances such as nitrogen and sulphur oxides. Furthermore, careless site operations result in toxic spillages which find their way into underground reservoirs and aquatic systems (Du Plessis, 2002:14; Kibert, 2013: 55). Statistical results compiled by Dixon (2010:2) revealed that the CI's contribution to global pollution is as follows: air quality (in the cities) 23%, emissions of climate change gases 50%, pollution of drinking water 40%, contribution to waste in landfills 50% and ozone depletion 50%.

2.3.3 Deforestation

For every structure that is erected, vegetation is lost. This because an area must be cleared and all forms of vegetation removed to ensure that the structure is built on a stable foundation. Depending on the construction method, several indigenous trees are harvested for use as building components or to produce materials. These practices have turned a blind eye to the rapidly diminishing forests. Studies have shown the earth's rainforests are disappearing at an alarming rate of 0.8 hectares or two (2) acres of rainforest per second. The effect of this is that 1.8 billion tons of carbon dioxide is released into the atmosphere every year (Kibert, 2016:66). The other impacts of the removal of trees and vegetation are soil erosion, land degradation, siltation of water courses, global warming (indirect) coupled with desertification and increased incidences of landslides. In addition, scholars have attributed the changes in the rate of absorption of surface water and the earth's surface temperature due to deforestation as the major causes of the altered rainfall patterns (Uher, 1999:243-253; Wang et al., 2014:350-363).

2.3.4 Generation of Excessive Waste

The CI contributes to the production of numerous forms of wastes, depending on the stage of construction, on the method of construction and the materials used. Other waste is generated during the manufacture of construction products. Various scholars identified that large volumes of waste the majority drawn from construction activities across the globe are dumped in landfills. For instance, the UK contributes to more than 50% of waste taken to landfills whilst the USA contributes about 29% and Australia contributes 20-30% (Ametepey and Ansah, 2014:936). This waste, especially in developing countries, finds its way into river courses, dams and any available hollow caused by illegal dumping (Du Plessis, 2002:14). On the other hand, Sterner (2002:22) posited that the production of this waste can be avoided and that which cannot has the potential to either be reused or recycled (Muhwezi et al., 2012:942-944; Mulenga & Kamalondo, 2017:1).

2.3.5 Decreased Health and Productivity of Building Occupants

Studies conducted by Pearce (2012:5) and Zarghami et al. (2018:107) indicated that a building's occupants' comfort, health and productivity are impacted by the internal air quality. This is seen in the indoor pollutant levels which range from 2.5 to 100 times more than the outdoor levels. Thus, with humans spending about 90% of their time indoors, they are have become prone to health problems such as asthma, irritation of the nose, eyes and throat, headaches, dizziness, elevated blood levels and other respiratory-related illnesses.

2.3.6 Disruption of Communities and Animal Habitation

In a quest to grow their economy, most countries focus on construction in the form of roads, buildings and bridges. These are often erected in or run through the communities as in the case of roads. This often leads to the displacement of communities and animals and also the loss of plant and animal species (Muhwezi et al., 2013:22; UNEP, 2003). Construction activities in some cases may not result in the displacement of animal species. However, the noise and light produced affect their breeding and feeding patterns and the consequences of this are seen in a reduction of population levels.

2.4 ORIGIN OF SUSTAINABILITY

Increased resource consumption and environmental degradation brought about by rapidly increasing populations and the advancement of humanity in the late 60s and early 70s is attributed to the emergence of the concept of sustainability. These events led to the world leaders gathering at a conference in Stockholm in 1972 to discuss ways in which to balance resource consumption, technological advancement and the well-being of the poor in society. It was at this conference that the subject of sustainable development (SD) was broached. On the other hand, scholars have found that sustainability has been in existence from the beginning of time in the form of the age-old wisdom that has been handed down in the various communities (Poveda & Lipsett, 2011:36). Over the last couple of years, the sustainability paradigm has gained impetus because of the effects of climate changes that are occurring at a rapid rate, financial crises and the ever-increasing food and energy prices (Kibert, 2013:1). A study conducted by Huisingh et al. (2015:1) found that global warming poses one of the greatest threats to the existence of humans and to political stability. They further stated that the main cause of global warming is the increase in carbon emissions worldwide. In agreement, Oke and Aigbavboa (2017:88) found that the increase in temperatures can be attributed to the depletion of the ozone layer as a result of increased carbon emissions which contain harmful gases. These emissions stem from human activities such as construction and manufacturing. Other activities that have aided global warming are increased globalisation and collaboration, industrialisation, innovative practices to enhance customer satisfaction, advancement in technology, extreme urbanisation and emigration to developed countries as a result of political instability, war and population increase.

It has been identified that there is an existing misconception in which sustainability and SD are regarded as two differing philosophies (Du Plessis, 2002: 5). Other scholars agree about the misconception of the two terms. Newport et al. (2003:359) noticed that the sustainability concept has not been properly understood or communicated. In a similar vein, it has been established that the absence of an accepted definition and focus has resulted in the sustainability concept having an array of definitions and opposing interpretations (Ogunmakinde et al., 2017:2772). To eliminate the confusion, the following definitions of sustainability and SD were found. Du Plessis (2002: 9-10) posited that the term ‘sustainability’ is derived from the word ‘sustain’ which means ‘to keep alive’ or to ‘keep going”. It is thus a state or condition that will prolong the existence of humanity. It is a goal that every human being aims to achieve despite the external and internal changes. Pearce (2006:201) simply defined sustainability as a word that means ‘lasting’ or ‘perpetual’ and further pointed out that development without sustainability is pointless. Nevertheless, sustainability covers all sectors and as such requires combined efforts from all spheres to ensure the continued existence of humans.

Sustainability can be viewed as either weak or strong, where weak sustainability considers the notion that the different forms of capital are fully interchangeable. This notion supports the view that natural capital can be exhausted unless an equivalent value is converted into manufactured capital. On the other hand, strong sustainability encompasses the idea that the environment performs unique functions that are necessary for the survival of human species and their welfare. It is important to note that these functions cannot be copied by humans (Du Plessis, 2002:5). The interpretation of strong sustainability brings to mind the following 19th century Cree Indian prophesy which states that “…only when the last tree has died, and the last river has been poisoned and the last fish has been caught will we realise that we cannot eat money.” Thus, the attainment of sustainability requires achieving a balance between social awareness, environmental responsibility and economic profitability. These three areas, as indicated in Fig 2.1, are popularly known as the triple bottom line. Studies have shown that they are interdependent and each equally contributes to the attainment of SD. It is therefore of utmost importance that the equilibrium of the three should be maintained (Goh & Rowlinson, 2015:5; Whang & Kim, 2015:76).

Figure 2.1**:** The triple bottom line

Source: https://www.rpmretail.com/single-post/2018/04/02/Your-Triple-Bottom-Line

2.5 EVOLUTION OF SUSTAINABLE DEVELOPMENT

SD is a term that was developed from the general context of sustainability. It is a paradigm that has caught the attention of government and non-governmental organisations, researchers and policymakers around the world. Numerous attempts continue to be made to ensure this is achieved by all industries. The latest initiative is the Agenda 2030 that was signed in 2015 (Ogunmakinde et al., 2017:2771). One of the popular definitions of SD is that penned by the Brundtland Commission (WCED, 1987) which states that the present needs should be met without compromising the future generations' ability to meet theirs (Kibert 2013:23). SD has been understood to be the continual development that humans must pursue to attain a state of sustainability. It is thus a continuous process that requires achieving a balance between human demands and what is ecologically possible. It is worth noting that a conclusion has not been reached on the correct definition of SD. Similarly, Ndou (2016:14) found that despite the popularity of SD it has no standard definition, thus the Brundtland definition of 1987 stands as the main reference point.

In a like manner, the Brundtland definition was posited to be opposed to the traditional way of conducting business, to interpret the word development differently and to enable scientists and consultants to develop a better understanding of the effect that construction projects have on the triple bottom line. Of equal importance are the two concepts contained in the definition.

Firstly, the word "needs" prioritises focusing on the needs of the poor; secondly, the definition considers the impacts of social, organisation and technological advancement on the availability of resources to meet both present and future needs (Poveda & Lipsett, 2011:36-37). On the other hand, the definition has been criticised for being too basic (Ogunmakinde et al., 2017:2772).

As the SD paradigm has evolved studies have shown that there is more emphasis on attaining a balance between the three pillars of sustainability (Goh & Rowlinson, 2015:2). This is seen in the definition of Oke et al. (2015) which states that SDs focuses on ensuring that a decent quality of life is experienced by all of humanity whilst maintaining moderate consumption so as not to deplete the earth's natural resources. Furthermore, SD has been identified as a paradigm that is shaping not only the structures that are being erected but also the way companies and organisations are managed (Kibert, 2016:8). A number of sectors have proposed different ways of attaining SD. This process has commenced with changes in name such as sustainable agriculture, sustainable production, and sustainable health practices. The built environment has also responded to calls to make the industry more sustainable by introducing sustainable construction (SC) (Abidin, 2010:422; Oke & Aigbavboa, 2017:88).

The principles on which SD is based differ in number from one scholar to the other. Oke and Aigbavboa (2017:89) established that SD is based on five principles, namely community development, precautionary behaviour, integration, continual improvement and equity within and between generations. Integration, as the name indicates, brings together the three elements of SD social, economic and environment which form the basis on which project decisions are made. Seeing that every development has an impact on the people and the environment, the second principle of SD encourages community involvement through an impact assessment. Another aspect termed 'precautionary behaviour' seeks to curb any threats that emerge during the construction process. The last two principles focus on the actions of the present generation in securing a stable future for the next generation through the protection of the environment. In agreement, Poveda and Lipsett (2011) identified the principles of SD to be based on the environment, public participation, futurity and equity. Azis et al. (2012:627) established SD principles to be the following: they should be people-centred, aim to eradicate social exclusion and poverty, focus on a long-term perspective, creating an open and supportive economic system, take costs and benefits into account, respect environmental limits, adopt the precautionary principle, transparency, facilitate information participation and access to justice, use scientific knowledge and adopt the principle of the polluter should be made to pay.

2.6 SUSTAINABILITY IN THE CONSTRUCTION INDUSTRY

With the rising environmental and health concerns, it has become evident that there is a need for the built environment to accelerate its implementation of sustainability (Chan et al., 2016:2). Sustainable construction is a term that has differing interpretations from country to country as each has its own way of approaching this paradigm, as observed in the varying scope and practices (Ogunbiyi, 2014:84). Kibwami and Tutesigensi (2016:64) stated that SC can simply be viewed as the CI's application of SD principles whilst Ogunbuyi (2014:89) summed up SC to be a set of processes by which the CI can provide infrastructure which improves the quality of life and ensures client satisfaction at present and in the future. This is because it allows for changes by the user, supports restoration of the environment and promotes minimal use of resources whilst ensuring that firms are competitive, and their businesses are profitable. Kibert (2013:8) defines SC as the creation and management of a healthy built environment through the implementation of ecological principles and the sensible use of resources. Similarly, Du Plessis's (2002:8) study on developing countries established that SC is an all-inclusive process that purposes to recreate the relationship between the built environment and nature. Furthermore, the SC process intends to reaffirm human dignity and enhance economic equity, thus indicating that SC impacts the entire project cycle with an emphasis on environmentally oriented design, operation and maintenance procedures.

The above is compounded in the definition which illustrates that SC is incorporated into construction businesses through the application of SD principles throughout the construction cycle. This cycle runs from the inception and planning of the project to the deconstruction stage and subsequent management of the waste that is produced (Tan et al., 2011:227). SC is known by several terms such as high performance, green construction, green building and sustainable building (Wang et al., 2014:350). Furthermore, the main purpose of SC, as established by Majadalani (2005:35), is to enhance economic sustainability through the provision of efficient and affordable structures of long-lasting value and quality whilst reducing the negative environmental impacts.

Having determined the definition and purpose of SC, it is imperative that its characteristics are identified. Bal et al. (2013: 696-697) purported that a project can be said to be sustainable if the following areas are satisfied:

- Building standards, regulations and legislation are considered in line with sustainability principles;
- Buildings are designed and maintained to enable a longer lifespan;
- Consideration is given for the short-term and long-term environmental aspects of a project;
- Government steers the awareness and adoption of sustainable buildings and construction practices through the provision of policies and incentives; and
- Stakeholders (investors, insurance companies, property developers, professional teams, end-users) have a keen interest in sustainability and spearhead its application.

2.7 PRINCIPLES OF SUSTAINABLE CONSTRUCTION

An analysis of the fundamentals of sustainability by Hill and Bowen (1997:18) indicated that SC is based on the four pillars of sustainability, namely social, economic, biophysical and technical. The social pillar focuses on improving the quality of life, creating a safe and healthy working environment in order to promote and protect human health. The economic pillar is concerned with the monetary benefits to be enjoyed by construction stakeholders whilst the biophysical pillar enables the maximisation of resource use or recycling and reduction using generic resources used in construction and minimising pollution. Finally, the technical pillar considers constructing durable, functional and quality structures.

In a similar vein, Abidin (2010:422) interpreted the principles of SC as incorporating the concern for the people's well-being by ensuring that they live in a healthy, harm-free and productive built environment that has a harmonious relationship with nature. It also ensures that today's activities satisfy the present needs and safeguard the interests of future generations through minimal damage to the environment and its resources. Regarding the economic aspect, this principle focuses on the environmental and social costs that will be incurred and the benefits to be gained from the projects. The technical aspect utilises expert knowledge and technology to obtain information and improve project efficiency, including the quality of buildings and services rendered. It also ensures legislative compliance and responsibility.

From their review of SC, the principles identified by Pearce et al. (2012:8) are indicated in Table 2.1.

Table 2.1: Principles of sustainable construction

AMERICAN INSTITUTE	PRINCIPLES
Office of the Federal Environmental Executive	Adopt a holistic design approach, reduce energy, material and water consumption, improve indoor air quality
US Environmental Protection Agency	Increase energy efficiency and renewable energy use, improve water efficiency, use environmentally preferable building materials, reduce waste, reduce toxics, improve indoor air quality, achieve smart growth and sustainable development
US Green Building	Improve sustainable site development, improve water efficiency, improve energy efficiency, conserve materials and resources, improve indoor environmental quality

(Pearce et al., 2012:8)

A further review of literature established that the principles of SC have been summed up in seven points which not only establish the basis for decisions during the design and construction phase but also throughout the building's existence. These principles were established in 1994 by the Conseil International du Batiment (CIB), an international construction research networking organisation. The principles were identified to be a reduction in resource consumption, application of life-cycle costing, use of recyclable resources, reuse of resources, protection of nature, elimination of toxins and a focus on quality. These principles are applied from planning to disposal (deconstruction) or across the whole life cycle of construction. In addition, they are applied to the resources that are vital to operations in the built environment. These resources, as illustrated in Fig 2.2, are energy, land, water, materials, energy and the ecosystem (Kibert, 2008:1).

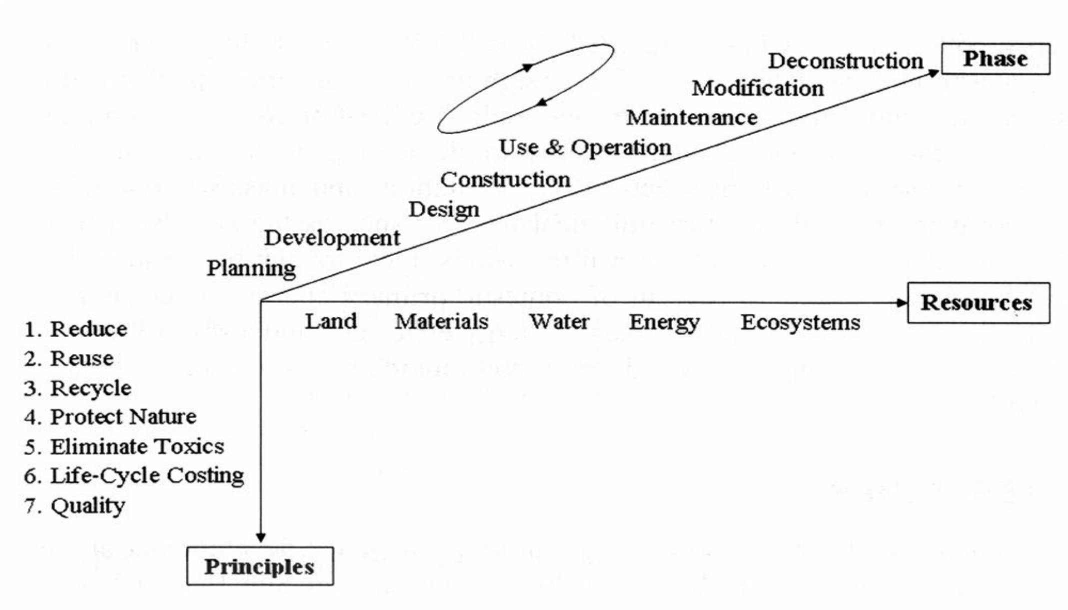


Figure 2.2: Framework for sustainable construction

(Kibert, 2013:8)

2.8 BARRIERS TO THE ADOPTION OF SUSTAINABLE CONSTRUCTION

Despite the popularity of SC paradigm from its inception, few successes have been recorded around the world. Thus, it is essential to understand what is hampering the adoption of SC by identifying the barriers in both developed and developing countries. A barrier or obstacle can be defined as something that prevents or impedes progress. There are two forms of barriers that have been identified, namely internal and external. Internal barriers are concerned with the level of awareness of sustainability, knowledge, attitude and the misconceptions that arise, whereas external barriers consider the various aspects of sustainability such as the availability of green material, technology and financing (Ayarkwa et al., 2017:379).

2.8.1 High Costs

Fear of high capital costs has overshadowed the adoption of SC. This situation is exacerbated by the notably high prices of sustainable material. This aspect tops the list of the deterrents hindering the adoption of SC by the various stakeholders and is the reason for the continued popularity of traditional methods of construction (Opoku & Ahmed, 2014:39; Kibert, 2008:8; Ametepey et al., 2015:1686; Häkkinen & Belloni, 2011:242). Clients are further deterred by a concern about higher risks based on the lack of previous experience, unfamiliar techniques, the requirement for additional testing and inspection and lack of supplier and manufacturer support. To aid the promotion of SC, life cycle cost (LCC) should be incorporated during the assessment of the various costs and their implications (Shi et al., 2013:2). Hydes and Creech (2000:403), on the other hand, argue that the increased cost attributed to the implementation of SC is because of an overestimation of the capital cost as it does not include the cost saving that can be obtained from the incorporation of energy-efficient measures in a structure. In addition, high consultants fees, the need to obtain building certification, the highly complex designs of sustainable buildings and the absence of financial incentives and innovative fiscal instruments that would help to cushion the higher first costs cannot be overlooked (Sodagar & Fieldson, 2007:104; Serpell et al., 2013:283; Chan et al., 2016:2).

From the perspective of developing nations, of which Zambia is one, it was found that the construction sector lacks the financial capability to implement sustainable practices and this is further exacerbated by their variable economies. With these underlying constraints, environmental protection is not a priority in developing countries (Du Plessis, 2002:35). Pitt et al. (2009:209) highlighted that there is a lack of proper understanding of the business case for sustainability. An additional factor determined by Du Plessis (2002:36) is that there is a lack of interest in sustainability issues by clients and other stakeholders in the CI. This is caused by the absence of alternative financial and microcredit mechanisms and ignorance by the developers and contractors of the benefits, such as competitive advantage, that can be gained from adopting SC.

2.8.2 Resistance to Change

The implementation of SC has been further hampered by a resistance to moving away from traditional construction methods. Studies conducted in Nigeria found that the main barrier to the implementation of SC can be traced back to the traditional construction methods that are still being used (Davies and Davies, 2017:5; Aghimien et al., 2017:39). This can be attributed to a lack of knowledge, information and understanding of the delivery of sustainable structures (Abidin & Awang, 2012:375; Saleh & Alalouch, 2015:181; Opoku & Ahmed, 2015:77). On the other hand, studies have found the various stakeholders are aware of issues to do with environmental protection and sustainability, but they lack the desire and right strategy to implement SC practices and would rather rest the responsibility of spearheading SC on the shoulders of government (Powmya & Abidin, 2014:39; Ayarkwa et al., 2017: 377).

2.8.3 Government Role

The government is integral to the adoption of SC as it enforces regulations, reviews existing legislation and enables the introduction of financial incentives, building codes and fiscal instruments. With that in mind it can be ascertained that with the power that the government holds they can enhance the adoption of SC by replacing existing regulations and building codes (Powmya & Abidin, 2014:36). Djokoto et al. (2014:140) cemented the observations of other scholars by stating that the formulation of policies would drive the implementation of SC by providing clarity on the existing policy framework. In addition, it would serve as an indicator of the government's future direction on SC. With the fragmented state of the construction industry, implementation of these policies would bring together the various stakeholders. On the other hand, Majdalani et al. (2006:34-37) argued that though the government plays an important role in enforcing regulations in the CI, they cannot work in isolation. Other stakeholders such as the clients and professionals must assist the government to develop policies, rules and regulations that will govern the CI. Furthermore, an effective way of encouraging change in behaviour in the CI is by implementing changes to the regulatory framework, particularly building regulations. Regulations on their own are not effective in promoting SC; they should be accompanied by education and economic incentives. In addition, the government should utilise its power as a major client and regulator to stir the nation's vision towards a sustainable CI.

2.8.4 Client Demand

Based on the laws of economics, where there is increased demand, supply increases proportionally. Thus, seeing that construction is a client-driven industry, their increased demand for sustainable structures would enhance the adoption of SC (Djokoto et al., 2014: 139). In agreement, Häkkinen and Belloni (2014:243) identified that the demand and willingness of the client are key to the development of SC. This is owing to the link between demand and other important segments such as supply, value and cost. In contrast, a study highlighted that increased demand is dependent on the client's being properly informed of the various SC practices and the benefits that can be obtained from its implementation (Pitt et al., 2009:208-209).

2.9 BENEFITS OF ADOPTING SUSTAINABLE CONSTRUCTION

In order to accelerate the shift from the traditional method of construction, it is imperative to bring to light the various benefits of implementing SC practices. Scholars have found that advantages of SC impact three keys areas, namely society, the environment and the economy.

2.9.1 Environmental Benefits

There are several environmental benefits that can be gained from SC. These are energy conservation due to improved construction methods and production of energy efficient structures which in turn result in decreased burdens on the environment and encourage restoration. SC enhances the protection of the ecosystem, improves air and water quality and reduces production of waste using renewable products and recycling. This contributes immensely to a reduction in global warming and resource consumption (Pearce, 2012:8; Adjarko et al., 2016:586; Ametepey & Aigabavboa, 2014:121; Hydes & Creech, 2000:403).

2.9.2 Social Benefits

Though there is more emphasis on environmental protection, society stands to gain from the adoption of SC through improved well-being. This as a result of residing in buildings of improved quality. Seeing that humans spend 90% of their time indoors, several illnesses suffered today such as asthma and other respiratory infections are due to building materials and components such as carpets, paints and air-conditioning. Thus, the implementation of sustainable technologies and building methods can lead to better health and would stimulate productivity in the case of employees (Kibert, 2013:465; Pearce, 2012:10). In addition, SC results in increased business and job opportunities.

2.9.3 Economic Benefits

Lastly, there are several economic benefits that should encourage the various stakeholders to turn to SC as it enhances company growth, increases competitive advantage and improves operational efficiency. Other advantages are an improved image of the company and cost saving through implementation of life cycle costing. Opoku et al. (2017:16) identified that savings in cost can be achieved by implementing sustainable thinking from the beginning of the project as compared to incorporating changes at a later stage. This is possible using the right materials and a reduction in the utilities installed. The other benefit is improved customer satisfaction (Obunbiyi et al., 2013: 82-84; Ogunbiyi et al.; 2014: Mousa, 2015:9; Opoku et al., 2017:16).

2.10 DRIVERS TO THE ADOPTION OF SUSTAINABLE CONSTRUCTION

The implementation of SC can only be a reality with the right influence. Drivers are defined as elements that steer or encourage the uptake of an activity (Ayarkwa et al., 2017: 379). The term 'driver' differs in the various sectors. From the SC perspective, drivers are factors that encourage the adoption of SC practices. These factors can include the possible benefits, decisions or actions that persuade people to participate in the implementation of SC (Darko et al., 2017:36). The various studies that have been carried out found that the drivers of SC are government regulations and policies, incentive schemes, culture and vision, corporate image, corporate social responsibility, reduced whole life cycle costs, increased property values, social conscience and attitudes and traditions, client awareness and demand, energy conservation and waste reduction (Durdyev et al., 2018:5; Darko et al., 2017:39; Serpell et al., 2013:281). Of equal importance, Andelin et al. (2015:29) observed that each region has different drivers owing to differing social and economic situations. Moreover, the CI has a number of stakeholders and they each have varying priorities. Three of these stakeholders are explained in detail.

2.10.1 Government

Governments play a major role in the adoption and subsequent implementation of SC through policy development such as standard legislation guidelines and assessment systems (Wang et al., 2014:354). According to Häkkinen and Belloni (2011:241), SC can be promoted to some extent by the creation of regulations that compel the various stakeholders to act sustainably. It has been observed that with the divided state of the construction sector and the large number of stakeholders, regulations are the way to proceed to enable SC practices to be implemented (Femenıas, 2005:73–83). In addition, the government through its position as a steerer of development can enhance SC by ensuring that all projects adopt SC methodologies. Another avenue that can be utilised by government is the introduction of incentive schemes as most firms are deterred by the high start-up costs of SC projects (Khalfan et al., 2015:942; Pitt et al., 2009:243). The provision of incentives can be implemented through the introduction of subsidies to construction firms in the form of financial discounts, deficit subsidies, and pre-tax loans and tax incentives (Shi et al., 2013:6).

2.10.2 Client

The client is considered to be one of the major drivers of SC (Abidin & Pasquire., 2005:169-170). Similarly, Häkkinen and Belloni (2011:243) found that with their direct relationship with cost, method, knowledge, supply and value, the client's demand for SC is essential to its development. As such one would contend that increased client awareness would go a long way in minimizing environmental impacts as they are in the position of diverting the focus from a financial gain only mind set. On the other hand, the question is raised as to whether they are knowledgeable enough to make the right decisions. This can be resolved through education despite the cost implication since the more informed the clients are, the more motivated they would be to embrace SC practices.

2.10.3 Professionals

Other stakeholders are the professionals with architects and engineers leading the pack in this category. These professionals are responsible for the design of structures and are involved in the construction stage (Majadalani et al., 2006). The vital role they play can be best understood when reference is made to the previous section regarding the adverse impacts of construction activities. The discussion clearly demonstrated that poorly designed and managed construction projects have significant impacts on sustainability.

2.11 LESSONS LEARNT

Notable observations from this section of literature were that the CI is a vital sector that enhances economic development throughout the world. This is noted in its contribution to about 10% of the GDP, though job creation and its being a vital link between sectors. In addition, it enables the provision of the basic needs in the form of shelter and sanitation. The industry is also known for its adverse impacts, not only on society but also on the environment. These are in the form of pollution, excessive consumption of resources, excessive generation of waste, deforestation, disruption of communities and animal habitation, decreased occupant health and productivity, loss of arable land and loss of life through substandard works and poor safety measures. Furthermore, this study identified that the shift towards sustainability has been motivated by the negative impacts that are being experienced such as changes in weather patterns, material scarcity and natural disasters. Most of these have been attributed to global warming. Global concern over the continued survival of humanity has resulted in the emergence of sustainable development (SD). SD focuses on the formation of mechanisms that ensure the provision of resources to meet not only the present needs but also those of the next generation. The SD concept has been adopted by the various sectors and the CI's implementation of this phenomenon is known as sustainable construction (SC). The main barriers of SC are higher first costs and lack of regulations whilst the major drivers are the introduction of financial incentives, increased demand and the introduction of SC-promoting regulations. Lastly, the benefits of adopting SC are the reduced consumption of natural resources, preservation of energy, improved well-being and cost saving.

2.12 CONCLUSION

The concept of sustainable construction was explained in detail. This commenced with the identification of the various contributions of the construction industry (CI). These were found to be in two forms, namely positive as seen in its contribution to development, and negative in the form of adverse impacts. The next sections introduced the concept of sustainability and brought to light the principles, barriers, benefits and drivers of its adoption. The ensuing chapter focuses on the practices that can enhance sustainability in the construction industry.

CHAPTER THREE

OVERVIEW OF SUSTAINABLE CONSTRUCTION PRACTICES

3.1 INTRODUCTION

In this chapter sustainable construction practices are presented. Each of these practices is discussed, commencing with a brief background and followed by its definitions and principles. The barriers, benefits and drivers for each practice are also discussed.

3.2 AN OVERVIEW OF SUSTAINABLE CONSTRUCTION PRACTICES

The worsening climatic conditions that are viewed as consequences of global warming, depletion of natural resources, land degradation and water and air pollution, among others, have led to increased calls for the adoption and subsequent implementation of sustainable development (SD) in the various sectors. The focus has been turned on the construction industry (CI) as it is interconnected with the other sectors. Evidence indicates that it is the major contributor to the disruption of the ecosystem and the depletion of the earth's resources (Opoku & Ahmed, 2014:91). The CI's response to this call is described as sustainable construction (SC) and the application of the principles of SD to the business and strategies of the institutions operating within this sector are what are known as sustainable construction practices. Tan et al. (2011:227) posited that SC is the application of SD principles in the entire construction cycle, from its inception to the design stage, followed by the construction stage which involves the production of materials. The last two stages are operation and maintenance, followed by deconstruction and administration of the waste that is produced.

According to Tan et al. (2011:228), there are six SC practices that can be incorporated into various construction organisations. The first focuses on ensuring that all stakeholders comply with all legislation enacted by the government that supports sustainability in three areas, namely the environment, society and the businesses. The second aims at improving the value of the project through the adoption of green designs and the establishment of a supply chain that promotes the implementation of these designs. The third practice calls for organisational restructuring as a means of enabling the implementation of sustainable strategies and policies whilst the fourth supports the use of innovation and technology and innovation as a means of enhancing sustainability in a construction firm's processes and the structures that are produced. As has been alluded to in the previous chapter, one of the main ways in which SC can be implemented is if people are aware and have the knowledge; therefore, firms should prioritise the training and education of all their staff. The last practice focuses on the development of a measurement and reporting system or making use of a firm's existing benchmarks in order to assess its social and environmental performance.

Out of all the practices that have been identified, this section focuses on the fourth one which taps into the use of technology and innovation as a way of enhancing SD in the CI. This is because it is through technology that humans interact with the environment through the extraction of resources for the creation of living spaces and the production of goods. The study by Vanegas et al. (1995:4) revealed that the use of technology by humans to tap into the environment's benefits has resulted in drastic consequences. This emphasises the need to develop technologies that promote sustainability by enabling the creation of products or services that not only benefit the environment but also uplift the livelihood of humans, both socially and economically.

The clamour for the adoption and ensuing implementation of SD principles in the various sectors has seen the emergence of several concepts and technologies which would accelerate the adoption of sustainability in construction projects. The first of the technologies identified is building information modelling (BIM) which has been introduced to aid project collaboration in an industry that is known for its fragmented state. Other concepts described as scientific and philosophical in nature and are borne out of the sustainability paradigm shift are construction ecology CE), design for environment (DfE), biomimicry, ecological economics (EE), cradle-to-cradle design (C2C), life cycle assessment (LCA), ecological footprint (EF) and life cycle costing (LCC) (Kibert, 2013:7,16-17,43). Additionally, the industrialised building system (IBS), value engineering (VE), lean construction (LC), Internet of Things (IoT), 3D printing and blockchain technology were identified as technologies that would enhance sustainability in the CI (Hussin et al., 2013:21; Kiroglu, 2017:703; Tiastsis et al., 2018:5; Li et al., 2019:8). In order to realise some of the benefits of sustainability such as improved resource utilisation, a reduction in the emission of harmful gases and the conservation of energy, more technologies are emerging and the ones that are existing are being improved upon through continued research.

3.2.1 Lean Construction

3.2.1.1 Overview

The generation of excessive waste is an activity synonymous with the CI. This is evidenced in the large quantities of construction waste filling the landfills and other illegal sites. Other forms of waste can be presented in the form of loss of productivity and material, project time and cost overruns. Azis et al. (2013:630) attribute the high wastage in construction to poor planning, frequent design changes, ordering errors, workers' mistakes and the inclement weather. The adoption and implementation of techniques such as lean construction (LC) would result in a decrease in the generation of numerous forms of waste.

Lean thinking or production emanated from the manufacturing industry where it was implemented in mass production by Henry Ford. This concept was improved upon by Fiji Toyoda and Taiichi Ohnom of Toyota in the 1950s owing to the scarcity of resources after the Second World War (Forbes & Ahmed, 2010:46). Though it lacks an accepted definition, lean thinking is a concept that focuses on the elimination of all forms of waste such as time, material and labour and aims to avoid the production of defects. Scholars have established that the term 'lean production' was borne out of the concept of halving the resources required to achieve the same or increased output. These resources are in the form of factory labour, the space used for manufacturing, the tools and raw materials. This form of production results in fewer defects and generates an increasing variety of products based on the mantra "What is needed, when it is needed and the amount that is needed". Additionally, the lean thinking focusses on value-adding activities from a project's inception till its completion. This results in an organisational culture that continuously looks to improve its output through value addition and the elimination of non-value adding items (Forbes & Ahmed, 2010:46, Dickson et al., 2009:177). The successful implementation of the lean concept in the automotive industry has led to increased interest and adoption of the lean concept in non-automotive industries such as construction, aerospace, electronics manufacturing and health (Bashir, 2013: 25). The acceptance of the lean way of thinking in the CI is known as lean construction (LC).

LC is an avenue in which sustainability can be promoted in the CI through the optimisation of resources, prioritising safety in all construction activities and implementing standard procedures to curb wastage and enhance efficiency (Nahmens & Ikuma, 2011:155-156). LC is an innovative philosophy that aims to contribute to the promotion of SD by ridding the CI of activities that are not value-adding and are thus known as waste (Ogunbuyi et al., 2013:82;

Huovili & Koskela, 1998:7). The application of the lean concept in the CI was pioneered by Lauri Koskela in 1992. Koskela viewed LC as the creation of a production system within the CI which results in facilities of value with the least wastage of material and time (Koskela et al., 2002:217). The forms of waste that lean aims to eliminate are excessive movements, overproducing, keeping excess stock, extra-processing, defects, rework, poor safety, waiting time, delay and transportation (Forbes & Ahmed, 2004:463). The lean concept focusses on balancing the main components of construction materials, people and resources. This dispels the myth that lean focusses on trimming all activities to the bone. Additionally, lean construction's production management approach of project delivery paves the way for the improved design and construction of infrastructure (Marhani et al., 2013:92,99).

3.2.1.2 Principles of lean construction

Babalola (2018:36) posited that there are five principles of LC, namely the identification of value from the customer's perspective, attaining customer pull at the opportune time, improved flow of the work process, seeking perfection and continuous improvement, and understanding the value stream. Principles specific to the CI were identified by Koskela (1992) as reduced product inconsistencies, reduced cycle time, benchmarking, management of flow, increased focus on the overall process and simplicity (Bashir, 2013:250). Ogunbiyi et al. (2013:82) summarised the lean principles to be value stream mapping, continuous improvement, pull system, flow, and involvement of employees. However, according to Bertelsen (2004:48), sectorial differences such as the dynamic state of the CI in comparison with the orderly and foreseeable state of the manufacturing industry hamper the application of lean principles in the CI. Furthermore, the successful application of LC in the project delivery in the CI involves the development of tools and techniques that are in line with lean principles (Bashir et al., 2011:250).

3.2.1.3 Barriers to lean construction

Abdullah et al. (2009:5-7) found that the major barriers to LC to be top management's lack of commitment and attention, difficulties in understanding the LC concept, inadequate training, poor communication among clients, lack of exposure to the need to adopt the LC concept, contractors' and consultants' attitude and their inability to work as a team and the lengthy implementation period of the lean concept. The top seven barriers identified by Marhani et al. (2013:96-97) were categorised as follows: managerial, technical, financial, government, educational, the process of LC and human attitude. The managerial aspect is concerned with the lack of commitment and support from top management and poor communication amongst the stakeholders. Lack of buildable designs tops the list in the technical category which includes the provision of benchmarks and certainty in the production process. Additionally, lack of constructability of architectural designs was found to be a barrier owing to limited knowledge of construction practices. The attitude category is concerned with the commitment, intent and co-operation exhibited by the stakeholders towards LC. Additionally, the implementation of LC also requires several time-consuming meetings if not well managed. Financial barriers were found to be inflation due to unstable market conditions, low salaries for professionals and additional construction costs.

A study by Shang and Sui Pheng (2014:159-162) established that the barriers to the adoption of LC are lack of government support, absence of a lean culture in the organisation, the firm's restricted utilisation of the procurement mode design and build, the construction firm's limited involvement in the design, insufficient lean knowledge, multi-layer subcontracting, inadequate application of off-site construction techniques, employee tolerance of untidy workplaces, insufficient management skills, lack of support from top management, high turnover of workforce, insufficient training, employee and management resistance to change, absence of a lean culture in the partners, inadequate delivery performance, hierarchies in organizational structures, rigorous requirements and approvals and lack of a long-term philosophy.

Similarly, Jamil and Fathi (2016:638) identified inadequate lean awareness in the form of skills and knowledge, insufficient commitment from top management, technological limitations, poor implementation strategy, lack of supportive organisation and teamwork, lack of enabling platforms for sharing visions and consensus and inefficient stakeholder relationship management as barriers to the adoption of LC. Lastly, the results of the study conducted by Ayarkwa et al. (2012:7) revealed that the 26 barriers to adoption of LC that were found can be reduced to six factors with the highest-ranked being inadequate control and planning. This factor consists of the following variables: control by the various stakeholders which is evidenced in the extensive use of subcontractors, lack of consistent government policies, delays in material delivery, the existing short-term relationships with suppliers, improper use of quality standards, lengthy implementation period, acceptance of the high generation of the different forms of waste, high dependency of design specifications on in-situ components and materials, lack of long-term commitment to change and innovation, delays in decision making and materials scarcity.

The second factor is termed as the absence of teamwork and this is seen in the fragmented nature of the industry, lack of interest shown by clients, lack of pronounced responsibilities of each individual and lack of involvement of specialists and contractors in the design process. The third item focuses on poor project management which consists of a poorly scripted project brief, absence of an implementation methodology that has been approved, lack of equipment, and unsuitable organisational structures. This is followed by the absence of the technical abilities in the professionals as portrayed in either incomplete or absent building designs and lack of standardisation. The last two barriers focus on two key issues, namely finances and communication. Financial barriers in the form of poor wages and corruption hinder the adoption of LC. Lastly, poor communication amongst the various stakeholders hampers the sharing and understanding of LC concepts.

3.2.1.4 Benefits of lean construction

LC not only offers several benefits in the project operation but also provides environmental, social and economic benefits. Mossam (2009:26-27) found that the major benefits of LC are productivity gain, reduced construction time, increased revenue for subcontractors and operatives, improved quality and health and safety, improved design and reduced defects. Other notable benefits are reduced waste generation, enhanced organisational and supply chain integration, and improved communication and design (Ogunbuyi, 2013:85). Based on the three key areas of sustainability, known as the triple bottom line, Nahmens and Ikuma (2012:155-156) identified that the benefits of implementing LC would result in a notable reduction in the quantity of waste being deposited in landfills as a result of construction of residences (environmental sustainability), improved productivity of construction operations and improved safety and health of workers (social sustainability). According to Sarhan et al. (2017:63), in their study in Saudi Arabia, customer satisfaction stood out as the main benefit of adopting lean construction techniques. Other benefits were found to be improved quality of products and increased productivity. These benefits are similar to those identified in studies conducted in Brazil and the Netherlands.

3.2.1.5 Drivers of lean construction

Drivers of the implementation of lean practice were identified to be waste elimination, optimisation, people utilisation, continuous improvement, process control, a means of improving the supply chain and providing value to the customer (Ogunbuyi et al., 2014:90). For example, cost reduction benefits, improving efficiency, improving product and services quality, time reduction benefits, increasing revenues and clients' satisfaction are among the factors that drove UK contracting organisations to apply lean practices. Similarly, Bashir’s (2013:25-26) review of LC in the UK revealed that firms were prompted to adopt LC in order to attain the following: increased revenue whilst reducing operating costs, improved efficiency and quality of product and services, reduction in production, an upsurge in client satisfaction, elimination of non-value adding activities and increased competitive advantage as the main drivers of adopting lean practices.

Ayarkwa et al. (2012:10) identified that from the management aspect, the training of employees on lean concepts should be prioritised. Other drivers are the delivery of construction materials within the stipulated time, continuous improvement being sought by all firms, increased productivity and improved quality, implementation of teamwork and measures to prevent defective production, focus on attaining competitive advantage by seeking to understand clients’ needs and expectations. Additionally, firms should be willing to improve or eliminate organisational cultures that do not promote lean construction and overlook the importance of employees in the decision-making process. The adoption of LC would be accelerated if government agencies were proactive in formulating applicable policies that would provide the necessary support that would enable lean methods to be feasible. Lastly, improving communication and information sharing on LC amongst the construction stakeholders would aid its adoption.

3.2.2 Biomimicry

3.2.2.1 Overview

The rapid rate at which natural resources are being depleted and the negative impact that the largest consumer of these resources, namely the construction industry, has on the environment have prompted the emergence of biomimicry. Biomimicry is a field inspired by the entire ecosystem and is potentially a worthy solution to the many challenges being faced today. This field has garnered popularity amongst the built environment professionals as it inspires innovation through the emulation of nature, and it serves as a means of promoting sustainability (Mahmoud & Zeiny, 2012:503; Kennedy et al., 2015:67).

Though biomimicry is a new field, a study by Radwan and Osama (2016:179) revealed that it existed in 500BC when Greek philosophers saw natural organisms as models for a harmonious balance. An example of the implementation of designs from nature in later years was the invention of the flying machine in 1482 by Leonardo Da Vinci which was inspired by birds. Da Vinci then went on to write that "…human ingenuity will never devise any inventions more beautiful, nor simpler, nor more to the purpose than nature does as nothing is wanting, and nothing is superfluous". The term 'biomimicry' came into existence in 1982 but was popularised by author and scientist, Janine Benyus, in her 1997 book entitled *Biomimicry: Innovation Inspired by Nature*. The term 'biomimicry' is derived from Greek words *bios* (life) and *mimesis* (imitation) which literally mean 'imitation of life'. Benyus defines biomimicry as the imitation and application of nature's ingenuity to resolve the problems faced today. This is because, with a lifespan of over 3.8 billion years, nature has proven to be a successful system that has survived many challenges. Additionally, Benyus posited that nature should be viewed as our *model* (source of inspiration), *measure* (of what works, what lasts, what is appropriate) and *mentor*. These three are the primary areas of biomimicry (Goss, 2009:6; Kibert, 2016:58; Nkandu & Alibaba, 2018:1).

Biomimicry is also described as man's exploration of nature's works of art, namely photosynthesis, self-assembly and natural selection. These are self-sustaining ecosystems which are applied to the design and manufacturing process to aid the earth's current problems (Oguntona & Aigbavboa, 2017:2772). The term 'biomimicry' is used interchangeably with other terms, namely biomimetics, bio-inspired design, bionics, bioprospecting, biosynthesis, biotechnology, bioengineering and biognosis (Valdecasas & Wheeler, 2018:1; Oguntona & Aigbavboa, 2017: 2493).

With nature as its model, biomimicry will pave the way for a more sustainable future through the resolution of the earth's problems which have been brought about owing to over-exploitation of resources, increased population and industrialisation. Biomimicry is considered to be transdisciplinary owing to its application in medicine, agriculture, aerodynamics, architecture, industrial design and human safety (Amin & Taleb, 2016:1). Furthermore, biomimicry is a suitable sustainable practice as it creates products and processes of high performance, saves energy, reduces the cost of materials and redefines and eliminates waste and subsequent environmental degradation (Kibert, 2016:58). This is evidenced in Table 3.1.

Table 3.1: Products and applications of biomimicry

PRODUCT	NATURAL INSPIRATION	FUNCTION
Ceramics	Abalone Shell	Manufacturing of super strong crystal structure of the inner shell
Concrete Alternative	Abalone Shell	Biomineralization process that stores carbon and creates durable, crack-resistant material
Lotusan Paint	Lotus Leaf	A micro-textured surface that allows for self-cleaning
Safety Road Reflectors	Cats' Eyes	Reflector cells that reflect even small amounts of light
Shinkansen 500 High Speed Train	Owl Feathers; Martin Kingfisher Beak	(1) Unique sawtooth feathers on owl wing block formation of speed vortices and inspired technology of "micro-vortex generation" (2) Long beak of Kingfisher inspired nose shape of the train to handle changes in air resistance when emerging from tunnels
Automobile Anti-Collision Safety Sensors	African Locust	Anti-collision sensors activated during swarms
Artificial Photosynthesis (Solar Energy Harvesting System)	Natural photosynthesis	Sunlight to energy conversion through the development of a synthetic molecule that mimics photo-initiated electron transfer process
Eastgate Complex	Termite Mound	Passive cooling and ventilation techniques where insects open and close holes according to need

(Goss, 2009:13-14)

3.2.2.2 Principles of biomimicry

There are nine principles of nature that form the basis of biomimicry as Janine Benyus indicated in her 1997 book entitled *Biomimicry: Innovation Inspired by Nature*. These are nature is driven by sunlight; nature preserves energy by using only the quantity it needs, nature fits form to function; all things are recycled by nature; nature values cooperation; nature thrives owing to diversity; nature requires local expertise; nature controls excesses from within; and nature taps the power of limits (Goss, 2009:6). According to the Biomimicry Group, there are six major principles and they constitute of 23 principles as indicated in Table 3.2. The six principles or life principles as described by other authors are a medium of integrating nature's ingenuity into design and serve as an essential benchmark. These principles were compiled based on their successful implementation by nature and so serve as a cardinal tool to redefine and guide design choices (Pólit, 2014:32).

Table 3.2: Principles of biomimicry

MAJOR PRINCIPLE	DESCRIPTION AND MINOR PRINCIPLES
Evolve to survive	Involves the continuous incorporation and expression of information in a form that ensures enduring performance. It is made up of three (3) principles namely, the replication of strategies that work, integrating the unexpected (what would be considered as mistakes are incorporated as these can lead to the creation of new form and functions) and exchanging information to create new options.
Adapt to changing conditions	Entails responding appropriately to the dynamic conditions. The following principles are applied to maintain integrity through self-renewal; embodying resilience through variation, redundancy, and decentralisation and incorporating diversity.
Being locally attuned and responsive	Focuses on a harmonious and united existence with the surrounding environment. It is composed of five (5) principles, namely utilising feedback loops, maximising on readily available materials; capturing the freely available energy; leveraging cyclic processes and cultivating cooperative relationships.
Integration of growth and development	Consists of optimally investing and engaging in strategies result in increased growth and development. It is composed of three (3) principles, namely building from the bottom up; and self-organising and combining modular and nested components.
resource efficiency (energy and material)	Involves the application of skills and moderation when taking advantage of opportunities and existing resources. This is governed by the following principles; recycling all materials; selecting low energy processes; multifunctional design and fitting form to function (select shape or pattern based on need).
The use of life friendly chemistry	Focuses on the use of life supporting chemistry processes. The three principles that govern this are building selectively with a small subset of elements; the breaking down of products into benign constituents (through the application of chemistry to produce harmless products) and using water as a solvent

(Oguntona & Aigbavboa, 2017:2493-2494)

3.2.2.3 Barriers of biomimicry

According to Buck (2017:133), higher initial costs, slow integration into organisational structures, unreceptive designers and managers, the prevalent application of short- to medium-term investment versus life cycle investment which has a stronger business case for biomimicry, uninformed regulators on the proper way to access present risk and potential risk as a means of removing all biases and lack of funds to promote research development on biomimicry were identified to be the major barriers to the adoption of biomimicry. Similarly, Kenney et al. (2013:6) identified high initial costs as the major barrier to the adoption of biomimicry. In addition to the high costs, existing regulations that do not promote the adoption of innovative technologies, fear of failure and the project-based nature of the CI hinder the adoption of new technologies as they are time consuming. On the other hand, Gamage and Hyde (2012:225) posited that the barriers to biomimicry adoption are lack of environmental policies, lack of application of biomimicry principles, language barrier (inability to understand the various biomimicry approaches), integration barriers (absence of biomimicry integration knowledge), inability to interpret biomimicry principles and lack of understanding of nature's processes and strategies. Finally, Zari (2008:776) found the current competitive economic context of the built environment, the independent approach of stakeholders, lack of knowledge sharing and different economic and legal frameworks as barriers to the adoption of biomimicry.

3.2.2.4 Benefits of biomimicry

A study by Buck (2017:130) found that biomimicry enhances "transdisciplinarity." This means that Biomimicry draws different disciplines together, can encourage behavioural change with eco-friendly infrastructure built right in the heart of communities, positively impact property value and help to reduce infrastructure maintenance cost. Vincent (2016:146-147) established that biomimicry results in the effective use of resources and promotes the recycling of material. Moreover, materials produced are durable and multifunctional and result in reduced costs. Zari (2016:74) identified that biomimicry could transform the CI's environmental performance and can serve as an evaluation benchmark. Furthermore, biomimicry promotes technology efficiency, serves as a model for technological development and creates a market for innovative technologies (Lurie-Luke, 2014:1502-1503). Zari (2010:181) revealed that biomimicry enables mitigation of climate change through innovative technologies that curb the emission of greenhouse gases, enhances the construction of eco-friendly structures (smart buildings) and encourages the maintenance of biodiversity, the ecosystem and bio-inspired structures, resulting in improved physical health and attracting higher premiums.

3.2.2.5 Drivers of biomimicry

In their quest to promote the adoption of biomimicry, Nkandu and Alibaba (2018:10) posited that there is a need for collaboration of multiple disciplines in a quest to produce structures and systems that not only benefit nature but also the occupants. In a similar vein, Eldin et al. (2016:385) cited that funding and inclusion of biologists to the design team would drive the adoption of biomimicry. In addition, increasing collaboration among researchers would also be useful for the improved understanding of a structure-function relationship and the extraction of useful engineering principles. In addition, the adaptation of models for practical applications would aid the adoption of biomimicry (Han et al., 2016:48). In contrast, El-Zeiny (2012:511) identified the inclusion of biomimicry in the current university syllabi as the major driver coupled with the organisation of networks, workshops and events as these would serve as vital platforms that could help forge links and transfer knowledge across disciplines.

3.2.3 Ecological Economics

3.2.3.1 Overview

The constant pursuit of economic growth has resulted in inhospitable consequences such as increased consumption of non-renewable resources, high emission of greenhouse gases, pollution and high energy consumption, among others (Muhaisen & Alhback, 2012:1; UNEP, 2003:6). Furthermore, these environmental problems are exacerbated by global climate change borne out of the energy-intensive and fossil-fuel-based technologies. This has led to the disturbance of ecosystems and the depletion of the Earth's natural resources. The world's environmental woes have been coupled with deepening economic instability (Capra & Jakobsen, 2017:833-834). In a quest to promote sustainable development, scholars have identified a method known as ecological economics (EE) that seeks to understand the environment, the activities that negatively impact it and how these impacts can be minimised whilst improving the quality of human life and ensuring the active flow of goods and services is maintained (Dodds, 1997:96; Oke et al., 2017:152).

Ndou (2016:19) established that EE emerged during the late 20th century owing to the need for environmental protection and economic sustainability. The term 'EE' when considered from the traditional perspective is the combination of two words, namely "ecology" and "economics", where ecology is the science of relationships between the members of an ecological community and their environment and economics as defined by Gregory Mankiw is the study of how society manages its scarce resources. When looked at from the broad sense or the systems view, EE is an economic theory and practice that views the economy as operating in the same spheres of society, nature and culture instead of dominating them (Capra & Jakobsen, 2017:834).

It is of paramount importance to note that the benefits of implementing this model in most cases are not tangible but are evident through reduced operating costs and a positive impact on society and the environment over a long period (Oke et al., 2018:1). Kibert (2013:46) points out that EE is an essential requirement of sustainable development as it addresses the relationship between the natural ecosystem and the human economy.

3.2.3.2 Principles of ecological economics

There are four (4) principles of EE that were posited by Capra and Jakobsen (2017:835-836). The first is that the economy is a living system that is nested within other living systems, namely nature, society, culture and politics. With the systems view of life, the process is revolutionised with nature being superior to the economy. The second principle considers the economy to be a network. As per the systems view of life, all living systems are organised in the form of a network. The network is described as a pattern of connections and relationships. This model of the patterns and relationships is what systems thinking is comprised of. The third principle states that the economy is an open system. Such a system consists of non-linear multiple connected feedback loops that allow it to regulate and balance itself. The fourth principle states that all living systems interact cognitively with their environment in ways that are determined by their own internal organization. This involves the consciousness and culture of an organisation, particularly in the area of ethics where today's ethical behaviour is based on the two fundamental values of human dignity and ecological sustainability. If these ethical values are not successfully incorporated into our personal lives, businesses, politics, and our economies, natural selection will see to it that humanity does not survive.

3.2.3.3 Barriers of ecological economics

Kibert (2016:59) identified the limited understanding of complex nonlinear natural systems, as well as the struggle of accurately representing these systems in relevant economic models as the major barriers to the adoption of EE. Studies have a revealed that procurement practices, lack of capacity for sustainable empowerment, construction techniques, increase in the cost of imported building material (lack of skills to produce other construction material), critical global issues (profound political and social instability, high unemployment and skilled labour), usage of new technology, availability of green infrastructure (land claim and zoning issues, heritage sites restricting development), principle of traditional construction standards, stakeholder involvement, building public confidence, globalization (global economic recession), statutes (building regulations and standards, height restrictions, health and safety provisions) and work responsibilities are the barriers to the adoption of EE (Oke et al., 2017:279).

3.2.3.4 Drivers of ecological economics

To aid the adoption of EE, it is recommended that education and training of all professionals in the CI on its successful implementation should be prioritised. Additionally, to enhance ecological economics awareness, the professionals should be encouraged to keep abreast with the emerging trends and the various principles necessary for improving the performance of construction projects. Regulatory bodies and government agencies who are tasked with the responsibility of delivering sustainable infrastructure and the overall performance of the construction project should be encouraged to improve their level of sensitisation on the need for adopting and implementing the concept in the CI (Oke et al., 2017:155-156). Similarly, Capra and Jakobsen (2017:843) established that increased awareness of the ecosystem or eco-literacy should become a compulsory skill for all politicians, business leaders, and professionals as this will promote the realisation of a sustainable society. This information on the ecosystem should be shared in the schools and higher institutions of learning. Continuous training and education of professionals should be emphasised.

3.2.4 Value Management

3.2.4.1 Overview

Increased calls for the CI to deliver structures that promote sustainability socially, economically and environmentally have led to the formation of various innovative technologies. Additionally, the competitive nature of the industry and firms' quest to ensure that projects of a high quality are delivered on time and within budget have motivated the creation of construction management tools, namely value management (VM), lean management (LM), facility management (FM) and building information modelling (BIM), among others (Oke & Aigbavboa, 2017:3-4).

Scholars have found VM originated from the manufacturing industry in the USA in the late 1940s owing to a material shortage brought about by the Second World War. Owing to the scarcity of production components, Lawrence Miles of the General Electric Company sought alternative components or resources that could perform the same function at a cheaper cost. During this period VM was referred to as value analysis (VA). This approach was maintained after the war as unnecessary costs were eliminated and the design was improved (Shen & Yu, 2012:2; Aghimien et al., 2018:2442). VM has gained popularity in the other sectors and amongst these was the CI in which this technology was introduced in the USA CI in the 1960s and the UK CI in the 1980s (Perera et al., 2011:95).

VM is often associated with value engineering (VE), value planning (VP) and value analysis (VA). Some scholars assert that VP takes place at the planning stage of a project, whilst VE takes place during the working drawing and production stage and VA is practised at the construction, occupation and post-occupation stages. The three terms form what is known as VM and this has been accepted and adopted as a construction management tool in the CI in most countries around the world. Though VM originates from the manufacturing industry, it is a cardinal component of the project, construction, lean, risk, and knowledge management system in the CI. It can be undertaken by a range of construction professionals but needs the involvement of experienced facilitators (Kelly et al., 2014:30; Aigbavboa et al., 2016:227). A further review of the work of Aigbavboa et al. (2016:227) revealed that that VM is not a cost-cutting exercise but it seeks to attain value for money. To aid its application, Shen and Liu (2004:9) defined VM as a systematic, structured and multi-disciplinary methodology the purpose of which is to enhance the whole life cost and value of a facility through the detection of opportunities to remove unnecessary costs while ensuring that quality, performance and other critical factors will meet or exceed the customer's expectations. On the other hand, Abidin and Pasquire (2005:2) posited that VM is an organised approach that aims to establish the meaning of value to a client through meeting a perceived need, clearly defining and agreeing with the project objectives and establishing how they can best be achieved. Furthermore, VM is an organised function-oriented systematic team approach directed at analysing the functions and costs of a system, supply, equipment, service or facility, for the purpose of enhancing its value through achieving the required functions specified by the clients at the lowest possible overall cost and consistent with requirements for performance (Shen &Yu, 2012:1). Similarly, Oke and Aigbavboa (2017:16) established that VM is a management process that involves the appropriate selection of materials, control, monitoring and managing of project team members, redesigning of spaces and components, as well as the optimisation of the process of producing a product in order to meet the stated project goals. In other words, VM can be set apart from similar cost-cutting or cost-saving exercises because it was found to be a process in which all resource forms are holistically managed. It is also essential to note that to ensure active participation from members of the team and to ensure that subsequent exercises are carried out successfully, VM adopts a systematic, logical and methodological approach.

From the study conducted by Aghimien et al. (2018:2443-2444), it was revealed that VM contributes massively to the attainment of economic sustainability on the projects in which it is implemented. This is because the participants are offered the opportunity to be involved in process and this would enable them to ensure that construction projects create an avenue for achieving value for money. However, caution should be taken to ensure that a balance is maintained between the economic pillar and the remaining two pillars, environmental and social. Additionally, VM aids sustainability through the elimination of areas of unnecessary designs that affect the cost and have no functional benefits. It also reduces the cost of construction, construction time, and provides value for money, thereby giving overall satisfaction to the client. Thus, VM impacts not only the economic component of sustainability but also an environmental one, namely the elimination of wastage, unnecessary designs, materials and processes.

3.2.4.2 Principles of Value Management

In their study, Oke and Aigbavboa (2017:16-18) established that the following need to be understood for VM to be successfully implemented. Firstly, VM is a management process and it requires a systematic approach. Secondly, teamwork is essential as the VM workshops are basically a platform in which professionals from all disciplines are brought together in teams to deliberate on the optimal cost and function of a component or item. The next aspect is that VM requires the implementation of functional analysis of element or product. Of equal importance is the whole-life cost concept which focuses on the costs to be incurred throughout the life of an element or product based on the materials selected. Similarly, the principle that considers the stages of the project or product aims to ensure that the materials selected can last the life of a project or product. For example, in construction a project runs from conception to demolition and thus the material selected should be able to withstand this period. Other cardinal principles focus on clients getting value for money from the project or product and getting maximum returns on their investment.

3.2.4.3 Barriers of value management

The adoption of VM has been hampered by the lack of willingness on the part of clients to adopt and pay for the exercise, insufficient information about the discipline, lack of awareness, and the lack of training. This has resulted in a wrong perception of the discipline (Aigbavboa et al., 2016:233). Luvara and Mwemezi (2017:12) identified a lack of awareness about VM by CI professionals, wrong choice of procurement route and lack of trained VM managers in the

CI as the barriers to the adoption of VM. An extensive study by Aghimien et al. (2018:822) identified a numbers of barriers, namely clients' lack of awareness of its existence and the benefits that can be derived from the integration of VM, inadequate training and education of professionals on the VM approach, absence of skilled personnel, clients not being willing to fund VM exercises, poor relationships and communication among relevant stakeholders, stakeholders not being open to new ideas and concepts, design teams' poor attitude towards VM, lack of understanding of VM terminology and methodology, lack of available of VM guidelines, lack of professionalism, the procurement method used for the project, lack of government encouragement and top management support and lack of readiness to adopt VM in the industry.

In the same vein, Oke and Aigbavboa (2017:175) posited the adoption of VM is hampered by the absence of insufficient education and training of professionals on VM basics, approach and technique; lack of political will and power; inconsistency in VM basics, approach and techniques; unstable economy; corruption and greediness of consultants and contractors; lack of implementation of recommendations emanating from previous studies; inconsistency in VM terminology and methodology; inadequate funds for the VM study; high initial costs, and finally, the culture within the CI being one that is focused on defeating competitors rather than meeting the demands of the client.

3.2.4.4 Benefits of value management

The major benefit that can be drawn from the adoption of VM is that it enables early identification of possible problems in the project, encourages the use of local sustainable materials in construction, eliminates the production of unnecessary designs, reduces defects and waste, curbs unnecessary costs and achieves value for money, ensures that the project is delivered in the most cost-effective way, enhances value and benefits for end users and enables efficient use of resources (Aghimien et al., 2018:3127).

In like manner, Aigbavboa et al. (2016:233) state that VM enhances project value, improves design efficiency, optimizes value for money, advances design decisions, creates clear focus on the project objectives, discovers project issues and constraints, enhances communication and efficiency by developing multidisciplinary and multitask teamwork, promotes sustainability, results in improved quality of work, provides an authoritative review of the project, and enhances competitiveness by facilitating technical and organizational innovation.

Of equal importance are the following benefits: VM enables decision makers to make sound business choices when it comes to product and service improvement for the purpose of enhancing customer satisfaction, improved communication and efficiency among the various disciplines and teams, enhancement of risk management measures, and the promotion of innovative service delivery processes (Aghimien & Oke, 2015:9).

3.2.4.5 Drivers of value management

A number of factors have been identified that can promote the adoption of VM. In their book on Sustainable VM, Oke and Aigbavboa (2017:179-181) identified dissemination of information on VM to all the stakeholders in order to create awareness through various means like education and training, involvement of the various stakeholders in the VM process, formulation of appropriate guidelines and regulations, development of comprehensive databases on SC and VM and offering economic incentives for projects that implement VM and other SCPs. Similarly, Aigbavboa et al. (2016:233) found that formulation of appropriate and relevant guidelines as well as legislation to adopt, enforce and monitor the application of the discipline, improved communication skills amongst the construction professionals and the adoption of innovative ideas and solutions suitable to the country's culture and citizens would promote the adoption of VM.

Perera et al. (2011:109) found that the major drivers to the adoption of VM are the proactivity of professional bodies and academic institutions in disseminating information on VM, training the CI professionals on the use of VM and emphasising the need for its adoption at early stages of design. In their study on the quantity surveying profession and VM, Bowen et al. (2010:61) established that there should be greater alignment between VM and the modern requirements of quality, risk and environmental management. Furthermore, refresher courses for QS professionals are recommended including simulation workshops and facilitator training.

3.2.5 Nanotechnology

3.2.5.1 Overview

The CI is the largest contributor to environmental degradation. The industry is responsible for the consumption of 40% of the energy generated, emits about one-third of global greenhouse gas emissions and consumes over one-third of the world's natural resources. This is attributed to the design, construction and operation of buildings with no regard for their impact on the environment. Other consequences of construction activities are environmental pollution, deforestation, soil erosion, ozone depletion, fossil fuel depletion, and human health risks. Additionally, buildings, unlike products in other sectors, have a longer lifespan of up to 80-100 years in developed countries (Baloi, 2003:337; Sev & Ezel, 2014:886; Babuka, 2016:1).

Recognition of the negative impacts of the construction industries activities has motivated the shift from the traditional method of construction to the adoption of innovative technologies that have the potential to aid the conservation of energy, reduce high greenhouse emissions, reduce non-renewable resource consumption and reduce the generation of waste. One of those innovative technologies that have been developed is nanotechnology (NT) (Babuka, 2016:1).

The term 'NT' originates from the Greek word *nano* which means 'dwarf' and indicates the division of one by a billion (Oke et al., 2017:3839). Babuka (2016:2) defined NT as the study and manipulation of matter at an atomic and molecular scale. Nanotechnology is a scientific field that works with structures that are smaller than 100 nanometres and is concerned with the development of materials, systems or devices within that size. A study by Sev and Ezel (2014:887) established that NT is an extension of the sciences and technologies that were developed many years ago. The first mention of NT was by Feynman in 1959. In 1986, subsequent to the work of Feynman, technologist K. Eric Drexler extensively explored nanotechnology in the book that he authored entitled *Engines of Creation: The Coming Era of Nanotechnology*.

Improvements over the years have resulted in NT being considered a real science or the "materials science" (Di Sia, 2017:1077). Sev and Ezel (2014:887) additionally identified that NT considers the controlling, understanding and restructuring of matter on the level of nanometers in order to produce materials of new properties and functions. Furthermore, one of the key features of NT is that it supports sustainability through the imitation of the natural systems which have no negative impact on the environment as they have exceptional performance and exhibit biodegradable characteristics. Continued advancement has served to resolve and further promises to resolve issues in the fields of energy, engineering, medicine, environment and transport, among others. Studies have shown that several problems faced by most of the aforementioned fields are attributed to the raw materials used and their properties (Oke et al., 2017:3840).

NT, as evidenced in the following applications, is resolving some of the problems being faced by several sectors. Di Sia (2017:1077) identified that NT improves the efficiency of wind structures (with greater area and lighter weight of wind turbines). In addition, nanotubes allow the storage of solar energy; nanowire bacteria for the remediation of sites contaminated by radioactive uranium; nanomembranes for water purification, nano computers; piezoelectric-crystals devices for generating electricity from nano-structural oscillations and self-cleaning and self-sanitizing tissues when exposed to sunlight. Pacheco-Torgal and Jalali (2011:582) found that NT contributes directly to the CI through the following: increased strength and durability of cementitious composites owing to the use of nanoparticles, carbon nanotubes and fibres. Cheaper and corrosion-free steel can be produced, resulting in the production of thermal insulation materials that are able to perform ten times better than the current commercial options; enabling the production of coats and thin films with self-colour change to minimize energy consumption and self-cleaning ability; the production of materials and nanosensors with self-repairing ability and sensing ability; improved techniques and pipe joining materials; reduction of the thermal transfer rate of fire and increases in the reflectivity of glass.

3.2.5.2 Barriers of nanotechnology

Sev and Ezel (2014:894-895) established that barriers to the adoption of NT are high material costs, the ambiguity concerning the various effects of NT materials on the environment and human health and the high energy required to produce nanomaterials. Similarly, Torgal and Jalali (2011:589) posited that the barriers to the adoption of NT are the high material cost of nanoparticles and the concerns raised over the toxicity of nanoparticles. Di Sia (2017:1079) found that the major barrier to the adoption of NT is the possible health risks and the socio-economic implications that require prompt evaluation.

3.2.5.3 Benefits of nanotechnology

The adoption of NT will enhance the functionality of traditional construction materials, reduce material carbon emissions, create a new construction material economy and result in materials for prolonged building life (Oke et al., 2017:3842). Additionally, NT will reduce waste, remove disease-causing chemicals in materials, aid environmental protection, improve the health of structures and reduce material environmental impact (Oke et al., 2018:291). In the same way, earlier studies identified the benefits of NT to be energy saving, reduced reliance on non-renewable resources, reduced waste generation and toxicity, reduced carbon emissions, the potential to change the service life and life-cycle costs and possible enhancement of the properties of traditional materials (Sev & Ezel, 2014:894). Furthermore, NT offers novel solutions for achieving sustainable buildings, neighbourhoods and cities, can improve properties of common materials and existing products, contribute to safety and damage protection of buildings, reduce the weight and volume of buildings, decrease the need for maintenance and operational upkeep, reduce energy consumption attributed to less cement usage and improved insulation, result in the production of materials that have anti fogging and self-cleaning properties, aid air quality and improve the mechanical properties, durability and elasticity of materials (Babuka, 2016:10; Lazaro et al., 2016:59).

3.2.5.4 Drivers of nanotechnology

The major driver to aid the adoption of NT identified by Oke et al. (2017:3843) is by construction contractors, consultants and regulators leading the way through sensitisation of the other stakeholders via training and research and development. Additionally, Oke et al. (2018:292) established that companies should be made aware of the benefits of developing a division that can carry out continuous research on emerging technologies that will aid innovation within the company and will offer investment opportunities. Analysis of qualitative, historical and other forms of quantitative data can also be adopted so as to continue with the examination of the value of nanotechnology, not only for construction materials but also for general use in the CI. In his study on NT, Di Sia (2017:1079) discovered that the main driver to the adoption of NT is to determine the potential risks and implications of adopting NT for society and the economy. Once determined, these risks should be promptly evaluated and minimized. Coupled with this, a clear and common definition of NT should be established, followed by a proactive approach to the management of risk; existing legislation should be reviewed and harmonised; coordination and cooperation among the various public bodies at national and international level should be encouraged and there should be transparent information dialogue amongst all stakeholders.

3.2.6 Life Cycle Assessment

3.2.6.1 Overview

A report by the United Nations Environment Programme indicated that with the current resource consumption by 2020, three planets will be required to meet the needs of the population. This has increased the need for implementation of SD across the various sectors. One of the sectors in the spotlight is the CI with high usage of non-renewable resources among other negative impacts on the environment. This has raised calls for the adoption of technological assessment systems that can ascertain the cause of the increased resource consumption, pollution and production of waste. One of the systems identified is Life Cycle Assessment (LCA). LCA has gained recognition from the onset of 21st century for it holistically examines the possible impacts of the decisions made regarding material selection throughout the life of the building. In addition, it promotes the use of appropriate materials and implementation of processes that reduce the environmental impact of buildings and organisations (Travessini et al., 2013:1; Dossche et al., 2017:302). LCA is a technique that comprehensively determines the environmental and resource impacts of a material, a product, or even a whole building over its entire life (Travessini et al., 2013:1). Other scholars such as Sterner (2002:23) posited that LCA is a technique that analyses and assesses the impact that a material, product or service has on the environment throughout its life cycle. This in most cases is from the purchase of raw materials up to disposal as waste. Similarly, Kibert (2013:365) defines LCA as the procedure for evaluating the environmental performance of a building process, product or service over the course of its full life cycle. This full life cycle can also be referred to as cradle-to-grave or cradle-to-cradle analysis. Additionally, Rashid and Yusoff (2015:245) revealed that LCA involves the consideration of alternative processes and products that would lead to a reduction in the environmental impact of construction buildings.

LCA involves the tabulation of all the energy, water, and materials resources, as well as all emissions to air, water, and land over the building's life span. The life span of the material stretches from the extraction of resources, the manufacturing process, the installation in a building, and the structure's ultimate disposal. The assessment also considers the resources needed to transport components from extraction through to disposal (Travessini et al., 2013:1) The LCA method consists of several steps, namely inventory analysis, impact assessment and interpretation of the impacts (Kibert, 2013:365). Asif et al. (2007:1392) add an extra step to complete the life cycle study, known as the improvement analysis step. Rashid and Yusoff (2015:245) identified the four phases of LCA to be defining goals and scopes, life cycle inventory, life cycle impact assessment (LCIA) and the last phase is the interpretation which identifies significant issues, assesses results to reach conclusions, explains the limitations and provides recommendations. The measurement of environmental performance considers a wide range of possible effects, namely acidification and acid deposition (dry and wet), eutrophication of water bodies, global warming potential, fossil fuel depletion, ozone depletion and toxic releases to air, water and land. LCA is an innovative and versatile technique in use in several sectors, Through its systematic evaluation of the current products in use, it can enhance sustainability in the CI through the promotion of the use of ecologically designed products and processes (Dossche et al., 2017:303). Thus, the main purpose of LCA is attaining a balance between satisfying the needs of the client and protecting the environment (Travessini et al., 2013:1).

3.2.6.2 Barriers to life cycle assessment

Despite its increasing popularity, LCA has several shortcomings. A study conducted in Canada established that the barriers to successful LCA are availability and limited access to data. This is because there is a shortage of useful project or context-specific data, partially due to the insufficient data in the current life cycle databases and tools. Furthermore, the other contributing factor to the data shortage is the uncertainty regarding possible future scenarios in the long lifetime of the buildings. The delay in obtaining the data affects the time and the resources required to complete the assessment. This has a ripple effect on financiers and policymakers as the delays would affect their interest in conducting an LCA prior to making important decisions (Teshnizi, 2018:177). Similarly, Dossche et al. (2017: 303) indicated that the major barriers to the adoption of LCA are the existence of varying databases with which LCAs can be carried out, the absence of benchmarks in the CI and a lack of integration between recycling activities and LCA tools which can negatively impact the results obtained. A study by Oritz et al. (2009:36) identified that there was insufficient information on the entire life cycle of a building. Secondly, Oritz et al. (2009:36) found that the body of knowledge contains case studies of LCA conducting in developing countries in Europe and the USA whilst comparative studies in developing countries do not exist.

3.2.6.3 Benefits and drivers of life cycle assessment

LCA not only results in the protection of the environment but provides a company with a competitive advantage (Travessini et al 2013:1). To promote the use of LCA in the CI, guidelines need to be established and the right tools should be identified to aid the interpretation of the results obtained from the analysis. In addition, alternative solutions should be identified that can improve the buildings' life cycle performance (Teshnizi, 2018:177). Furthermore, proper communication of LCA research will add to its implementation (Dossche et al., 2017:210).

3.2.7 Life Cycle Costing

3.2.7.1 Overview

The construction industry the world over is faced with numerous challenges. Among these are rising inflation, stiff competition, reduced purchasing power, resource scarcity and a demand for value for money by stakeholders. Studies have also shown that the life span of the buildings paves the way for additional maintenance costs (Heravola, 2017:565). The quest to establish the costs that are attributed to the creation, use and disposal of a product has fuelled the implementation of life cycle costing (LCC) in various sectors. Dwaikat and Ali (2018:303) identified LCC in the CI as a technique that is used within the CI to evaluate the costs of a building, commencing from its design, construction, its operation and ending at its disposal. In contrast, scholars posited that despite LCC's successful application in other industries, the CI has been slow in adopting this innovative technique (D'Incognito, 2015:203). Despite the presence of ambiguous historical records on LCC's origin, scholars have claimed that it was first used in the mid-1960s by the United States Department of Defence to assist in the procurement of military equipment (Dwaikat & Ali, 2018:303; Heralova, 2017:566).

Life cycle costing (LCC) is a methodology that enables an assessment to be done of costs that would be incurred throughout the life of a product or building in the CI (Corvo, 2017:1). Life cycle costing (LCC) is often confused with life-cycle assessment (LCA). What differentiates the two terms is that whilst LCC is the calculation of the costs of a product throughout its life cycle, LCA, on the other hand, is an assessment of the environmental impacts, such as greenhouse gas emissions that occur over the life cycle of the product (Luttenberger et al., 2017:431). Additional literature found that the use of LCC is the ability to account for a building or building system's costs from design to disposal. Other terms by which LCC is known are whole life costs, through life costing and total ownership costs (Pelzeter, 2007:117; Chiurugwi et al., 2010:2). The practical application of this methodology is that it enables the preparation of documentation of all the costs that would be incurred in each phase of the building. These costs can then be reduced to obtain the present value (PV). This reduction allows for comparisons between alternative building systems (by comparing the PV of many alternative systems), thus ensuring long-term cost saving (Hodges, 2005:318; D'Incognito et al., 2013:203). LCC primarily aids decision making when faced with choosing from several competing project alternatives. Although this can be done at any stage of the project, the benefits of carrying out the exercise are greatest when done in the early stages of design (Kishk et al., 2003:3). In addition, LCC contributes to SD through its use as an instrument for optimising buildings with a long-term perspective and aids the exploration of the economic principles of sustainability (Pelzeter, 2007:115).

3.2.7.2 Barriers of life cycle costing

D'Incognito et al. (2014:203) established that the major barriers to the adoption of LCC are the inappropriateness of the existing tools and methodologies and the lack or insufficient quality of input data. These barriers are technical barriers. The social barrier is the existence of varying beliefs amongst the stakeholders and these hamper the adoption of innovative methodologies in the CI. Additionally, the study found that despite a noticeable increase in the addition to the body of knowledge on LCC, there seems to be a widening rift between theory and practice. A study by De Giacomo et al. (2019:3) identified internal and external barriers to the adoption of LCC in public institutions. Internal barriers were found to be lack of practitioners' awareness, lack of familiarity with the concept of LCC, lack of skilled staff, institutions' resistance to change and adoption of innovative methodologies and lack of resources to spearhead the adoption of LCC. External barriers were found to be a lack of clarity regarding LCC, lack of financial incentives, lack of reliable data to support LCC, lack of a standard method of application and ambiguity surrounding the benefits of LCC. Similarly, the availability of reliable data, diverging life cycle costs standards, and the disparity between design information availability and the real importance of the design stage for decisions were identified as the main barriers to the adoption of LCC (Heralova, 2017:570).

3.2.7.3 Benefits of life cycle costing

LCC can serve as an essential decision making and management tool. As a management tool, LCC assists in the identification of the actual costs incurred in operating assets. It could also serve as a valuable tool when tasked with providing clients with an estimate of the actual running costs of the building. Moreover, it can also be used for budgeting purposes. In addition, it can be a valuable feedback device when designing (Kishk, 2003:2-3). On the other hand, Heralova (2017:569) established that stakeholders stand to benefit from LCC through involvement in the calculation process which involves gathering data, predicting future effects and identifying environmental aspects among others.

3.2.7.4 Drivers of life cycle costing

In their study on LCA and LCC, D'Incognito et al. (2014:213) identified investment in formal and technical education and adopting a financial system that is compatible with long-term strategies as the main drivers to the adoption of LCC. In contrast, Chiurugwi et al. (2010:2) identified the development of a standardised LCC methodology and implementing the inclusion of LCC as a mandatory requirement for public-private partnership (PPP) and private finance institution (PFI) tenders.

3.2.8 Industrial Building Systems (IBS)

3.2.8.1 Overview

Increased population calls for the adoption of sustainable methods of construction owing to global warming and a need for a reduction in construction time are among the factors that have led to the emergence of industrialised building systems (IBS). Despite the ambiguity that exists on the origins and definition of IBS, a study in Iran established that IBS came into existence in the 20th century. It is defined as a construction technique in which components are manufactured in a controlled environment off or on-site. These components are then taken to site (if manufactured off-site), placed in their allocated spots and thereafter assembled into a structure with minimal additional site work (Hung et al., 2015:1). The term IBS is used interchangeably with the following terms: prefabrication, modern method of construction (MMC), pre-assembly, offsite production (OSP) and offsite construction (OSC), offsite manufacturing (OSM), and modular industrialised building system. A popular branch of IBS that has been implemented in other parts of the world is modular construction systems (MCS) (Kamar et al., 2011:125; Musa et al., 2014: 79). IBS has been successfully adopted in Japan (Sekisui House), Netherlands (Wenswonen), Sweden (Open House) and the UK (Living Solution) (Kamar et al., 2009:2).

IBS is classified into seven forms, namely frame system (pre-cast or steel), panelised system, on-site fabrication, sub-assembly and components, blockwork system, hybrid system and volumetric (modular system) (Musa et al., 2014:216; Aziz & Abdullah, 2015:2). Studies conducted indicate that the adoption of IBS will aid the sustainability in the CI through waste minimisation, production of energy-efficient structures and long-term economic stability (Mohammad, 2013:12).

3.2.8.2 Barriers of industrial building systems

In their study of IBS, Aziz and Abdullah (2015) identified a lack of expertise amongst CI players as a major barrier to the adoption of IBS. Other barriers established were technical issues which include aspects of engineering safety, connection and joinery of the various components, lack of government support in the form of funding and provision of incentives and the lower cost of the conventional method of construction. Khoshnava et al. (2014:1641,1646) established that lack of policy implementation, cost and financial issues, lack of knowledge, lack of expertise, lack of building codes and standards, resistance from customers, lack of government incentives, lack of assessment, lack of research R&D and lack of understanding about green and sustainability issues as barriers to the adoption of IBS.

Kamar et al. (2009:8) categorised IBS barriers as readiness (lack of support from private sector and lack of experience), knowledge (lack of understanding on design and planning, lack of professional training in IBS), planning and regulation (lack of support and assurance from government, red tape, lack of design and integration, lack of incentives and push factors, current procurement systems), negative perception (fear of customers rejection, not popular among the designers, unattractive owing to past failure), cost and equipment (lack of local developed technology, higher initial costs, lack of equipment and machinery, lack of a testing facility for IBS components) and awareness (lack of awareness among contractors and among approving authorities, misunderstanding of the building regulations). Lastly, Mohammad (2013:13) identified that the lack of knowledgeable and skilled personnel in IBS, the fragmented nature of the CI, insufficient information and demonstration structures supporting the benefits of IBS versus the conventional method and the alleged inferior quality of IBS projects due to their use on low-cost housing, coupled with bad experiences encountered by occupants of these structures have tainted the image of IBS.

3.2.8.3 Benefits of industrial building systems

Khosshnava et al. (2014:1646) identified cost and time certainty, improved construction quality and productivity and reduced occupational safety and health risks as the major benefits of IBS. Similarly, Hassim et al. (2009:937) posited that IBS speeds up the construction process, minimises hazards and risks and enables the integration of sustainability strategies. On the other hand, Nawi et al. (2011:2) established that the main benefit of IBS is reduced wastage during the construction process, optimised use of materials, and a reduction in the negative impacts of construction activities on the environment. A study by several scholars found that

IBS results in reduced use of raw materials as the structures can be dismantled and rebuilt at a new location, and improved air quality and working conditions for employees as the panels are factory-produced (Musa et al., 2014: 216). IBS opens doors for new business opportunities and can serve as a conducive platform for the promotion of innovations that would not only aid the economy and positively impact society but would also reduce the strain being placed on the environment.

3.2.8.4 Drivers of industrial building systems

Khosshnava et al. (2014:1646) found that the government's supportive policies and activities, a change in attitude, innovation, creativity, research and support and cooperation from all stakeholders would aid the adoption of IBS. In an early study on IBS, Kamar et al. (2009:10) identified training and education, leadership and the organisational structure, prudent cost management and financials with detailed calculations on cost and investment projection as the main drivers of the adoption of IBS.

3.2.9 Building Information Modelling (BIM)

3.2.9.1 Overview

The quest for sustainability in the CI has led to the emergence and adoption of digital technologies that would aid the sector which is hampered by fragmentation amongst its professionals. In addition, the technologies would enhance the elimination of waste generation and other negative impacts on the environment. One technology that gained prominence over the last decade in the architecture, engineering and construction (AEC) industry is building information modelling (BIM) (Wong & Fan, 2013:139; Oke et al., 2016:609; Sahil, 2016:1). Studies have shown that the BIM concept emerged in the early days of computers and it was then developed by Prof. Charles Eastman who created a building database known as a building description system (BDS) in the 1970s (Latiffi et al., 2013:1; Ibem et al., 2018:904). BDS later evolved into the popular ArchCAD. BIM is continuing its proliferation in both industrial and academic circles as the ‘new CAD’ paradigm.

A study conducted by Sahil (2016:2) posited that individuals and organizations have different definitions of BIM and this is attributed to their use. Succar (2009: 357) defined BIM as a set of interrelated processes, policies and technologies that result in a methodology that can manage the essential building design and project data in digital format throughout the building's life cycle. On the other hand, BIM has been identified as a set of applications and processes capable of generating and managing project information throughout the project development phases with numerous benefits to the project stakeholders (Olawumi & Chan, 2018:1). In their study, Ibem et al. (2018: 904) summarised BIM as mainly consisting of four elements, namely as a structured dataset describing a building; as a tool for creating building and project information; the act of creating a building information model; and a business structure or system for effective management of activities related to the design, planning, erection, management and operation of building and infrastructure projects. The application of BIM assists in the following: aids visualisation and detection of clashes, enables the generation of shop drawings, and its inbuilt software aids cost estimating and construction sequencing, including the delivery of construction components. BIM also enables a forensic analysis of a building to be carried out through graphical illustration of potential failures, leaks, evacuation plans, to mention but a few. Other applications are in the management of facilities where BIM can be used for renovations, space planning and maintenance operations (Azhar 2011:242-243).

3.2.9.2 Barriers of building information modelling

In his study on the adoption of BIM in developing counties Sahil (2016:11) reviewed the work of Love and Smith (2003) on BIM in the UK and USA which recognised a resistance to new technology, people's refusal to learn, copyright issues and training costs, and a waste of human resource and time as the main drawbacks to the adoption of BIM. Khosrowshahi and Arayici (2012:623) found that the use of BIM in UK construction companies was inhibited by most firms not being familiar with BIM use. Their reluctance to initiate staff training was due to high implementation costs which overshadow the benefits that that can be obtained from BIM, lack of culture change in the organisation and lack of demand for use of BIM. Olawumi and Chan (2018:19) established that there are two main barriers to the application of BIM, namely interoperability and procedural uncertainties.

3.2.9.3 Benefits of building information modelling

According to Olawumi and Chan (2018:18), the benefits of adopting BIM are that it enhances the overall project quality, productivity and efficiency. It also could simulate building performances and energy usage, result in products of superior design and facilitate the use of alternative designs. It also aids in the reduction of the carbon footprint of a building. Other benefits are increased collaboration within project teams, improved profitability, reduced costs, better time management, and improved customer-client relationships (Azhar, 2011:25). A study by Yan and Damian (2008:5) shows that the main benefits of BIM are a reduction in construction time and a reduction in spending on operation and overhead costs. Moreover, it improves the process of construction, the project documents that are produced and the relationship between clients and architects. Other benefits of BIM are reduces the need to fix issues on site, reduces construction waste, diminishes the probability of delays and cost overrun due to rework and contributes positively to the improvement in asset lifecycle management (Davies et al., 2018:6). BIM can aid the energy efficiency and indoor environmental quality of building facilities through its combined use with other sustainable practices such as life cycle cost assessment (LCA), sustainable design, sustainable material selection, waste management, and daylighting simulation and analysis.

3.2.9.4 Drivers of building information modelling

Davies et al. (2018:6) identified the inclusion of BIM in university syllabi, training for professionals on BIM technology and increased avenues for dissemination of BIM knowledge as the main drivers of the adoption of BIM. In their study conducted on BIM in Nigeria, Ibem et al. (2018:913) recommended that BIM-specific programmes and policies should be formulated by firms, professional associations and government. These should be aimed at improving the knowledge base of architects in BIM and promoting its adoption. Similarly, Newton and Chileshe (2014:11) identified education and increased awareness as the main drivers to the adoption of BIM. The study by Olawumi and Chan (2018:18) posited that extensive and well-coordinated attempts to bridge the literature gap on BIM, namely the absence/inadequacy of BIM standards and models, lack of motivation by project stakeholders to implement BIM and sustainability practices in their projects and the difficulty in measuring some of the identified benefits which are qualitative, would pave the way for the adoption of BIM.

3.2.10 Cradle-to-Cradle Design

3.2.10.1 Overview

Efforts to reduce the emissions of greenhouse gases (GHG) and the effective use of scarce resources resulted in the emergence of cradle-to-cradle (C2C) design. C2C design was introduced in 2002 by architect William McDonough and chemist Dr. Michael Braungart as a systematic process of evaluating products that could be safely used without any harm to people or the environment (Yudelson, 2007:73). According to McDonough and Braungart (2003:13-14), C2C design is an ecologically intelligent approach to architecture as it incorporates materials, buildings and patterns of settlement which are not only healthy but are also restorative. The C2C design, unlike the cradle-to-grave design, perceives human systems as nutrient cycles in which every material can support life (Kibert, 2013:102-104). The benefit of this design is that unlike the cradle-to-grave system where materials are a waste management problem, there is no waste as it is based on a closed-loop nutrient cycle of nature. Thus, with models based on regenerative cycles, C2C design seeks to promote the creation of structures, systems and communities that have a positive influence on the environment and human health.

3.2.10.2 Principles of cradle-to-cradle design

C2C design strives to ensure that all items produced result in an improved environment, economy and health. There are three main principles of C2C design. The first, which states that "waste equals food", considers the notion that all materials should be nutrients for other product life cycles, either in a biological metabolism or technical metabolism. The second principle promotes the use of current solar income for sustainable energy. The production of C2C products requires the use of only sustainable energy sources as these are available in abundance. The last principle celebrates diversity. C2C design is based on the understanding that in order to improve a system's resilience, diversity is necessary. Focusing on one criterion could cause instability and imbalance in a wider context (De Pauw et al., 2014:175; Toxopeus et al., 2015:385).

3.2.10.3 Barriers of cradle-to-cradle design

De Pauw et al. (2014:175) identified the lack of literature that analyses the application of C2C in production design as the main barrier to the adoption of C2C. In addition, the existence of ambiguities in the application of the principles of C2C was identified as a barrier to the adoption of C2C (Reay et al., 2011:41-43). Ankrah et al. (2015:53-55) identified that the barriers of C2C can be broken down into four barriers. The first are socio-cultural barriers namely lack of knowledge sharing attributed to the multiple meanings of the existing eco-efficient strategies, stakeholders are operating in silos and not collaborating with each other, stakeholders prefer conventional technologies and products over new products and technologies as these have been tried and tested and stakeholders have an attraction for short-term rather than long-term operational benefits. The second barriers are technological in nature and these are in the form of the absence of a detailed building material database that meets C2C criteria, lack of knowledgeable professionals who are experienced in the adoption and proper installation of C2C oriented technologies and lack of renewable energy technologies that can supply the bulk of energy required. The third barriers are economic in nature and described as follows low demand for C2C designs and products, the absence of a proven economic model to illustrate to client stakeholders long-term economic value of implementing C2C and lack of proven examples to portray the commercial attractiveness of C2C developments. Lastly, legal and regulatory barriers were found to be lack of flexibility in existing building regulations, legal difficulties in establishing take-back lease agreements and embeddedness of existing legislation in the eco-efficiency vision. Of all the identified barriers the one that stood out is the pluralistic meaning of existing sustainable and/or green building strategies with the differing solutions that are sometimes presented.

3.2.10.4 Drivers of cradle to cradle design

A study by Ankrah et al. (2015:55) found that the barriers of C2C could become drivers if measures are put in place that encourage technological innovation that is C2C-oriented. This can be in the form of the necessary legal and regulatory support framework as well as a clear C2C framework which includes guides and manuals that would enable C2C in designs to be realised. Additionally, further research should be conducted to appease the ambiguity surrounding the principles of C2C.

3.2.11 Construction Ecology

Several studies have identified the ecosystem as a holder of profound lessons and a suitable model for the transition to a sustainable way of life. These studies have unearthed disciplines that are focused on redesigning the linear economy, namely biomimicry, industry ecology, construction ecology and design for the environment (Kibert et al., 2003:7-8). The term ‘construction ecology’ (CE) is a concept derived out of industrial ecology, a science that emerged in the late 1980s with a focus on the physical, chemical, and biological interactions and interrelationships both within and among industrial and ecological systems (Kibert, 2016:57). In their study of CE, Kibert et al. (2003:8) posited that CE describes how the CI would attain sustainability through the application of nature’s lessons in two key areas. Firstly, the area concerned with the manufacturing of building products and secondly, the demolition of existing structures and assembly of manufactured products into new or renovated structures. CE is a vehicle through which the industry would embrace sustainability through a closed-loop materials system integrated with eco-industrial and natural systems. It would depend solely on renewable energy sources and would foster the preservation of natural system functions. The benefits that the CI can draw from implementation of CE are that buildings would be de-constructible at the end of their useful lives, would have components that are detachable, making replacement easy and can be recycled, and components are produced from recycled materials and promote the health of the occupants (Kibert, 2016:57).

3.2.12 Ecological Footprint

3.2.12.1 Overview

The alarming statistics indicating the high consumption of non-renewable resources, the pollution of water bodies and the rate of land degradation among other negative environmental impacts of excessive consumerism have helped to kindle the popularity of the concept known as ecological footprint (EF). EF emerged in the early 90s as a result of the work of Prof. William Rees and Dr Mathis Wackernagel (Barret et al., 2005:235). The emergence of EF is attributed to calls made by the Agenda 21 of the 1992 United Nations Conference on Environment and Development in Rio for the improvement in the availability and quality of sustainability data to aid decision making (Lin et al., 2018:2).

Kibert (2013:47) described EF as the inverse of carrying capacity as it represents the amount of land that is required to support a given population. Furthermore, EF measures the resources required to meet human consumption and to ensure a balance in the ecosystem, for example croplands, grazing lands for animal products, forested areas to produce wood products, marine areas for fisheries, built-up land for housing and infrastructure, and forested land needed to absorb carbon dioxide emissions. EF also exposes the disproportionate land-area available to the world's rich and poor countries (Fiala, 2008:519). Furthermore, EF is an account-based system of indicators whose main focus is the recognition that the Earth has a limited number of biological products that support all life on it (Lin et al., 2018:3). Thus, EF is a concept that tries to solve the problem from the SD perspective of how people can be able to have a decent quality of life without extinguishing the limited life supporting planetary systems.

In addition, the function of EF is likened to that of economic indicators such as the GDP or the retail prices index (RPI) that have been adopted as a way of representing dimensions of the financial economy. This is because it serves as an aggregated indicator of natural resource consumption such as energy and materials. EF analysis has garnered popularity in several countries as seen in its application which includes use as a high-level indicator to set targets and to guide sustainability and development policy formulation across the globe. It is also used as a tool to educate and raise awareness on the unsustainable consumption of natural resources. In the financial sector it is used to calculate the environmental risk for sovereign-credit analysis, transition risk, food-price shock, local environmental-degradation risk, and trade dependency (Barret et al., 2005:235; Lin et al., 2018:17).

3.2.12.2 Benefits, barriers and drivers of ecological footprint

The major benefit of adopting EF was identified to be the clarity of the concept and its presentation in a format that can easily be understood. The clearness of its message serves as a beneficial indicator for both policymakers and the general public. Additionally, the calculation which forms the basis of EF can easily be carried. Lastly, the more detailed calculations that are carried out consider world trade (Moffat, 2000:359). EF offers a comprehensive approach to monitoring the use and overuse of natural resources, and the consequent impacts on ecosystems and biodiversity (Lin et al., 2018:2).

On the other hand, Moffat (2000:360) established that some scholars have criticised the fact that EF is unable to achieve its intended purpose as it fails to address what it was designed to control, this being the unsustainable consumption rate of natural resources. In addition, he found that scholars perceive EF to be an "attention grabbing" mechanism. Furthermore, EF is a static measurement and a concept that is averse to technological changes. Additionally, EF does not include the measure of underground resources such as oceans, ignores flows, lacks measures of equity and does not offer policy prescriptions. Similarly, in his review of EF, Fiala (2008:519) critiqued the use of EF as an ideal measure of sustainability owing to the view that the assumptions which form the basis of this view are flawed. This is illustrated in the arbitrariness of assuming both zero greenhouse gas emissions and national boundaries. The other setbacks are that EF is an entirely static measure and so cannot capture technological changes. In addition, a lack of correlation exists between land degradation and the ecological footprint, which indicates that it does not bring to light the bigger sustainability issues (Fiala, 2008:524).

For EF analysis to be adopted there is a need for commitment to be shown by all individuals in the various organisations. Secondly, for EF to be used as a monitoring tool, it needs to be re-calculated on a regular basis. Thirdly, EF must be integrated into the organisations through the major strategies that are propelling it forward. Lastly, there is a need for transparency and accountability when scrutinising both the data sources and carrying out the calculations (Barret et al., 2005:247).

3.2.13 Design for Environment

3.2.13.1 Overview

The rapid changes in the world today as a result of advancements in science and technology have brought about several positive changes to human existence. On the other hand, technological advancement has been linked to the increasing rift between humans and nature through the production of excessive waste and the destruction of natural resources. This destruction has been linked to the formation of products used in the various sectors which negatively impact the environment during their entire life cycle. This cycle commences from the extraction and processing of raw materials to the manufacturing, assembly, and distribution stages followed by the packing, use, maintenance and ending at its disposal. The quest towards protecting the environment through the formation of products that become beneficial inputs for the next products at the end of their lifecycle has prompted the formation of design for the environment (DFE) (Fitzgerald et al., 2010:2). In their book promoting DFE as a tool for a sustainable supply chain, Bevilacqua et al. (2012:20) established that DFE is a methodical analysis of the design performance of a product during its entire life cycle with the focus on ensuring environmental, health, and safety objectives.

In a similar manner, DFE, or green design as it is at times referred to, is a methodology that incorporates the environmental aspect into the products and processes of engineering procedures and considers the entire product life cycle (Kibert, 2016:58). The concept of DFE was formulated in 1992 by several electronic firms that attempted to create environmental awareness in product development. This is supported by the identification of the American Electronics Association as the first initiator of DFE (Bevilacqua et al., 2012:20). Though it emerged from the electronics sector, DFE can be applied in the CI during the design phase as a barometer that ensures the formation of green products which at the end of their life span can be reused or recycled. For example, a window assembly design based on DFE strategies would be easy to remove from the building and to disassemble into its basic metal, glass, and plastic components. In addition, consideration of the value of the materials used in the formation of these products is paramount so as motivate the industrial system to keep them in productive use (Kibert, 2016:58).

3.2.13.2 Principles of design for the environment

From the work of Bevilacqua et al. (2012:22-23) as indicated in Table 3.3, the principles or guidelines as they are termed are considered to the easiest way of ushering in environmental considerations during the design phase. The implementation of the guidelines or principles with appropriate education would aid the reduction in the formation of products that pose a danger to the environment.

Table 3.3: Principles of design for the environment

LIFE CYCLE	GUIDELINES/ PRINCIPLES
Optimization of initial lifetime	Durability and reliability, maintenance and repair can be done easily, user can take care of the product
Selection of low-impact materials	Materials should have the following characteristics non-hazardous or exhaustible, should have a low energy content, should be recyclable or consist of recycled materials
Reduction of material	Reduction in weight and volume (transport)
Optimization of production techniques	alternate production techniques that have fewer processes are selected, implement techniques that consume clean energy in moderate quantities, generate less waste and use minimal consumables for production
Reduction of the environmental impact in the user stage	energy consumed is minimal, clean energy source, a small number of clean consumables required, no energy or auxiliary material use
Efficient distribution system	Less/clean packaging, efficient transport mode and logistics
Optimization of end-of-life system	Reuse of product, remanufacturing/refurbishing recycling of materials, clean burning

(Bevilacqua et al., 2012:22-23)

3.2.13.3 Barriers and drivers to the adoption of design for environment

In their study, Fitzgerald et al. (2010:2) identified the major barrier to the adoption of DfE to be the low priority assigned to environmental issues by organisations. This is because organisations are not willing to alter the functionality, unit cost, or time to market for the formation of products that have less environmental impacts. On the other hand, the adoption of DfE is driven by an organisation's social responsibility and regulations even though this may not result in increased profits.

3.2.14 Internet of Things

3.2.14.1 Overview

The onset of the 21st century has seen a fast-paced revolution in the digital realm. One of the trends that have emerged is the Internet of Things (IoT). IoT, as posited by Gubbi et al. (2013:4), is the "…interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications". Urie (2019:1) defined IoT as a network of embedded meters, sensors, appliances and devices that can transmit and receive data through the Internet about changes to their current physical state and the surrounding environment. Tang et al. (2019:129) established that IoT-enabling technologies include, among others, identification and recognition technologies, sensing technologies, communication technologies and networks, software and algorithms, hardware, software and cloud platforms, position technologies, data processing solutions, power and energy storage and security mechanisms. The advancements in the digital era have spread into the built environment and this can be seen in increased research focussed on smart cities, building, infrastructure and communities (Jia et al., 2019:111). Jia et al. (2019:111) further established that the research focus on smart communities has been on developing an approach that will enable occupants to have reliable and energy-efficient services.

In their extensive study Tiastsis et al. (2018:5) identified the following applications of IoT; for health and fitness, monitoring and treatment of illness, increasing wellness, proactive lifestyle management, improved task execution, protection in hazardous working environments, automation of domestic chores and energy management, security and safety, self and automated checkouts, in-store offers, and inventory optimization. IoT is also used in the manufacturing, medical and agriculture sectors for robot manufacturing of components or irrigation in agriculture and the optimization of a supply chain of materials. In the sectors such as the CI with an unpredictable environment, IoT is used to ensure high utilisation of plant and equipment, operations optimisation, and worker safety. Additionally, with the increased calls to enhance sustainability in the construction, researchers are looking into ways in which IoT can be used to minimising environmental impacts. This is indicated in the study of Jia et al. (2019:111) who posited that despite the existing research on the development of smart buildings, communities and cities, this area requires further exploration in order to bridge the gap between technology and its application in the built environment.

3.2.14.2 Barriers, benefits and drivers of internet of things

In a well-articulated study of IoT and the construction sector, Urie (2019:3) found that the adoption of IoT in the industry is hampered by the fragmented nature of the industry with contractors and smaller subcontractors dividing the work. The smaller the site means that there is no need for complex sensors and software as operations can be efficiently managed by the foreman. Additionally, the short duration of some projects does not encourage the use of IoT as productivity gains and substantial time or cost-saving are obtained over a longer period. Furthermore, if an IoT device loses connectivity it cannot send data in real-time, losing the ability to track and provide insights into preventative maintenance. Additionally, although IoT can help benchmark preferred levels through sensors, it cannot replace the benefits of physical observation. In the aspect of completed buildings, occupants are at risk of losing control of their comfort and the environment in which they reside if the data coming from IoT technology is mismanaged and processed incorrectly.

IoT will benefit the CI through the implementation of the Just-In-Time provision which enables the monitoring of project progress, material and equipment usage. This will lead to cost saving and timely completion of projects. Other benefits are enhanced remote usage and activity monitoring, power and fuel saving on construction sites and the construction of smart buildings. To promote the adoption of IoT in the CI, Jia et al. (2019:124) found that continued research on IoT application is required.

3.2.15 3-Dimensional Printing

3.2.15.1 Overview

3D printing is a process through which physical objects are created by the deposition of material in layers based on a digital model (Sakin and Kiroglu, 2017:703). These scholars further identified that the software, hardware, and materials are required to work together seamlessly to enable the printing of objects to be achieved. There seems to be a contradiction about when the first 3D printer was invented. Sakin and Kiroglu, 2017:703 indicated that it was invented in 1983 by Charles W. Hull, whilst Hager et al. (2016:293) indicated that it was invented in 1984. Despite the discrepancy in information, 3D printing is one of the fastest growing technologies as it can be used to create everything from prototypes and simple parts to highly technical final products such as airplane parts, life-saving medical implants, motor car parts and even artificial organs using layers of human cells. 3D printing is also known as “additive manufacturing,” especially within the manufacturing industry (Sakin & Tiastsis et al., 2018:5; Li et al., 2019:8; Kiroglu, 2017:703). The sectors where 3D printing is being used are the medical, automotive and aerospace industries (Hager et al., 2016:293).

3.2.15.2 Benefits of adopting 3D printing

Sakin and Kiroglu (2017:703) established that the benefits of 3D printing are material saving and less wastage as printed products only use as much material as needed to form them. In addition, there are reduced transportation costs if products are printed on-site although it is important to note that the cost of transporting the printer can be expensive owing to the size of printers currently needed for construction. 3D printing enhances innovative designs as 3D printing can achieve shapes that conventional techniques cannot, reduce labour costs and reduce health and safety risks. Similarly, Hager et al. (2016:299) found that 3D printing results in reduced construction costs and enhances sustainability through an environmentally friendly construction process in which raw materials with low embodied energy are used. Furthermore, it enables improved health and safety on site with less dust generation and results in improved construction time.

3.2.15.3 Barriers and drivers of 3D printing

On the other hand, there is still a great deal of anxiety that needs to be addressed. The main unknown is whether the development of 3D printing technology will result in job losses for thousands of qualified workers (Hager et al., 2016:299). Sakin and Kiroglu (2017:709) posited that there are several challenges that hamper the adoption of 3D. Firstly, it is more costly than conventional construction owing to the high cost of a 3D printer and the additional cost of transporting it to site. The second challenge is the lack of familiarity in the industry with 3D printing technologies and applications. Furthermore, the current process of construction with 3D is constrained by the limited number of materials that can be used although studies continue to be done to enable the use of multiple materials to produce more complex assemblies. Other barriers are the high initial costs to create the digital model that will result in safe, cost-effective products, and the fact that the printers are slower in comparison to traditional construction although they can work 24 hours a day, seven days a week. Lastly, 3D printing may result in loss of employment for several skilled construction employees. The use of 3D can be promoted if there is a reduction in the cost of equipment and software. Secondly, the printer needs to be able to work in the adverse conditions of construction sites (Yeh & Chen, 2018:215).

3.2.16 Blockchain

3.2.16.1 Overview

In their study, Li et al. (2019:2) posited that Blockchain or distributed ledger technology (DLT) as it is described in some circles was introduced in 2008 through Satoshi Nakamoto's white paper on Bitcoin. It was first utilised in 2009 as a verification tool for cryptocurrencies but it has found to have multiple applications. These are in the form of smart energy, smart cities and the sharing economy, smart government, smart homes, and intelligent transport. Blockchain is also used in construction management, and in business models and organisational structures. Furthermore, there are indications that blockchain would enhance sustainability in the energy sector by providing solutions to some of the challenges hindering the sector's migration to sustainable energy in three key areas, namely decarbonisation, decentralisation and digitalisation (Li et al., 2019:8).

Historical studies show that the concept on which blockchain is based on first emerged in 1983 when digital cash was dispensed via a central server trusted to prevent double spending (Pilkington, 2016:1). Though there is no established definition of blockchain at present, Wu and Tan (2018:3) posited that blockchain technology is a new distributed infrastructure and computing paradigm that is based on a time-stamped "block and chain" data structure. This technology uses distributed node consensus algorithms to add and update data, cryptographic methods to secure data transmissions and access, and smart contracts made up of automated script code to program and manipulate the data.

3.2.16.2 Benefits and barriers of blockchain

Studies indicate that blockchain would benefit the economic, political, humanitarian, and legal sectors by reconfiguring the workings of society and operations (Li et al., 2019:2,5). On the other hand, the adoption is hampered in several ways, namely it requires the development of rules for authentication of data so as to reduce the probability of fraudulent activity throughout the supply chain. In the case of the smart contracts, these need to be properly coded as a badly programmed contract could be disastrous. Secondly, blockchain is susceptible to human error, especially when creating contracts as an ill programmed contract could prove to be disastrous. In addition, there is a negative stigma that overshadows Bitcoin with regards to criminal activity and the darknet and this has spilled over onto blockchain technology. Most importantly, blockchain is seen to be a high energy consumer.

3.3 BARRIERS TO THE ADOPTION OF SUSTAINABLE CONSTRUCTION PRACTICES

The adoption of the various SCPs that have been identified is confronted by numerous barriers that are summarised into six categories, namely management, technical, attitude, government, financial and other**.**

3.3.1 Management

In their study of lean construction, Abdullah et al. (2009:5-7) identified a lack of commitment and attentiveness exhibited by top management in construction organisations as the main barrier to the adoption of SCPs. Similarly, Marhani et al. (2013:96-97) established the support and commitment of management as the top barrier. From the study on DfE, it was observed that environmental issues were the least prioritised by organisations (Fitzgerald et al., 2010:2).

3.3.2 Technical

In their extensive study of BIM, Olawumi and Chan (2018:19) established that there are two main barriers to the adoption of SCPs, namely interoperability and procedural uncertainties. From the study on the adoption of LCA, the existence of varying databases and the absence of benchmarks in the CI are the main barriers to the adoption of SCPs (Dossche et al., 2017: 303). D'Incognito et al. (2014:203) established that the inappropriateness of the existing tools and methodologies and the lack or insufficient quality of input data are major technical barriers that impede the adoption of LCC. A scholarly review of barriers to the adoption of VM identified inadequate training and education and a lack of awareness amongst the professionals (Oke & Aigbavboa, 2017:175; Aghimien et al., 2018:822). Another technical barrier is a lack of buildable or constructible architectural designs as a result of limited knowledge of construction practices (Marhani et al., 2013:96-97).

3.3.3 Attitude

A review of the adoption of BIM in the UK and USA identified the barriers that are concerned with the attitude of the various stakeholders in the CI as resistance to new technology, people's refusal to learn, copyright issues and training costs (Sahil, 2016:11). Other barriers attributed to attitude from the study on C2C were found to be that development stakeholders are operating in silos and not collaborating with each other and that stakeholders prefer conventional technologies and products over new products and technologies as these have been tried and tested and have an attraction for short-term rather than longer-term operational benefits (Ankrah et al., 2015: 53-55).

3.3.4 Government

Khosshnava et al. (2014:1641-1646) established that a major barrier to the adoption of IBS is the lack of policy implementation. Other barriers relating to the government are lack of building codes and standards, lack of assessment, lack of incentives and lack of understanding about sustainability issues. From the study on LC, regulatory authorities' intervention and inconsistency in policies and lack of standardisation were found to be the governmental barriers Ayarkwa et al., 2012:9).

3.3.5 Financial

In terms of the financial barriers from the review of biomimicry, it was found that high initial costs and the competitive nature of the built environment hamper the adoption of SCPs (Zari 2008:776; Kenney et al., 2013:6; Buck, 2017:133). Similarly, from the literature review of LCA, the time and financial resources required to conduct the study deter the interest of financers and policymakers from conducting an LCA (Teshnizi, 2018:177). Sev and Ezel (2014:894-895) established the barrier to the adoption of NT as high material costs.

3.4 BENEFITS OF ADOPTING SUSTAINABLE CONSTRUCTION PRACTICES

The benefits to be drawn from the adoption of the various SCPs fall into the three categories that form the pillars of sustainability, namely environmental, economic and social.

3.4.1 Environmental Benefits

Numerous environmental benefits can be gained from the adoption of various SCPs. From the scholarly review of nanotechnology, it was found that its adoption would result in improved function of traditional construction materials, reduced carbon emitted by materials, energy saving, reduced reliance on non-renewable resources and reduced waste generation and toxicity (Oke et al., 2017:3842; Oke et al., 2018:291). Other benefits are reduced energy consumption attributed to less cement usage and improved insulation, the production of materials that have anti-fogging and self-cleaning properties, improved air quality and improved mechanical properties, durability and elasticity of materials (Babuka, 2016:10; Lazaro et al., 2016:59). Similarly, the adoption of a SCP known as biomimicry would aid the mitigation of climate change through the creation of innovative technologies that curb the emissions of greenhouse gases, enhance the construction of eco-friendly structures and encourage the maintenance of biodiversity and the ecosystem (Zari, 2010:181).

3.4.2 Economic Benefits

There are various economic benefits that can be obtained by means of the various SCPs. Khosshnava et al. (2014:1646) identified cost and time certainty, improved construction quality and productivity as the economic benefits of IBS. Similarly, Hassim et al. (2009:937) posited that IBS speeds up the construction process, minimises hazards and risks and enables the integration of sustainability strategies. IBS also opens doors for new business opportunities and can serve as a conducive platform for the promotion of innovations that would improve the economy. Additionally, Olawumi and Chan (2018:18) posited that the adoption of BIM results in improved project productivity, quality and efficiency. It also can simulate building performances and energy usage, resulting in products of superior design. Furthermore, BIM facilitates the use of alternative designs. Other benefits of BIM are the fact that it decreases the need to “fix issues on site”, construction waste is reduced, the probability of delays and cost overrun due to rework are reduced and it contributes positively to the improvement in asset life cycle management (Zhabrinna et al., 2018:6).

Other SCPs such as LCC can serve as an essential decision making and management tool. As a management tool, LCC assists in the identification of the actual costs incurred in operating assets. It could also serve as a valuable tool when tasked with providing clients with an estimate of the actual running costs of the building. Moreover, it can be used for budgeting purposes. In addition, it can be a valuable feedback device when designing (Kishk, 2003:2-3). In their study of VM, Aghimien et al. (2018:3125) posited that it enables early identification of possible problems in the project, encourages the use of local sustainable materials in construction, eliminates the production of unnecessary designs, reduces defects and waste, curbs unnecessary costs, achieves value for money, ensures that the project is delivered in the most cost-effective way, enhances value and benefits for end users and enables the efficient use of resources. In like manner, Aigbavboa et al. (2016:233) state that VM enhances project value, improves design efficiency, optimizes value for money, advances design decisions, creates clear focus on the project objectives, discovers project issues and constraints, enhances communication and efficiency by developing multidisciplinary and multitask teamwork, promotes sustainability, results in improved quality of work, provides an authoritative review of the project, and enhances competitiveness by facilitating technical and organizational innovation. Of equal importance is the fact that VM enables decision makers to make sound business choices when it comes to product and service improvement for the purpose of enhancing customer satisfaction. Further benefits are improved communication and efficiency among the various disciplines and teams, the enhancement of risk management measures and the promotion of innovative service delivery processes (Aghimien & Oke, 2015:9).

3.4.3 Social Benefits

According to Azhar (2011:25), the adoption of BIM would result in improved collaboration amongst project teams, reduced costs, increased profitability, better time management, and improved customer-client relationship (Azhar, 2011:25). A study by Yan and Damian (2008:5) shows that the social benefits that can be gained from BIM are an improvement in the construction process and the quality of project documents that are produced. Aghimien et al. (2018:3127) established that VM contributes to the promotion of SC as it encourages the use of local sustainable materials in construction, eliminates unnecessary cost and improves the attainment of value for money. Moreover, it enhances the competitive edge for the contractor, can identify possible problems early in the project, improves communication, and enhances mutual trust.

3.5 DRIVERS OF THE ADOPTION OF SUSTAINABLE CONSTRUCTION PRACTICES

From the literature review, the following were identified to be drivers to the adoption of the various SCPs: policies and regulations, training and education, increased client and stakeholder awareness, increased demand, economic incentives, research and development and measurement standards.

3.5.1 Policies and Regulations

From the study of VM, Oke and Aigbavboa (2017:179) identified the formulation of the necessary and appropriate guidelines and regulations as the main drivers of the adoption of SCPs. Similarly, Ayarkwa, (2012:10) posited that government agencies need to be proactive in formulating applicable policies and providing the necessary support that would enable the implementation of the various SCPS to be feasible.

3.5.2 Training and Education

In their quest to promote the adoption of biomimicry, Nkandu and Alibaba (2018:10) posited that there is a need for collaboration of multiple disciplines in a quest to produce structures and systems that not only benefit nature but also the occupants. From the VM perspective, Oke and Aigbavboa (2017:179) indicated that training and education and the dissemination of information on VM to all the stakeholders would aid its adoption. In their study on LCA and LCC, D'Incognito et al. (2014:213) identified investment in formal and technical education as one of the main drivers of the adoption of LCC. On the other hand, El-Zeiny (2012:511) identified the inclusion of biomimicry in the current university syllabi as the major driver coupled with the organisation of workshops and events as these would serve as vital platforms that could help forge links and transfer knowledge across disciplines. Similarly, Davies et al. (2018:6) identified the inclusion of BIM in university syllabi, training for professionals on BIM technology and increased avenues for dissemination of BIM knowledge as the main drivers of the adoption of BIM.

3.5.3 Increased Client and Stakeholder Awareness

The major driver to aid the adoption of NT identified by Oke et al. (2017:3843) is by construction contractors, consultants and regulators leading the way through sensitisation of the other stakeholders by means of training, and research and development. Similarly, from the study on the adoption of LCC in the UK CI, it was established that quantity surveyors, through their interaction with the client as cost advisors, would use this platform to promote its use as their lack of demand of this analytical costing tool is attributed to their being unaware (Chiurugwi et al., 2010:8).

3.5.4 Increased Client Demand

The CI has been observed as being client driven and therefore their increased awareness and subsequent demand would result in the construction of sustainable buildings (Opoku, 2014:126). Similarly, in their study of LCC and LCA, D'Incognito et al. (2014:212) found that the client and the professionals are the main actors in the adoption of these practices. This was summed up as follows: "If there is low demand, there will be low adoption and vice-versa."

3.5.5 Economic Incentives

One means of promoting the adoption of SCPs is through the introduction of economic incentives for projects that adopt sustainable goals (Oke & Aigbavboa, 2017:179). The practical application of the use of economic incentives as a means of promoting SCPs is through their incorporation in the procurement and contracts awarded in construction projects.

3.5.6 Research and Development

The purpose of further research to improve the function of the various SCPs cannot be over-emphasised, as indicated by several scholars. In order to drive the adoption of C2C, Ankrah et al. (2015:55) established that further research was required in order to resolve the ambiguity surrounding the principles of C2C. Oke et al. (2017:3843) posited that findings from research and development coupled with training would aid the sensitisation of the various stakeholders in the CI on the various innovative technologies that have been developed. Additionally, Oke et al. (2018:292) established that companies should be made aware of the benefits of developing a division that can carry out continuous research on emerging technologies as this will aid innovation within the company and will offer investment opportunities.

3.5.7 Measurement Standard

The establishment of measuring standards would serve as a platform for the adoption of the various SCPS as observed in the literature review. From their study of BIM, Olawumi and Chan (2018:18) theorised that extensive and well-coordinated efforts to bridge the literature gap on the absence or inadequacy of BIM standards and models and the difficulty in measuring some of the identified benefits which are qualitative, would pave the way for the adoption of BIM. Similarly, Chiurugwi et al. (2010:2) identified that the development of a standardised LCC methodology would aid its adoption in the UK CI.

3.6 LESSONS LEARNT

The worsening effects of unsustainable human activities have increased calls for all sectors to adopt sustainable development. The CI's response to this call is known as sustainable construction (SC) and the application of the principles of SD to the business and strategies of the institutions operating within this sector are what are known as sustainable construction practices. These are practices that are implemented in the entire construction cycle which runs from planning, design, extraction of raw materials, construction of buildings and infrastructure and ends at deconstruction and management of the resulting waste.

Through the review of literature, it was established that there are six practices that focus on compliance with sustainability, design and procurement, technology and innovation, organisational structure and process, education and training, measurement, and reporting. Of the six practices, this section focused on the use of technology and innovation as a means of enhancing SD in the CI. The purpose of its selection is borne out of its interaction with the environment and the extraction of resources for the creation of living spaces and the production of goods. Studies have shown that this interaction with the environment has resulted in drastic consequences, hence the need to develop technologies that satisfy the three pillars of sustainability by enabling the creation of products or services that benefit the environment and uplift the livelihood of humans, result in improved process efficiency, reduce risk and enhance cost saving.

A review of literature has revealed several technologies that have emerged across sectors with a view to enhancing sustainability. These are lean construction, biomimicry, nanotechnology, ecological economics, life cycle costing, life cycle assessment, building information modelling, value management, ecological footprint, design for the environment, construction ecology, industrialised building systems, cradle-to-cradle design, Internet of Things, 3D printing and blockchain technology.

Lean thinking is a concept that emerged in the car manufacturing industry in the 1950s owing to a scarcity of resources as it enables the utilisation of half the resources that would be consumed in the production of goods. Additionally, lean focuses on the elimination of all forms of waste such as time, material, labour and production of defects. Lean will enhance sustainability in the CI through optimising resources, prioritising safety in all activities, implementing standard procedures to curb wastage and enhancing efficiency. Another waste eliminating innovative practice that was identified is industrial building systems (IBS). Despite the ambiguity around its definition, IBS came into existence in the 20th century and is a construction technique in which components are manufactured in a controlled environment off- or on-site. These components are then taken to site (if manufactured off-site), placed in their allocated spots and thereafter assembled into a structure with minimal additional site work. Literature reveals that it promotes sustainability through minimisation of waste and production of energy efficient structures, resulting in economic stability in the long run.

In the quest to ensure that sustainability is attained in the three pillars on which this paradigm focuses, practices were identified that promote the economic and environmental aspects. Ecological economics (EE) is an economic theory and practice that sees the economy as operating in the same spheres of society, nature and culture instead of dominating them. It is of paramount importance to note that the benefits of implementing this model in most cases are not tangible but are evident through reduced operating costs and a positive impact on society and the environment over a long period. It was also established that EE is an essential requirement of sustainable development as it addresses the relationship between the natural ecosystem and the human economy. VM is a practice that contributes meaningfully to the three spheres of sustainability as it is a systematic, structured and multi-disciplinary methodology that enables the elimination of areas of unnecessary designs that affect the cost and have no functional benefits. It also reduces the cost of construction and construction time, as well as providing value for money, thereby giving overall satisfaction to the client. Thus, VM impacts not only the economic component of sustainability but also the environmental one through the elimination of wastage, unnecessary designs, materials and process.

Another essential practice is life cycle costing (LCC) which is a methodology that enables an assessment to be done of costs that would be incurred throughout the life of a product or building in the CI. LCC contributes to the implementation of SD by ensuring that structures are built not only based on the long-term perspective but also with a focus on the economic aspect of sustainability. This innovative tool not only results in cost saving but also promotes the social aspect of sustainability by unifying the fragmented CI. Building information modelling (BIM) is a set of applications and processes capable of generating and managing project information throughout the project development phases which results in several benefits. These applications aid the visualisation and detection of clashes, enable the generation of shop drawings, and have in built software that aids cost estimating and construction sequencing which includes the delivery of construction components. BIM also enables a forensic analysis of a building to be carried out through graphical illustration of potential failures, leaks and evacuation plans.

The study also identified that the ecosystem holds profound lessons and is a suitable model for the transition to a sustainable way of life. These lessons can be drawn from the following disciplines biomimicry, industry ecology, construction ecology, and design for the environment. Biomimicry is known as a transdisciplinary tool as it is used in various industries, namely medicine, agriculture, aerodynamics, architecture, industrial design and human safety. The term 'biomimicry' is derived from Greek words *bios* (life) and *mimesis* (imitation) which is summarised as an imitation of life. Biomimicry focuses on the use of nature as a model (source of inspiration), measure (of what works, what lasts, what is appropriate) and mentor. This tool promotes sustainability through the creation of products and processes of high performance, saving energy, reducing the cost of materials and redefining and eliminating waste and subsequent environmental degradation.

The second is construction ecology (CE) which is a concept borne out of industrial ecology, a science that emerged in the late 1980s. It looks at the physical, chemical, and biological interactions and interrelationships both within and among industrial and ecological systems. Literature indicates that CE focuses on the enhancement of sustainability in the CI through the application of nature's lessons in two key areas: firstly, in the manufacturing of building products and secondly, in the demolition of existing structures and assembly of manufactured products into new or renovated structures. CE is a vehicle by means of which the industry would embrace sustainability through a closed-loop materials system integrated with eco-industrial and natural systems. It would depend solely on renewable energy sources and would foster the preservation of natural system functions. Another tool is design for environment (DfE) which is a methodical analysis of the design performance of a product throughout its entire life cycle. DfE can be applied in the CI during the design phase. During this phase, it can be used as a barometer that ensures the formation of green products which, at the end of their life span, can be reused or recycled.

A similar concept is cradle-to-cradle (C2C) design which has been identified by scholars as an ecologically intelligent approach to architecture that incorporates materials, buildings and patterns of settlement which are not only healthy but are also restorative. This is because the cradle-to-cradle design, unlike the cradle-to-grave design, perceives human systems as nutrient cycles in which every material can support life. Rather than seeing materials as a waste management problem in the cradle-to-grave system, C2C design is based on the closed-loop nutrient cycles of nature, in which there is no waste.

The long life span of structure over time has a negative impact, not only on the environment but also on the occupants. This is attributed to the materials that these structures are composed of. In line with this, one practice that has gained recognition is nanotechnology (NT). This is a scientific field that works with structures that are smaller than 100 nanometres and is concerned with the development of materials, systems or devices within that size. NT supports sustainability through the imitation of the natural systems which have no negative impact on the environment as they have exceptional performance and exhibit biodegradable characteristics.

Efforts to preserve the rapidly diminishing resources for the next generation and the promotion of the social aspect of sustainability which involves the proportionate distribution of resources led to the emergence of the ecological footprint (EF). EF is the measure of the resources required to meet human consumption and to ensure a balance in the ecosystem, for example, grazing lands for animal products, forested areas to produce wood products, marine areas for fisheries, built-up land for housing and infrastructure, and forested land needed to absorb carbon dioxide emissions. EF also exposes the disproportionate land area available to the world's rich and poor countries. This concept tries to solve the problem from the SD perspective of how people can be able to have decent quality of life without extinguishing the limited life supporting planetary systems. Life cycle assessment (LCA) is a technique that comprehensively determines the environmental and resource impacts of a material, a product, or even a whole building over its entire life. Additionally, LCA involves the consideration of alternative processes and products that would lead to a reduction in the environmental impact of construction buildings. Other practices that seek to not only preserve the diminishing resources but also improve the quality of life are the Internet of Things (IoT), 3D printing and blockchain technology.

Despite the numerous ways in which the identified practices can enhance sustainability, there are several perceived barriers to their adoption. These are management barriers namely lack of commitment and attentiveness exhibited by top management in construction and environmental issues being the least prioritised by organisation. The second are technical barriers in the form of interoperability and procedural uncertainties, the existence of varying databases and the absence of benchmarks in the CI, inappropriateness of the existing tools and methodologies and the lack or insufficient quality of input, inadequate training and education, lack of awareness amongst the professionals and lack of constructability of architectural designs as a result of limited knowledge of construction practices. Another of barriers are related to attitude like the resistance to new technology, people's refusal to learn, copyright issues, stakeholders operating in silos and not collaborating with each other, stakeholders preferring conventional technologies and products over new products and technologies as these have been tried and tested. Furthermore, stakeholders have an attraction for short-term rather than longer-term operational benefits. In addition to the afore mentioned barriers this established that there are government barriers namely lack of policy implementation, lack of building codes and standards, lack of assessment, lack of incentives and lack of understanding about sustainability issues, lack of regulatory authorities' intervention and inconsistency in policies and lack of standardisation. The last form of barriers that were identified financial related in the form of high initial costs, the competitive nature of the built environment, time and financial resources required to conduct analytical methodologies such as LCA deter the interest of financers and policy makers.

Several benefits can be drawn from the adoption of sustainable practices as identified through literature. They are environmental benefits such as enhancement of the functionality of traditional construction materials, a reduction in material carbon emissions, energy saving, reduced reliance on non-renewable resources, reduction in waste generation and toxicity, reduced maintenance and operational upkeep, improved air quality, improved durability and elasticity of materials, effective use of resources, promotion of the recycling of material, the mitigation of climate change through the creation of innovative technologies that curb the emission of greenhouse gases and enhancing the construction of eco-friendly structures. The second form of benefits are economic in the form of cost and time certainty, improved construction quality and productivity and opens doors for new business opportunities. In addition SCPs can serve as a conducive platform for the promotion of innovations that would improve the economy, diminish the probability of delays and cost overrun due to rework, contribute postively to the improvement of asset lifecycle management, can serve as an essential decision making and management tool, improves design efficiency, optimizes value for money, advances design decisions, creates clear focus on the project objectives, discovers project issues and constraints, enhances communication and efficiency by developing multidisciplinary and multitask teamwork, promotes sustainability, results in improved quality of work, provides an authoritative review of the project, enhances competitiveness by facilitating technical and organizational innovation, enhanced communication and efficiency by developing multidisciplinary and multitask teamwork and enhancement of risk management measures and promotion of innovative service delivery processes. Lastly, social benefits of adopting SCPS were found to be increased collaboration within project teams, better time management, improved customer–client relationship, improvement in the construction process and the quality of project documents that are produced and enhances the competitive edge of the contractor. Other social benefits are SCPS can be used to identify possible problems early in the project, improve communication and enhance mutual trust, relationship and confidence in the industry, ensures that projects are delivered in the most cost-effective way and they encourage challenging the status quo and developing innovative design solutions.

Finally, through literature, it was revealed that the following are the drivers or promotional factors that can enhance the adoption of SCPs. The first are policies and regulations in the form of the formulation of the necessary and appropriate guidelines and regulations. The next driver is training and education through collaboration of multiple disciplines, inclusion of the various SCPs in the current university syllabi, organisation of networking opportunities like workshops and events and conducting training for professionals. Other vital drivers are increased client and stakeholder awareness, increased client demand, introduction of economic incentives for projects that adopt sustainable goals, continued research on emerging technologies that will aid innovation within the company and offer investment opportunities and establishment of measuring standards and standard methodology for implementation of each SCP.

3.7 CONCLUSION

Examination of the work done by the various scholars revealed that there are a number of practices developed in the various sectors that can be adopted by the construction industry in order to enhance the implementation of sustainable development. The establishment of measuring standards and methodology of the various practices and increased awareness and their subsequent demand will aid the adoption of these practices.

The next chapter reviews literature pertaining to the performance and sustainability of the Zambian construction industry (ZCI).

CHAPTER FOUR

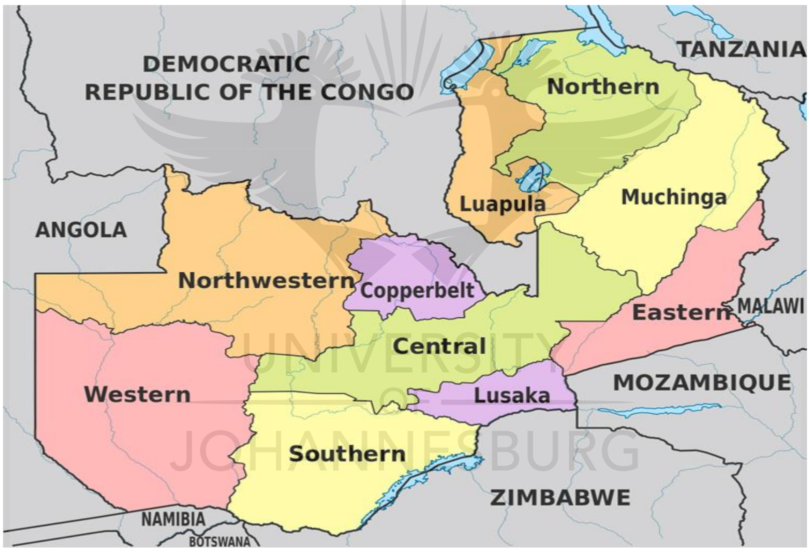
SUSTAINABILITY IN THE ZAMBIAN CONSTRUCTION INDUSTRY

4.1 INTRODUCTION

This section of the study seeks to gain an understanding of the Zambian construction industry by analysing the environment in which it operates and the activities that dominate it. The section ends with an insight into how Zambia is addressing the concept of sustainable development.

4.2 BACKGROUND OF ZAMBIA

The Republic of Zambia is a landlocked nation as which is situated in South Central Africa as illustrated in Map 4.1. It covers an area of 752 600sqkm



Map 4.1: Map of Zambia
(Shakantu et al., 2016:133).

The Zambian economy has faced major setbacks the last couple as seen in the forecasted GDP growth of 3.6 % in 2017 to 2.9% in 2021. This decline in growth is attributed to a decreased global demand for copper the commodity that accounts for 70% of Zambia's export earnings. Zambia's economic growth of 2.3% in 2020 appears unlikely due to macroeconomic instability attributed to public debt that is increasing at an alarming rate, the growing fiscal deficit and shrinking foreign reserves that will possibly limit investment activity. Other factors are severe drought conditions that have not only impacted the output at hydropower dams but have also resulted in poor agricultural harvest which has in turn brought about food shortages.

Furthermore, high inflation rate and the depreciating Kwacha have reigned consumer spending. The looming 2021 elections have also ushered in political instability and a lack of investor confidence. Zambia's population stands at 17.8 million (Robert & Caesar, 2018:2; Zambia Country Report, 2018:7; Zambia Economic Outlook, 2020).

4.3 THE ZAMBIAN CONSTRUCTION INDUSTRY

The construction industry (CI) plays a cardinal role in the development of Zambia's economy. Activities in the sector in the last couple of years include, among others, construction of schools, stadia, hospitals, roads and commercial and residential property (Seventh National Development Plan, 2017:27). This has been motivated by the country's political commitment to steer development through infrastructure development. This commitment was strongest between 2010 and 2017 when the country's capital spending on physical assets grew from ZMK2.5 billion in 2010 to a peak of ZMW12.8 billion in 2015 before dropping to ZMW8.3 billion in 2017. This expenditure accounted for 17% of the total budget expenditure in 2010, rose to a high of 25% in 2015 and then deteriorated to a low of 14% in 2017.

The funds were allocated to two key areas; firstly the Accelerated National Roads Construction Programme (ANRCP) or Link Zambia 8000 road project which commenced in 2012 for the purpose of transforming Zambia into a land-linked country through the completion of 8,000 km of the road network in three phases. The second was the revival of the old districts and the creation of new districts from the existing 72 in 2011 to 108 in 2017. The formation of the new districts required administrative infrastructure consisting of road networks, schools, offices, personnel housing and health facilities. Other factors that have contributed to the state of the construction sector are economic and demographic. Studies show that the demand for infrastructure is highest in urban areas with Lusaka taking the lion's share with its population density of 5,805 persons per m^2. Additionally, Lusaka's central location and capital city status have enabled it to be a preferred destination for private investments in residential housing, as well as in commercial private buildings for office accommodation, shopping malls and supermarkets (Robert & Caesar, 2018:2).

Despite the growth seen in the Zambian construction industry (ZCI), the country, similar to other developing nations, faces challenges in the form of inadequate housing, rapid urbanisation and lack of infrastructure (Du Plessis, 2002:3). Furthermore, the country's major economic activities, namely mining and construction, have been carried out with no regard for the environment and the community. For example, one of the mining activities, smelting, discharges toxic gases into the atmosphere which cause retarded growth of vegetation and affects the well-being of the community. The negative consequences of construction of infrastructure in the form of dams, roads and buildings are the exertion of extreme pressure on the environment through unsustainable and unplanned urban development and the pollution of surface and groundwater as buildings are constructed with on-site sanitation. Other consequences are interference of movement of wildlife, loss of productive agricultural lands, soil erosion, impairment of the delicate eco-systems, soil erosion, changes to drainage patterns, enhanced urbanisation, displacement of people and demographic changes, loss of animal and plant species, desertification, soil erosion and the high prevalence of floods (Musenga & Aigbavboa, 2018; EIA Guidelines for Construction Industry, 2016:2). To mitigate this situation, the Zambian government has introduced several initiatives and has also partnered with international organisations in order to promote sustainable development in the CI.

4.4 ORGANISATIONS AND INITIATIVES PROMOTING SUSTAINABILITY IN THE ZAMBIAN CONSTRUCTION INDUSTRY

4.4.1 Vision 2030

The Zambian government's efforts to meet the sustainable development goals (SDGs) are reflected in their long-term plan known as the Vison 2030. This document was presented to the nation in 2006 by the third republican president, Levy Mwanawasa. This document indicates that the country aims to become a "prosperous middle-income nation" with the principles below serving as a guide:

i) sustainable development
ii) ensuring that democratic principles are upheld
iii) respect for human rights
iv) ensuring that sound family and traditional values prevail
v) a positive attitude towards work
vi) peaceful coexistence
vii) upholding good traditional values

Further review of this document indicated that the attainment of economic and environmental sustainability would be in the form of a dynamic and competitive economy that is self-sustaining, free from donor dependence, immune to external shocks and protective of physical and biological systems.

Additionally, the Zambian government's plan for the attainment of sustainable development focuses on reducing the high unemployment rate, reducing widening economic inequalities and investing in rural development. The sector specific plan for the CI is to create and maintain productive and social infrastructure and services such as health facilities, rail network, energy, roads, storage facilities, communications systems, education, training and public utilities (Zambia Vision 2030, 2006:2).

4.4.2 Zambia Environmental Management Agency

The Zambia Environmental Agency (ZEMA), formerly known as the Environmental Council of Zambia (ECZ), was established as an independent body through the enactment of the Environmental Protection and Pollution Control Act (EPPCA) No. 12 of 1990 (CAP 204 of the Laws of Zambia). The role of ZEMA is to monitor and coordinate the management of the environment through the enforcement of regulations, to raise awareness, and to prevent and control pollution for the purpose of securing the health and welfare of persons, animals, plants and the environment (EIA process in Zambia, n.d:4).

Additionally, ZEMA has been mandated to administer the Environmental Impact Assessment (EIA) process. The EIA process was enacted through Statutory Instrument No.28 of 1997 (SI 28, 1997) as a means of promoting SD by ensuring that the concern for the environment is incorporated into economic activities. In addition, the purpose of the EIA is to reduce, mitigate or prevent adverse impacts on the environment. EIA was borne out of a concept known as integrated environmental management which is a management tool promoting sustainable development that emerged owing to the pressure put on industries to ensure that new projects are socially and environmentally sound. Furthermore, ZEMA, in conjunction with various stakeholders, among them Zambia Green Jobs Programme through the United Nations Environment Programme (UNEP), developed sector-specific environmental impact assessment (EIA) guidelines for the Zambian CI (EIA Guidelines for the CI, 2016:1-2).

4.4.3 Zambia Green Jobs Programme

The Zambia Green Jobs Programme (ZGJP) was launched in 2013 for a period of four years for the purpose of providing technical and developmental assistance to micro, small and medium-scale enterprises (MSMEs) to establish competitive and sustainable businesses in the CI. The programme was a collaboration between the Zambian Government and the United Nations (UN), including the Food and Agriculture Organization (FAO), The United Nations Environment programme (UNEP), the United Nations Conference on Trade and Development (UNCTAD), the International Trade Centre (ITC) and the International Labour Organization (ILO). Included in this partnership was a cross-section of Zambian organisations, one of these being NCC (Zambia Green Jobs Programme, 2017). The programme was headed by the ILO and funded by the Finish government.

Implementation of the programme was done in three ways. The first was the creation of awareness, and the imparting of technical and practical knowledge on green building through the various learning institutions, namely the Copperbelt University School of the Built Environment in liaison with Thornpark Construction Training School, NCC School of Construction, University of Zambia's School of Engineering Technology Development Advisory Unit (TDAU), and the Zambia Institute of Architects (ZIA). Additional support came from the Zambia Network for Environmental Educators and Practitioners, the Zambia Environmental Management Agency, and the Zambia Union of Journalists. Hands-on demonstration houses were built using green building methods and powered with eco-efficient technological fittings under the guidance of the VTT Technical Research Centre of Finland, UNEP, UN HABITAT and ILO. Secondly, the programme facilitated regulatory reform by initiating dialogue between government institutions and the private sector so as to enact regulations that would promote the adoption of green building practices by both public and private housing developers in Zambia. The third focused on upskilling the various MSMEs with business and financial knowledge for the purpose of creating an environment that will not only encourage private sector development but will also result in green or sustained growth (Zambia Green Jobs Programme, 2016).

4.4.4 National Council for Construction

The National Council for Construction (NCC) is a statutory body that was set up under the National Council of Construction Act No. 13 of 2003. Its birth was as a result of the creation and approval of a government policy document in 1995 called the National Policy on CI (NPCI). The NCC is tasked with the mandate to promote, train, develop and regulate the Zambian CI. Under this Act, the body is responsible for the registering of contractors and bringing together professional bodies or organizations whose members are engaged in activities related to the CI (National Council for Construction, 2017).

4.5 LESSONS LEARNT

Zambia is a landlocked country the economy of which relies heavily on the mining sector. The construction industry plays a major role in the country's growth and its activities are motivated by political, economic and demographic factors. Despite their positive contributions to Zambia's growth, construction activities have negatively impacted the environment and society. This is evidenced in the pollution of surface and groundwater as buildings are constructed with on-site sanitation, the exertion of extreme pressure on the environment through unsustainable and unplanned urban development, interference in the movement of wildlife, loss of productive agricultural lands, soil erosion, impairment of the delicate eco-systems, soil erosion, changes to drainage patterns, enhanced urbanisation, displacement of people and demographic changes, loss of animal and plant species, desertification, soil erosion and the high prevalence of floods.

To mitigate this situation, the government has been involved in various initiatives that would enhance SD in the country. The first is the country's response to the attainment of sustainable development goals (SDGs) in the form of their long-term plan known as Vison 2030. In this plan, the country aims to become a prosperous middle-income country that not only seeks to excel economically but also to preserve its biodiversity and ensure a harmonious existence of its citizens. The Government has also established institutions that regulate the construction industry, namely the Zambia Environmental Agency (ZEMA) and the National Council for Construction (NCC). In order to promote sustainability in the construction industry, the government partnered with various institutions in a programme known as the Zambia Green Jobs Programme (ZGJP) that was launched in 2013 for a period of four years. The purpose of this programme was to provide technical and developmental assistance to MSMEs in the construction industry. This assistance was in the form of knowledge transfer on green building, paving the way for the enactment of regulations that would promote green structures and upskilling the contractors on how to run a successful construction business. Despite the government's illustration of its commitment to the attainment of SD, a lot more needs to be done to enhance sustainability in Zambia

4.6 CONCLUSION

The literature reviewed gave a brief background of the country in which the Zambian CI (ZCI) operates. Despite its positive contributions, it was found that the ZCI negatively impacts the environment and the community. Through literature, it was established that there are several organisations and initiatives that have been developed to enhance sustainable development in Zambia.

The next chapter will discuss the research methodology adopted by this study in order to meet its objectives.

CHAPTER FIVE

RESEARCH METHODOLOGY AND DESIGN

5.1 INTRODUCTION

This chapter presents the methodology implemented by this study in order to meet its research objectives. This section commences with a discussion on the design adopted by the study, the geographical area in which the study was conducted and the population sample. Furthermore, the data collection instrument, the analysis and the methods implemented to check the validity and reliability of the data are described as a means of effectively evaluating the adoption of sustainable practices in the Zambian CI.

5.2 RATIONALE OF THE STUDY

The rationale of the study is to contribute to the body of knowledge on the enhancement of sustainability in the CI through sustainable construction practices (SCPs). This is achieved by identifying the various sustainable construction practices that have emerged, as well as the barriers to, benefits and ways of promoting their adoption in the Zambian CI.

5.3 RESEARCH APPROACH AND DESIGN

A research approach, as posited by Creswell and Creswell (2018:3), is a plan or process that commences with a wide range of assumptions that are narrowed down to comprehensive methods of collecting data followed by analysis and interpretation of the data collected. Additionally, Creswell and Creswell (2018:3) identified that there are three approaches that are commonly used, namely qualitative, quantitative and mixed. In the same vein, Kumar (2011: 94) defined research design as a procedural plan utilised by a researcher to accurately, economically, objectively and validly answer the research questions. For this research, the quantitative approach was adopted.

Quantitative research is the use of numerical data to gather information about the world through a systematic, formal and objective process (Burn & Grove, 1993:26). It is a method used to describe variables, examine the relationship between these variables and determine the cause and effect interaction between variables. This research methodology is also described as being numerically orientated since the data collected is in the form of numbers. In addition, it has been found that the method accords the researcher the ability to maintain a level of objectivity from the subject of the research. A visual representation of this research is illustrated in Figure 5.1. The results obtained from the data collection process are used to support, falsify or expand existing theories or even to establish new theory (SACQSP, Mod.18: 25).

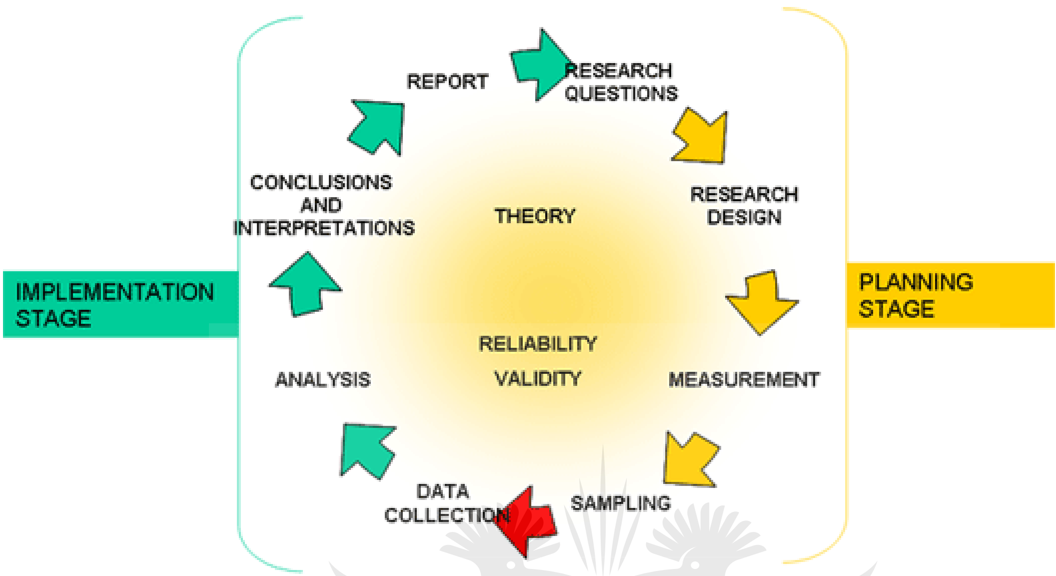


Figure 5.1 Quantitative research process

Source: http://www. http://myy.haaga-helia.fi/~taaak/r/

For this study, a descriptive survey (Kumar, 2011:10) was chosen as it methodically gives a precise interpretation of the characteristics of an individual, group or situation. Examples of these characteristics are behaviour, opinions, abilities, beliefs and knowledge. The method was selected for the purpose of meeting the objectives of this study, namely the identification of the adverse impacts of construction activities in the Zambian CI, the assessment of the level of awareness of sustainable construction practices amongst the professionals in the Zambian CI and the identification of the barriers, benefits and drivers to the adoption and implementation of SD practices in the Zambian CI.

5.4 RESEARCH AREA

The study focused on construction professionals practising in the various provinces in Zambia as per Map 5.1. The study was not only limited to Lusaka, Zambia's most populated province which is also home to its capital city. This was done to ensure that the researcher obtained a holistic view of the adoption and implementation of sustainable construction practices in the Zambian CI. The target group in the research areas were quantity surveyors, architects, construction managers, civil engineers, construction project managers, mechanical engineers, project managers, electrical engineers, town planners and land surveyors involved in construction projects in Zambia.

Map 5.1: Zambia provinces

Source: http://ontheworldmap.com/zambia/zambia-provinces-map.html

5.5 TARGET POPULATION

According to Burns and Grove (1993:779), population or target population as it is sometimes referred to, is the overall number of people eligible for inclusion in a study. Similarly, Alvi (2016:10) established that the term 'target population' points to all the members who meet the criterion specified for a research investigation. The target population in this study were Zambian construction professionals who are registered with the various professional bodies in Zambia. This measure was considered vital for the survey to ensure that the results obtained are an accurate reflection of the populations' view with regard to adopting SD practices in Zambia. These professionals were issued a comprehensive questionnaire in order to determine their level of awareness of sustainable construction practices as well as obtaining their views of what the barriers, drivers and benefits of adopting and implementing these practices are.

5.6 SAMPLING

A sample is a sub-group of the population that serves as the focus of the research enquiry. This group is carefully selected to ensure the study population is represented (Kumar, 2011:397). Alvi (2016:11) posited that sampling is simply a process by means of which a sample is extracted from a population. In quantitative research, there are two forms of sampling, namely random or probability and non-random or non-probability sampling.

In random sampling, every member or individual has an equal opportunity of being selected for the sample (Alvi, 2016:12). This sampling type requires the population to be defined precisely and it has five methods, namely systematic random sampling, stratified random sampling, simple random sampling, multistage sampling and factor sampling. Non-probability sampling, on the other hand, is one in which not every member of the population has an equal chance of being selected. This sampling design is used when the individuals in a population are unknown or cannot be identified or where the population is not precisely defined. The advantage of this sampling type is that is cheap and not time-consuming. There are four main methods of this sampling technique, namely convenience sampling, snowball sampling, purposive sampling and quota sampling (Burns & Grove, 1993:245). This study adopted convenience sampling.

Convenience sampling can also be identified by the terms ‘accidental sampling’ or ‘opportunity sampling’ (Alvi, 2016:27-33). In this form of sampling, the researcher can include participants with the right criteria and who can be approached easily or conveniently. It also used where the target population is defined with a broad category.

5.7 SAMPLE SIZE

A sample size of 150 respondents was identified amongst the professionals in the Zambian CI. These respondents consisted of quantity surveyors, architects, construction managers, civil engineers, construction project managers, mechanical engineers, project managers, electrical engineers, town planners and land surveyors from both the public and private sectors.

5.8 DATA COLLECTION

A list of would-be respondents was generated after obtaining approval of the questionnaire for data collection from the supervisor of the current study. In order to reach the professionals in the various provinces of Zambia, the questionnaire in Google Forms was distributed as a web link via email and various platforms. Data collection was carried out over a period of two months. The questionnaire took approximate fifteen minutes to complete.

5.9 INSTRUMENT OF DATA COLLECTION

For the purpose of determining the level of awareness of SD practices and identifying the barriers, drivers and benefits to the adoption and implementation of these practices in the Zambian CI, a questionnaire was used for data collection. According to Burns and Grove (1993:370), there are two forms of questionnaires; the open-ended and the closed ended. In the open-ended questionnaires, the respondents are required to respond in writing in their own words and can provide more details as they wish. The downside of these questions is that they are difficult to interpret and analyse. With the closed-ended questions, the respondents are given options related to the research topic as determined by the researcher. For this study, a closed-ended questionnaire was adopted.

The questionnaire which was designed in Zambia's official language, English, consisted of a cover letter and six sections, namely A, B, C, D, E and F. The cover letter introduced the topic and assured the respondents of the anonymity of their responses. Section A aimed at establishing the demographics of the respondents for the purpose of observing facts and other explanations towards the study. This information would aid the interpretation of the results. Section B sought to identify the adverse impacts of construction activities in Zambia. Section C evaluated the level of awareness of sustainable construction practices amongst the Zambian construction professionals. Sections D to F of the questionnaire sought to determine the barriers to, benefits and drivers of the adoption and implementation of sustainable construction practices in the Zambian CI. To ensure that reliable data is obtained, instructions and guidelines were attached to the questionnaires to guide the respondents on how to answer the questions.

5.10 PERIOD OF DATA COLLECTION

The data was collected by the researcher in the months of August to September 2019.

5.11 DATA ANALYSIS

Data analysis is defined as the manipulation of letters, words or symbols to establish the relevant relationships or facts (Alreck & Settle, 1985:407). Of the 150 questionnaires that were distributed, 120 were returned and found to be suitable for use. The data from the 120 questionnaires was analysed and interpreted using Excel Microsoft spreadsheet and the

Statistical Package for Social Science (SPSS) computer software. In Excel, pie charts and graphs were computed from the raw data whilst SPSS enabled the computation of mean item scores, factor analysis and Cronbach's alpha.

5.11.1 Mean Item Score

A five-point Likert scale was used to determine the following; adverse impacts of construction activities in Zambia, the level of awareness of sustainable construction practices and identification of the drivers of, barriers to and benefits of adopting sustainable construction practices in the Zambian construction industry. The scales were applied to the factors that were obtained from the reviewed literature. The adopted five Likert scales were as follows;

1 = No extent; 2 = Small extent; 3 = Moderate extent; 4 = Large extent; 5 = Very large extent
1 = Not at all aware, 2 = Slightly aware, 3 = Somewhat aware, 4 = Moderately aware and 5 = Extremely aware

The five-point scale was converted to a mean item score (MS) for each of the factors of the five objectives as indicated above. The indices were then used to determine the rank of each item. The ranking made it possible to cross-reference the relative importance of the items as perceived by the respondents. This method was used to analyse the data collected from the questionnaire survey.

The computation of the relative MS was calculated from the total of all weighted responses and then relating it to the total responses. This was based on the principle that respondents' scores on all the selected criteria, considered together, are the empirically determined indices of relative importance. The index of MS of a factor is the sum of the respondents' actual scores (on the five-point scale) given by all the respondents as a proportion of the sum of all maximum possible scores on the five-point scale that all the respondents could give to that criterion. A weighting was assigned to each response, ranging from one to five for the responses of 'no extent' to 'very large extent' and the same was assigned to the other responses for 'not all aware' to 'extremely aware'. An illustration of how this is expressed mathematically is presented below. The MS was calculated for each item as follows:

$MS = 1n1 + 2n2 + 3n3 + 4n4 + 5n5$ …………………………………… Equation 1.0

ΣN

where:

n1 = Number of respondents for ’ no extent’;

n2 = Number of respondents for ‘small extent’;

n3 = Number of respondents for ‘moderate extent’;

n4 = Number of respondents for ‘large extent’;

n5 = Number of respondents for ‘very large extent’;

N = Total number of respondents

After mathematical computations, the criteria are then ranked in descending order of their MS (from the highest to the lowest). A mean value of 3.00 or more was deemed to be significant to the study.

5.11.2 Factor Analysis

Factor analysis (FA) is a procedure that applies mathematical principles in order to easily interpret observed data through the discovery of patterns in a set of variables (Yong & Pearce, 2013:76). Factor analysis enables the condensing of a large set of variables or scale items down to a smaller, more manageable number of dimensions or factors. It does this by summarising the underlying patterns of correlation and looking for ‘clumps’ or groups of closely related items. This technique is often used when developing scales and measures to identify the underlying structure (Pallant, 2016:108). The origins of FA date back to the early 1900s through Charles Spearman’s interest in human ability and his development of the Two-Factor Theory. This eventually led to a burgeoning of work on the theories and mathematical principles of factor analysis. Owing to the technological advancements of computers, FA can be applied in several fields such as behavioural and social sciences, medicine, economics, and geography. There are two main techniques of FA, namely exploratory factor analysis (EFA) and confirmatory factor analysis (CFA).

CFA attempts to confirm hypotheses and uses path analysis diagrams to represent variables and factors, whereas EFA tries to uncover complex patterns by exploring the dataset and testing predictions. Costello and Osborne (2005:1) defined EFA as a complex procedure with few absolute guidelines and many options. Furthermore, study design, data properties, and the questions to be answered all have a bearing on which procedures will yield the maximum benefit. In an extensive study on FA conducted by Pallant (2016:202) the following was established: Firstly, EFA is often used in the early stages of research to gather information (explore) about the interrelationships among a set of variables whilst CFA is a more complex and sophisticated set of techniques used later in the research process to test (confirm) specific hypotheses or theories concerning the structure underlying a set of variables. Furthermore, Yong and Pearce (2013:80) found that for FA to be carried out successfully, the following need to be noted: There must be univariate and multivariate normality within the data. It is also important that there is an absence of univariate and multivariate outliers. The analysis also requires that a large sample is used to ensure reliability for the factors. One of the limitations of this technique is that naming the factors can be problematic

This study adopted the EFA as it is a widely used and applied statistical technique in the social sciences. Prior to proceeding with factor analysis, the necessary tests as suggested by Pallant (2016:203) were done to ascertain the adequacy of the sample size. Firstly, in determining the strength of the inter-correlation of the variables, the correlation matrix should show correlations greater than $r = 0.3$. To assess the factorability of the data two measures are generated. The first is Bartlett's test of sphericity which should have values of $p < 0.5$ for the data to be statistically significant. This is followed by the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy value the value of which should be 0.6 or above for the factor analysis to be considered appropriate. In addition, the data was subjected to principal component analysis (PCA) with varimax rotation. This was used to establish the number of factors to extract using Kaiser's criterion. The total number of components that have an eigenvalue of 1 or more are determined and adopted. The eigenvalue is described as a mathematical property of a matrix deployed both as a criterion of establishing the number of factors to extract and as a measure of variance accounted for by a given dimension. Furthermore, the graphical scree test or Catell's scree test was reported. According to Pallant (2016:205), Catell recommends that all factors above the elbow or point where there is a break in the plot should be retained as these contribute the most to the explanation of the variance in the data. The last report that was present was the total variance.

5.11.3 Validity and Reliability Test

The Statistical Package for the Social Science Version 25 (SPSS V24) was used to measure the validity and reliability of the selected variables. The Cronbach's alpha, according to Tavakol and Dennick (2011:53), measures the internal consistency of a test or scale. It describes the extent to which all the items in a test measure the same concept and hence it is connected to the inter-relatedness of the items within the test. The minimum accepted Cronbach's alpha value is 0.7 but the most preferred are values above 0.8 (Pallant, 2007:98). This study therefore adopted Cronbach's alpha value of 0.7.

5.11.4 Non-Parametric Test

The Mann-Whitney U test as defined by Pallant (2016:250) is a technique that is used to determine the differences between two independent groups on a continuous measure. The distinct feature of this test is that instead of comparing means it compares medians of the two groups and goes on to check whether there is a significant difference in the ranks of the two groups.

5.12 DELIMITATIONS OF THE STUDY

The delimitations are those characteristics that limit the scope and define the boundaries of one's study. The delimitations are in one's control. Delimiting factors include the choice of objectives, the research questions, variables of interest, theoretical perspectives (as opposed to what could have been adopted), and the population chosen by the research as the areas of investigation (Simon, 2011:1). Therefore, this study's respondents were construction professionals, namely quantity surveyors, architects, construction managers, civil engineers, construction project managers, mechanical engineers, project managers, electrical engineers, town planners and land surveyors who are involved in construction projects in Zambia. This study only determined the adverse impacts of construction activities in Zambia. The study further assessed the awareness level of SDPs amongst the construction professionals in the Zambian CI. Lastly, the study identified the barriers to, the potential benefits and drivers of the adoption and implementation of sustainable construction practices Zambian CI.

5.13 ETHICAL CONSIDERATION

The ethical consideration in this research was two-fold. Firstly, this research considered the obligation to the various scholars whose work contributed to the literature by acknowledging and citing their work accurately. Any research that is to involve collecting data from people needs to foresee that there will be ethical issues that will be encountered (SACQSP, Mod 18:21). With that in mind, the obligation to the participants was to ensure that their privacy was maintained. Burns and Grove (1993:99) pointed out that the research participant has the right to anonymity and the assurance that the information collected will be confidential. As such, the data collecting medium in this research, the questionnaire, indicated that confidentiality would be maintained, and the information collected would only be used for academic purposes. This was illustrated through a written cover letter obtained from the Department of Construction Management and Quantity Surveying that was affixed to all the questionnaires that were sent out. In addition, the respondents to the questionnaire were not coerced to respond to questions that they felt were inappropriate.

5.14 CONCLUSION

In this chapter, the research methodology used for the study was described extensively. This included the research design, the population, sample, and data collection instruments with justification why the questionnaire was used. A section describing how the data was analysed formed part of this chapter. Lastly, measures that were taken into consideration to ensure that ethical standards were met are presented.

The next chapter presents the analysis and discussion of the data collected.

CHAPTER SIX

DATA ANALYSIS AND INTERPRETATION

6.1 CHAPTER INTRODUCTION

As per the heading, this chapter focuses on the analysis and subsequent interpretation of the data collected from the respondents through a concise questionnaire. The respondents were construction professionals, namely quantity surveyors, architects, construction managers, civil engineers, construction project managers, mechanical engineers, project managers, electrical engineers, town planners and land surveyors who are involved in construction projects in Zambia's ten (10) provinces. The questionnaire which served as the quantitative data collection tool comprised twelve questions, all of which were answered. The analysis was based on one hundred and twenty- two (122) correctly completed questionnaires that were received out of the one hundred and fifty that were sent out. This represents a response rate of 81.3%.

6.2 SECTION A: BIOGRAPHICAL DATA ANALYSIS

6.2.1 Distribution of Sample According to Educational Qualification

This reveals that most of the respondents possess a bachelor's degree, representing 63.1%, followed by those with a diploma representing 7.4%, master's holders represent 2.7% and those with a doctoral degree represent 2.5 %. There were no respondents with a grade 12 qualification or a certificate. This is presented in Fig 6.1.

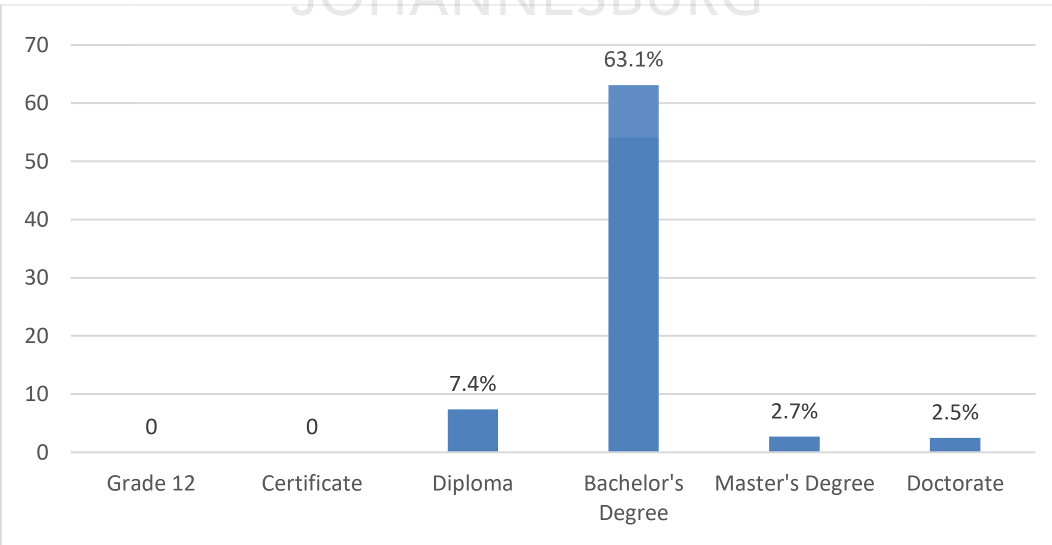


Figure 6.1: Respondents' educational qualification

6.2.2 Distribution of Sample According to Professional Affiliation

The sample according to professional qualification as presented in Fig 6.2 was distributed as follows: 37.7% of the respondents were civil engineers, 15.6% were quantity surveyors, 9.8% were architects, 9.0% were electrical engineers, 8.2% were project managers, 7.4% were construction managers, 6.6% were mechanical engineers and 1.6% were either land surveyors or town planners.

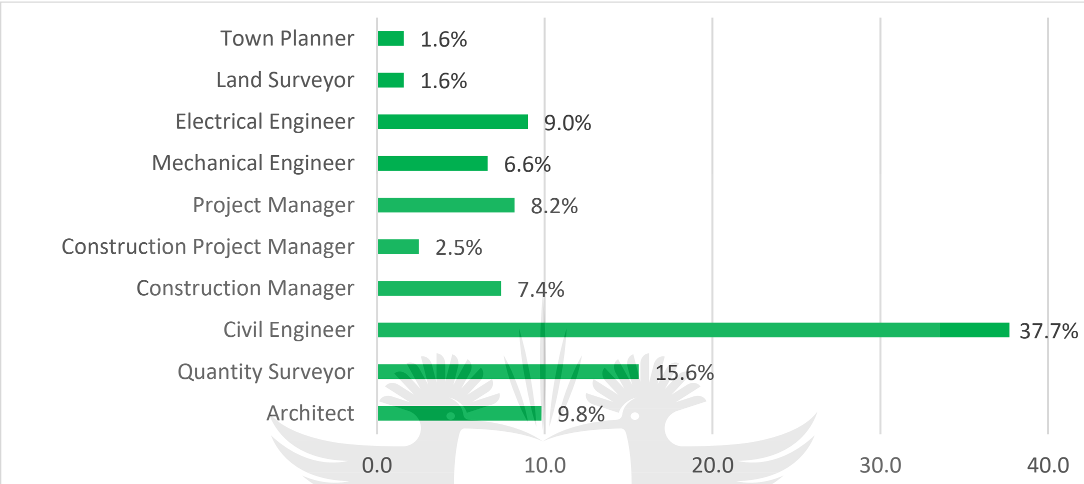


Figure 6.2: Respondents' professional affiliation

6.2.3 Distribution of Sample According to Years of Experience

The distribution of the sample according to the respondents' years of experience in the CI is shown in Fig 6.3. This reveals that 53.8% had experience that ranged between one and five years, 20.2% had experience in the range of six and 10 years, 15.4% had experience that ranged between 11 and 15 years, 4.8% had experience in the range of 16 and 20 years and those with 20 years and more working experience in the CI accounted for 5.8%.

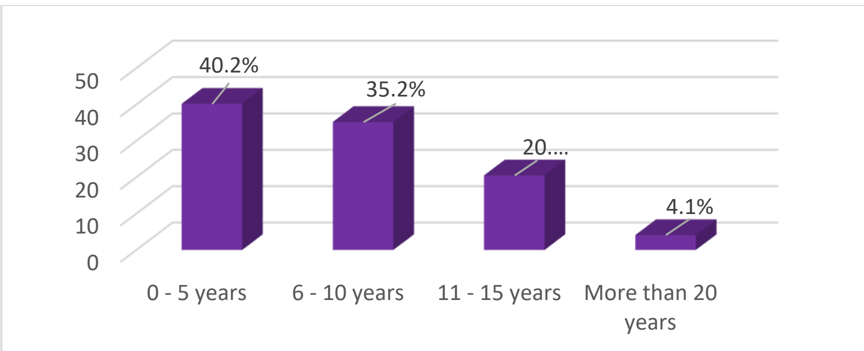


Figure 6.3: Respondents' construction experience

6.2.4 Distribution of Sample According to Their Employer

The distribution of the sample according to their employer shows that 61.5% of the respondents work for private organisations, while 38.5% work for public (government) organisations. This is presented in Fig 6.4.

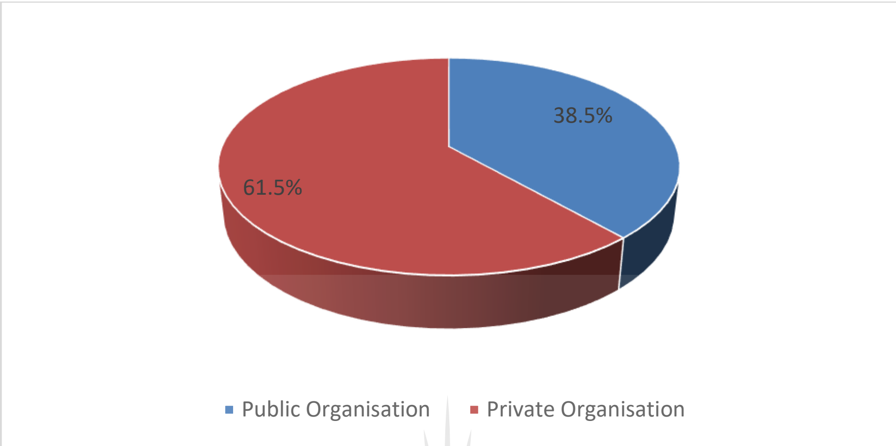


Figure 6.4: Respondents' current employer

6.2.5 Distribution of Sample According to The Province They Work in

The distribution of the sample according to the province they work in is shown in Fig 6.5. This shows that 56.6% of the respondents work in Lusaka province, 15.6% work on the Copperbelt, 8.2% work in Southern Province, 6.6% work in North- Western Province, 5.7% work in Luapula Province, 4.1% work in Central Province, 1.6% work in either Eastern or Northern Province. The research survey was not able to reach respondents in Muchinga Province.

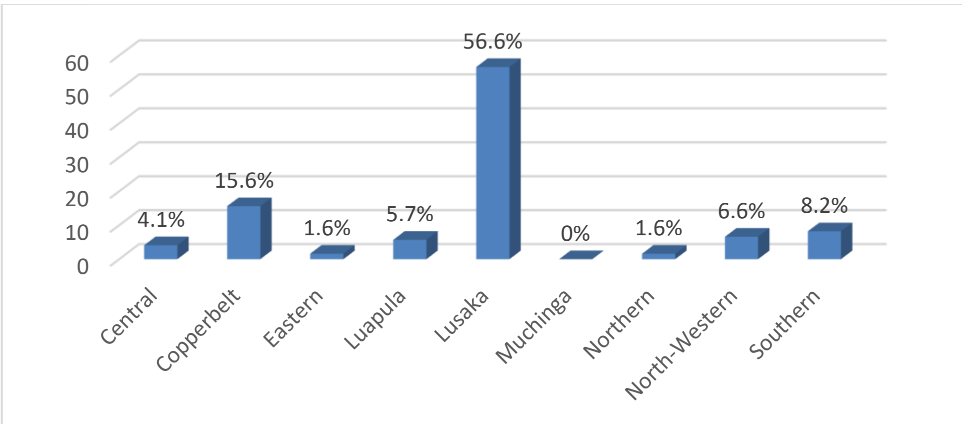


Figure 6.5: Province in which respondents' currently work

6.2.6 Distribution of Sample According to Construction Projects Involved in the Last 12 months

The distribution of the sample according to the respondents' number of construction projects involved in the past 12 months is shown in Fig 6.6. This reveals that the majority are involved in three to four projects representing 27.9%, followed by one to two projects representing 26.2%, more than eight projects representing 16.4% and five to six projects representing 15.6%. Respondents that are involved in seven to eight projects representing 8.2% and those that are not currently involved in any construction projects represent 5.7%.

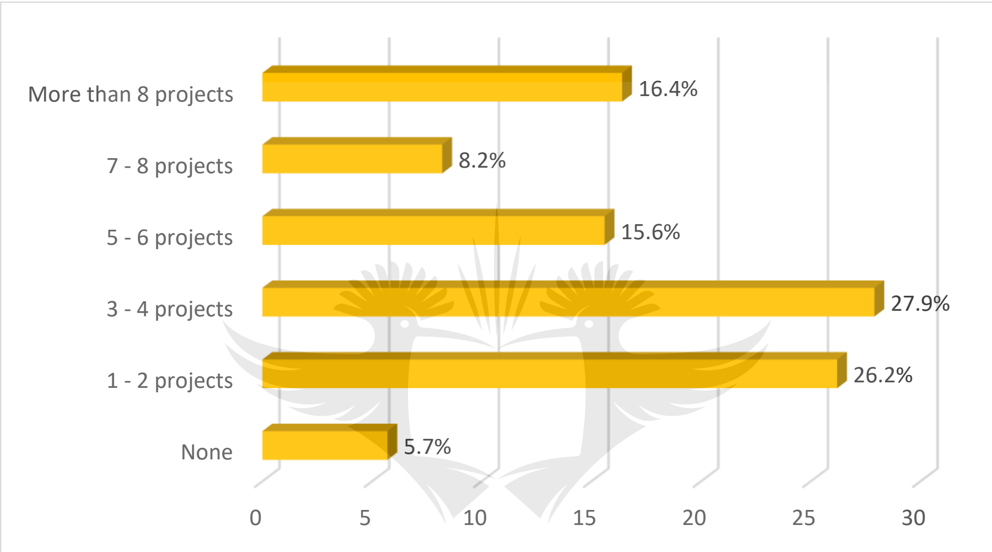


Figure 6.6: Respondents' involvement in construction projects the last 12 months

6.2.7 Distribution of Sample According to Sustainable Construction Projects Involved

The distribution of the sample according to the respondents' number of sustainable construction projects they were ever involved in is presented in Fig 6.7. This shows that the majority have been involved in one to two projects, representing 36.1%, followed by those who have been involved in three to four projects representing 23%. Those who have never been involved in a sustainable construction project represent 21.3%, while those involved in more than eight projects represent 13.9%, followed by five to six projects representing 4.1% and lastly, those who have been involved in seven to eight projects represent 1.9%.

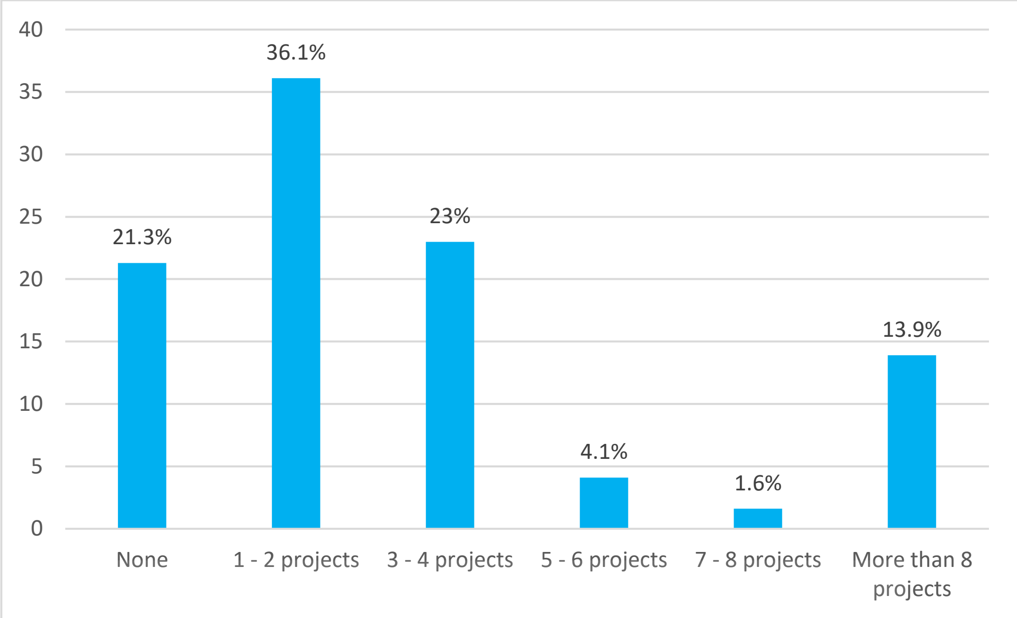


Figure 6.7: Respondents' involvement in sustainable construction projects

6.3 SECTION B: ADVERSE IMPACTS OF CONSTRUCTION ACTIVITIES

The results of section B of the questionnaire which determines the adverse impacts of construction activities in Zambia are presented in this section. The mean score (MS) of the questions, skewness, as well as the exploratory factor analysis (EFA) of the results are also presented. The ranking of all the factors from the highest to the lowest is revealed through the descriptive results revealed in tabular form. Included in the table are the individual mean, standard deviation and non-parametric test results of the factors.

6.3.1 Results from Descriptive Analysis and Non- Parametric Test

The results of the MS of the questions, skewness of the data and the Mann-Whitney U test are presented and discussed below.

Table 6.1: Adverse impacts of construction activities

Adverse Impacts	MS	Standard Deviation	Mann-Whitney U	Asymp. Sig. (2-tailed)	Rank **(R)**
Increased energy consumption	3.62	0.999	1678.500	0.644	1
Deforestation	3.42	1.067	1587.000	0.337	2
Climate change	3.32	1.054	1648.500	0.529	3
Generation of excessive waste	3.31	1.107	1737.000	0.889	4
Depletion of non-renewable material resources	3.26	1.097	1720.000	0.817	5
Degradation of the ecosystem	3.25	1.023	1717.000	0.803	6
Increased land pollution	3.16	1.031	1687.000	0.680	7
Land degradation	3.14	1.007	1753.500	0.960	8

Depletion of non- renewable energy resources	3.11	1.006	1522.500	0.188	9
Increased air pollution	3.11	0.981	1644.500	0.519	10
Irreversible transformation of valuable land	3.10	1.032	1522.500	0.189	11
Soil erosion	3.02	0.966	1549.000	0.245	12
Habitat destruction	3.01	1.032	1761.500	0.996	13
Disruption of natural ecosystem	3.00	0.988	1415.500	0.056	14
Increased water pollution	2.97	1.098	1434.000	0.071	15
Ozone depletion	2.90	1.024	1456.500	0.096	16
Degradation of waterways	2.87	1.178	1749.500	0.943	17
Declined health of construction workers	2.59	0.925	1566.500	0.282	18
Transformation of habitable land into deserts	2.56	1.021	1432.500	0.073	19
Loss of marine life	2.44	1.091	1533.000	0.210	20
Acid rains	2.35	1.036	1327.000	0.017	21
Decreased productivity level of building occupants	2.31	1.092	1361.500	0.026	22
Declined health of building occupants	2.29	0.940	1553.000	0.244	23

Table 6.1 reveals the respondents' ranking of the adverse impacts of construction activities in Zambia. It shows that 'increased energy consumption' was ranked first with a MS of 3.62, standard deviation (SD) of 0.999, Mann-Whitney U 1678.50 and asymp. sig. value of 0.644; 'deforestation' was ranked second with a MS of 3.42, SD of 1.067, Mann-Whitney U 1587.000 and asymp. sig. value of 0.337; 'climate change' was ranked third with a MS of 3.32, SD of 1.054, Mann-Whitney U 1648.500 and asymp.sig. value of 0.529; 'generation of excessive waste' was ranked fourth with a MS of 3.31, SD of 1.107, Mann-Whitney U 1737.000 and asymp. sig. value of 0.889; 'depletion of non-renewable material resources' was ranked fifth with a MS of 3.11, SD of 1.097, Mann-Whitney U 1720.000 and asymp. sig. value of 0.817; 'degradation of the ecosystem' was ranked sixth with MS of 3.25, SD of 1.023, Mann-Whitney U 1717.000 and asymp. sig. of 0.803; 'increased land pollution' was ranked seventh with a MS 3.16, SD of 1.031, Mann-Whitney U 1687.000 and asymp. sig. of 0.680; 'land degradation' was ranked eighth with MS of 3.14, SD of 1.007, Mann-Whitney U 1753.500 and asymp. sig. of 0.960; 'depletion of non- renewable energy resources' was ranked ninth with MS of 3.11, SD of 1.006, Mann-Whitney U 1522.500 and asymp. sig. of 0.188; 'increased air pollution' was ranked tenth with a MS of 3.11, SD of 0.981, Mann-Whitney U 1644.500 and asymp. sig. of 0.519 and 'irreversible transformation of valuable land' was ranked eleventh with a MS of 3.10, SD of 1.032, Mann-Whitney U 1522.500 and asymp. sig. of 0.189. This was followed by 'soil erosion' that was ranked twelfth with a MS of 3.02, SD of 0.966, Mann-Whitney U 1549.000 and asymp. sig. of 0.245.

Additionally, 'habitat destruction' was ranked thirteenth with a MS of 3.01, SD of 1.032, Mann-Whitney U 1761.500 and asymp. sig. value of 0.996; 'disruption of natural ecosystem' was ranked fourteenth with a MS of 3.00, SD of 0.988, Mann-Whitney U 1415.500 and asymp.

sig. value of 0.056; ‘increased water pollution’ was ranked fifteenth with a MS of 2.97, SD of 1.098, Mann-Whitney U 1434.000 and asymp. sig. value of 0.071; ‘ozone depletion’ was ranked sixteenth with a MS of 2.90, SD of 1.024, Mann-Whitney U 1456.500 and asymp. sig. value of 0.096; ‘degradation of waterways’ was ranked seventeenth with a means score of 2.87, SD of 1.178, Mann-Whitney U 1749.500 and asymp. sig. value of 0.943; ‘declined health of construction workers’ was ranked eighteenth with a MS of 2.59, SD of 0.925, Mann-Whitney U 1566.500 and asymp. sig. value of 0.282; ‘transformation of habitable land into deserts’ was ranked nineteenth with a MS of 2.56, SD of 1.021, Mann-Whitney U 1432.500 and asymp. sig. value of 0.073; ‘loss of marine life’ was ranked twentieth with a MS of 2.44, SD of 1.091, Mann-Whitney U 1533.500 and asymp. sig. value of 0.210; ‘acid rains’ was ranked twenty-first with a MS of 2.35, SD of 1.036, Mann-Whitney U 1327.000 and asymp. sig. value of 0.017; ‘decreased productivity level of building occupants’ was ranked twenty-second with a MS of 2.31, SD of 1.092, Mann-Whitney U 1361.500 and asymp. sig. value of 0.026 and lastly, ‘declined health of building occupants’ was ranked twenty-third with a MS of 2.29, SD of 0.940, Mann-Whitney U 1553.000 and asymp. sig. value of 0.244.

6.3.2 Results from Exploratory Factor Analysis

After a series of procedures as described in chapter 6, the results from the EFA on the adverse impacts of construction activities are presented in Tables 6.2 to 6.6 and Fig 6.8. This commences with the presentation of definitions of the identified variables in Table 6.2.

Table 6.2: Definition of adverse impacts of construction activities

Variable	Definition
B08.1	Depletion of non- renewable energy resources
B08.2	Depletion of non-renewable material resources
B08.3	Soil erosion
B08.4	Increased air pollution
B08.5	Loss of marine life
B08.6	Climate change
B08.7	Degradation of the ecosystem
B08.8	Transformation of habitable land into deserts
B08.9	Increased land pollution
B08.10	Deforestation
B08.11	Habitat destruction
B08.12	Increased water pollution
B08.13	Irreversible transformation of valuable land
B08.14	Disruption of natural ecosystem

B08.15	Increased energy consumption
B08.16	Generation of excessive waste
B08.17	Ozone depletion
B08.18	Land degradation
B08.19	Degradation of waterways
B08.20	Acid rains
B08.21	Decreased productivity level of building occupants
B08.22	Declined health of building occupants
B08.23	Declined health of construction workers

Prior to performing the principal component analysis (PCA), the suitability of the data for factor analysis was assessed. The inspection of the correlation matrix revealed the presence of coefficients of above 0.3 as presented in Table 6.3. As shown in Table 6.4, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy achieved a value of 0.901, exceeding the recommended minimum value of 0.6 and Bartlett's test of sphericity was also statistically significant (less than 0.05), thus supporting the factorability of the correlation matrix.

The data was subjected to PCA (with varimax rotation). The eigenvalue was set at conventional high value of 1.0. As shown in Table 6.5, three (3) factors with eigenvalues exceeding 1.0 were extracted. The scree plot presented in Fig 6.8 also revealed the excluded factors by indicating the cut-off point at which the eigenvalues levelled off. The total variance explained by each of the extracted factor is as follows: Factor 1 (49.853%), Factor 2 (8.812%) and Factor 3 (6.612%). This is shown in Table 6.6. Thus, the final statistics of the PCA and the extracted factors accounted for approximately 65% of the total cumulative variance.

Table 6.3: Correlation matrix of factor analysis for adverse impacts of construction activities

	B08.1	B08.2	B08.3	B08.4	B08.5	B08.6	B08.7	B08.8	B08.9	B08.10	B08.11	B08.12	B08.13	B08.14	B08.15	B08.16	B08.17	B08.18	B08.19	B08.20	B08.21	B08.22	B08.23
B08.1	**1.000**	0.759	0.499	0.380	0.495	0.417	0.382	0.187	0.181	0.402	0.373	0.393	0.252	0.258	0.224	0.272	0.324	0.302	0.124	0.246	0.155	0.183	0.193
B08.2	0.759	**1.000**	0.610	0.394	0.524	0.384	0.354	0.274	0.239	0.435	0.436	0.433	0.393	0.351	0.295	0.354	0.340	0.378	0.270	0.318	0.207	0.199	0.270
B08.3	0.499	0.610	**1.000**	0.590	0.507	0.471	0.445	0.355	0.411	0.503	0.489	0.468	0.412	0.303	0.352	0.534	0.470	0.489	0.337	0.470	0.290	0.356	0.307
B08.4	0.380	0.394	0.590	**1.000**	0.439	0.508	0.556	0.390	0.553	0.507	0.456	0.502	0.413	0.461	0.382	0.477	0.513	0.436	0.364	0.537	0.306	0.367	0.389
B08.5	0.495	0.524	0.507	0.439	**1.000**	0.551	0.501	0.407	0.398	0.486	0.613	0.543	0.401	0.337	0.374	0.453	0.476	0.447	0.515	0.402	0.168	0.246	0.214
B08.6	0.417	0.384	0.471	0.508	0.551	**1.000**	0.693	0.539	0.461	0.615	0.635	0.495	0.396	0.452	0.484	0.551	0.665	0.573	0.480	0.448	0.279	0.315	0.271
B08.7	0.382	0.354	0.445	0.556	0.501	0.693	**1.00**0	0.556	0.659	0.678	0.710	0.552	0.541	0.622	0.553	0.465	0.623	0.608	0.589	0.495	0.353	0.304	0.282
B08.8	0.187	0.274	0.355	0.390	0.407	0.539	0.556	**1.000**	0.588	0.543	0.592	0.356	0.544	0.549	0.378	0.430	0.417	0.487	0.460	0.414	0.355	0.374	0.331
B08.9	0.181	0.239	0.411	0.553	0.398	0.461	0.659	0.588	**1.000**	0.628	0.635	0.552	0.590	0.600	0.542	0.440	0.548	0.599	0.603	0.572	0.439	0.479	0.461
B08.10	0.402	0.435	0.503	0.507	0.486	0.615	0.678	0.543	0.628	**1.000**	0.732	0.654	0.608	0.573	0.615	0.554	0.651	0.646	0.524	0.419	0.412	0.341	0.284
B08.11	0.373	0.436	0.489	0.456	0.613	0.635	0.710	0.592	0.635	0.732	**1.000**	0.678	0.597	0.681	0.564	0.547	0.587	0.643	0.674	0.507	0.372	0.389	0.341
B08.12	0.393	0.433	0.468	0.502	0.543	0.495	0.552	0.356	0.552	0.654	0.678	**1.000**	0.594	0.534	0.569	0.478	0.556	0.602	0.616	0.570	0.429	0.417	0.369
B08.13	0.252	0.393	0.412	0.413	0.401	0.396	0.541	0.544	0.590	0.608	0.597	0.594	**1.000**	0.706	0.526	0.465	0.455	0.599	0.602	0.485	0.508	0.431	0.328
B08.14	0.258	0.351	0.303	0.461	0.337	0.452	0.622	0.549	0.600	0.573	0.681	0.534	0.706	**1.000**	0.562	0.461	0.523	0.607	0.533	0.509	0.383	0.445	0.281
B08.15	0.224	0.295	0.352	0.382	0.374	0.484	0.553	0.378	0.542	0.615	0.564	0.569	0.526	0.562	**1.000**	0.638	0.537	0.538	0.555	0.385	0.457	0.389	0.279
B08.16	0.272	0.354	0.534	0.477	0.453	0.551	0.465	0.430	0.440	0.554	0.547	0.478	0.465	0.461	0.638	**1.000**	0.698	0.695	0.583	0.552	0.480	0.477	0.344
B08.17	0.324	0.340	0.470	0.513	0.476	0.665	0.623	0.417	0.548	0.651	0.587	0.556	0.455	0.523	0.537	0.698	**1.000**	0.679	0.510	0.571	0.353	0.407	0.315
B08.18	0.302	0.378	0.489	0.436	0.447	0.573	0.608	0.487	0.599	0.646	0.643	0.602	0.599	0.607	0.538	0.695	0.679	**1.000**	0.699	0.626	0.487	0.569	0.444
B08.19	0.124	0.270	0.337	0.364	0.515	0.480	0.589	0.460	0.603	0.524	0.674	0.616	0.602	0.533	0.555	0.583	0.510	0.699	**1.000**	0.594	0.514	0.475	0.367
B08.20	0.246	0.318	0.470	0.537	0.402	0.448	0.495	0.414	0.572	0.419	0.507	0.570	0.485	0.509	0.385	0.552	0.571	0.626	0.594	**1.000**	0.545	0.634	0.540
B08.21	0.155	0.207	0.290	0.306	0.168	0.279	0.353	0.355	0.439	0.412	0.372	0.429	0.508	0.383	0.457	0.480	0.353	0.487	0.514	0.545	**1.000**	0.766	0.586
B08.22	0.183	0.199	0.356	0.367	0.246	0.315	0.304	0.374	0.479	0.341	0.389	0.417	0.431	0.445	0.389	0.477	0.407	0.569	0.475	0.634	0.766	**1.000**	0.735
B08.23	0.193	0.270	0.307	0.389	0.214	0.271	0.282	0.331	0.461	0.284	0.341	0.369	0.328	0.281	0.279	0.344	0.315	0.444	0.367	0.540	0.586	0.735	**1.000**

Table 6.4: KMO and Bartlett's test for adverse impacts of construction activities

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.901
Bartlett's Test of Sphericity	Approx. Chi-Square	2121.552
	Df	253
	Sig.	.000

Table 6.5: Rotated factor matrix [a] for adverse impacts of construction activities

	Factors		
	1	2	3
Habitat destruction	**0.792**		
Degradation of the ecosystem	**0.786**		
Deforestation	**0.757**		
Disruption of natural ecosystem	**0.747**		
Increased land pollution	**0.719**		
Degradation of waterways	**0.719**		
Increased energy consumption	**0.692**		
Irreversible transformation of valuable land	**0.678**		
Land degradation	**0.676**		
Ozone depletion	**0.667**		
Transformation of habitable land into deserts	**0.657**		
Climate change	**0.652**		
Increased water pollution	**0.613**		
Generation of excessive waste	**0.574**		
Declined health of building occupants		**0.882**	
Declined health of construction workers		**0.822**	
Decreased productivity level of building occupants		**0.794**	
Acid rains		**0.628**	
Depletion of non- renewable energy resources			**0.870**
Depletion of non-renewable material resources			**0.846**
Soil erosion			**0.704**
Loss of marine life			**0.599**
Increased air pollution			**0.484**
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalisation.[a]			
a. Rotation converged in 6 iterations.			

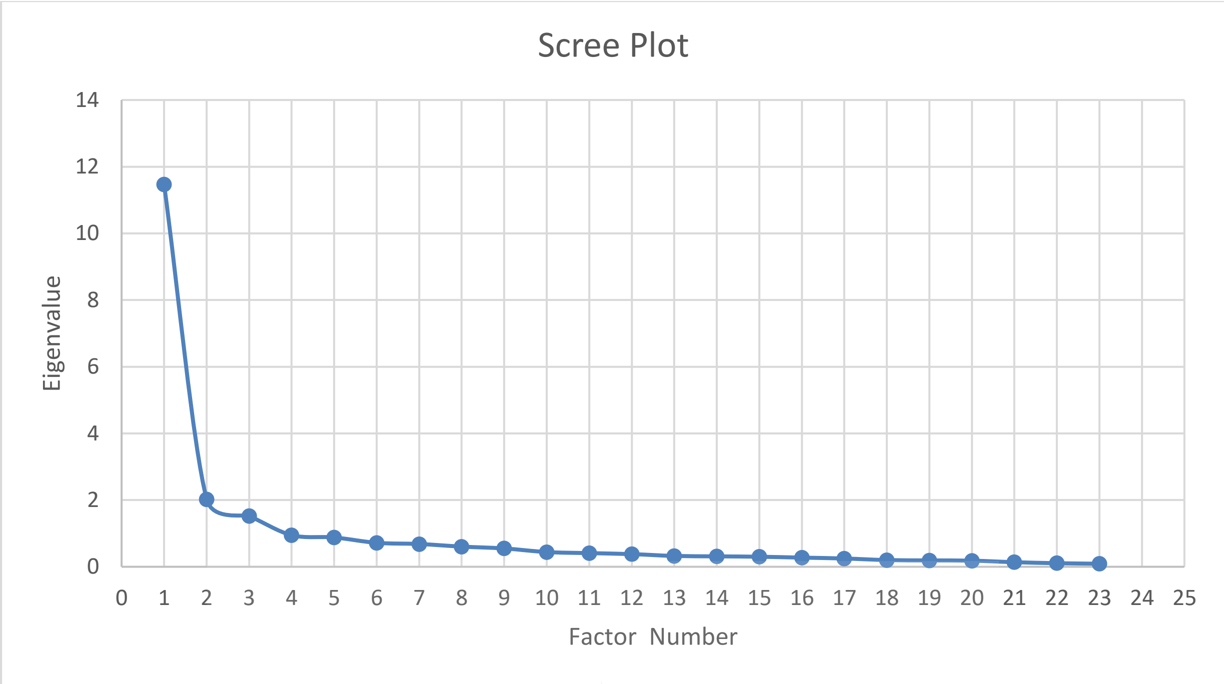


Figure 6.8: Scree plot for factor analysis for adverse impacts of construction activities

Table 6.6: Total variance explained for adverse impacts of construction activities

Factors	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	**11.466**	49.853	49.853	11.466	49.853	49.853	7.718	33.555	33.555
2	**2.027**	8.812	58.665	2.027	8.812	58.665	3.657	15.899	49.454
3	**1.521**	6.612	**65.277**	1.521	6.612	65.277	3.639	15.823	65.277
4	0.949	4.125	69.402						
5	0.880	3.826	73.229						
6	0.718	3.123	76.351						
7	0.683	2.968	79.319						
8	0.605	2.631	81.950						
9	0.550	2.389	84.339						
10	0.441	1.918	86.257						
11	0.409	1.778	88.036						
12	0.380	1.651	89.687						
13	0.325	1.413	91.100						
14	0.313	1.360	92.461						
15	0.301	1.311	93.771						
16	0.274	1.192	94.964						
17	0.248	1.079	96.043						
18	0.201	0.872	96.915						
19	0.191	0.831	97.746						
20	0.183	0.796	98.542						
21	0.137	0.596	99.139						
22	0.107	0.466	99.605						
23	0.091	0.395	100.000						
Extraction Method: Principal Component Analysis.									

Principal axis factoring revealed the presence of three (3) factors with eigenvalues above 1 as shown in Table 6.5. Based on the examination of the inherent relationships among the variables under each factor, the following interpretations were made: Factor 1 was termed

environmental degrading impacts; Factor 2 **decreased human health and productivity** and Factor 3 **resource depletion and pollution**. The names given to these factors were derived from a close examination of the variables within each of the factors. The variables contained within each of the three factors extracted are also indicated.

6.3.2.1 Factor 1: Environmental degrading impacts

As presented in Table 6.5, the fourteen (14) extracted adverse impacts of construction activities for Factor 1 were *habitat destruction* (79.2%), *degradation of the ecosystem* (786%), *deforestation* (75.7%), *disruption of natural ecosystem* (74.7%), *increased land pollution and degradation of waterways* (71.9%), *increased energy consumption* (61.9%), *irreversible transformation of valuable land* (67.8%), *land degradation* (67.6%), *ozone depletion* (66.7%), *transformation of habitable land into deserts* (65.7%), *climate change* (65.2%) *increased water pollution (61.3%) and generation of excessive waste* (57.4%). The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 6.2. This factor accounted for 49.853% of the variance.

6.3.2.2 Factor 2: Decreased human health and productivity

As presented in Table 6.5, four (4) extracted adverse impacts of construction activities for Factor 2 were *declined health of building occupants* (88.2%), *declined health of construction workers* (82.2%), *decreased productivity level of building occupants* (79.4%) and *acid rains* (62.8%). The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 6.2. This factor accounted for 8.812% of the variance.

6.3.2.3 Factor 3: Resource depletion and pollution

This factor accounted for 6.612% of the variance. The five (5) extracted adverse impacts for Factor 3 were *depletion of non- renewable energy resources* (87%), *depletion of non-renewable material resources* (84.6%), *soil erosion* (70.4%), *loss of marine life* (59.9%) and *increased air pollution* (48.4%) as presented in Table 6.5. The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 6.2.

6.4 SECTION C: LEVEL OF AWARENESS OF SUSTAINABLE CONSTRUCTION PRACTICES

The results of section C of the questionnaire which determines the level of awareness of sustainable construction practices amongst the professionals in the Zambian CI are presented in this section. The mean score (MS) of the questions, skewness, as well as the exploratory factor analysis (EFA) of the results are also presented. The ranking of all the factors from the highest to the lowest is revealed through the descriptive results revealed in tabular form. Included in the table are the individual mean, standard deviation and non-parametric test results of the factors.

6.4.1 Results from Descriptive Analysis and Non- Parametric Test

The results of the MS of the questions, skewness of the data and Mann-Whitney U test are presented and discussed below

Table 6.7: Level of awareness of sustainable construction practices

Sustainable construction practices	MS	Standard Deviation	Mann-Whitney U	Asymp. Sig. (2-tailed)	(**R**)
3D Printing (Additive Manufacturing)	3.70	1.285	1596.500	0.368	1
Value Management	3.48	1.294	1565.500	0.287	2
Design for Environment	3.37	1.312	1640.500	0.467	3
Building Information Modelling	3.34	1.388	1622.500	0.450	4
Life Cycle Costing	3.22	1.519	1640.500	0.505	5
Internet of Things	3.09	1.483	1680.000	0.655	6
Lean Construction	3.06	1.462	1392.500	0.043	7
Life Cycle Assessment	2.98	1.463	1493.000	0.135	8
Industrialised Building System	2.91	1.253	1491.500	0.144	9
Construction Ecology	2.54	1.274	1741.000	0.908	10
Ecological economics	2.39	1.140	1578.500	0.319	11
Ecological Footprint	2.37	1.300	1449.500	0.091	12
Blockchain Technology	2.30	1.303	1454.500	0.087	13
Nanotechnology	2.17	1.264	1574.500	0.312	14
Cradle to Cradle design	2.11	1.241	1476.500	0.118	15
Biomimicry	1.63	0.902	1476.000	0.116	16

Table 6.7 reveals the respondents' rankings of their awareness level of sustainable construction practices in Zambia. It shows that '3-D Printing (Additive Manufacturing)' was ranked first with a MS of 3.70, SD of 1.285, Mann-Whitney U 1596.500 and asymp. sig. value of 0.368, 'value management' with a MS of 3.48, SD of 1.294, Mann-Whitney U 1565.500 and asymp. sig. value of 0.287 was ranked second, 'design for environment' with a MS of 3.37, SD of

1.312, Mann-Whitney U 1640.500 and asymp. sig. value of 0.467was ranked third, ‘building information modelling’ with a MS of 3.34, SD of 1.388, Mann-Whitney U 1622.500 and asymp. sig. value of 0.450 was ranked fourth, ‘life cycle costing’ with a MS of 3.22, SD of 1.519, Mann-Whitney U 1640.500 and asymp. sig. value of 0.505 was ranked fifth, ‘Internet of Things’ with a MS of 3.09, SD of 1.483, Mann-Whitney U 1680.000 and asymp. sig. value of 0.655 was ranked sixth, ‘lean construction’ with a MS of 3.06, SD of 1.462, Mann-Whitney U 1392.500 and asymp. sig. value of 0.043 was ranked seventh whilst ‘life cycle assessment’ with a MS of 2.98, SD of 1.463, Mann-Whitney U 1493.000 and asymp. sig. value of 0.135 was ranked eighth.

Furthermore, ‘industrialised building system’ was ranked ninth with a MS of 2.91, SD of 1.253, Mann-Whitney U 1491.500 and asymp. sig. value of 0.144, ‘construction ecology’ with a MS of 2.54, SD of 1.274, Mann-Whitney U 1741.000 and asymp. sig. value of 0.908 was ranked tenth, ‘ecological economics with a MS of 2.39, SD of 1.140, Mann-Whitney U 1578.500 and asymp. sig. value of 0.319 was ranked eleventh, ‘ecological footprint’ was ranked twelfth with a MS of 2.37, SD of 1.300, Mann-Whitney U 1449.500 and asymp. sig. value of 0.091, ‘blockchain technology’ with a MS of 2.30, SD of 1.303, Mann-Whitney U 1454.500 and asymp. sig. value of 0.087 was ranked thirteenth, ‘nanotechnology’ with a MS of 2.17, SD of 1.264, Mann-Whitney U 1574.500 and asymp. sig. value of 0.312 was ranked fourteenth ‘cradle-to-cradle design’ with a MS of 2.11, SD of 1.241, Mann-Whitney U 1476.500 and asymp. sig. value of 0.118 was ranked fifteenth and lastly, ‘biomimicry’ with a MS of 1.63, SD of 0.902, Mann-Whitney U 1476.000 and asymp. sig. value of 0.116 was ranked sixteenth.

6.4.2 Results from Exploratory Factor Analysis

The results from the EFA on the level of awareness of SD practices are presented in Tables 6.8 to 6.12 and Fig 6.9. The definitions of the identified variables are presented in Table 6.8.

Table 6.8: Definition for the level of awareness of sustainable construction practices

Variable	Definition
C09.1	Life Cycle Costing
C09.2	Construction Ecology
C09.3	Biomimicry
C09.4	Life Cycle Assessment
C09.5	Ecological economics
C09.6	Value Management
C09.7	Ecological Footprint
C09.8	Nanotechnology
C09.9	Design for Environment
C09.10	Lean Construction
C09.11	Industrialised Building System
C09.12	Building Information Modelling
C09.13	Cradle to Cradle design
C09.14	Internet of Things
C09.15	3D Printing (Additive Manufacturing)
C09.16	Blockchain Technology

Prior to performing the PCA, the suitability of the data for factor analysis was assessed. Inspection of the correlation matrix revealed the presence of coefficients of above 0.3 as presented in Table 6.9. As shown in Table 6.10, the KMO measure of sampling adequacy achieved a value of 0.896, exceeding the recommended minimum value of 0.6 and the Bartlett's test of sphericity was also statistically significant (less than 0.05), thus supporting the factorability of the correlation matrix.

The data was subjected to PCA (with varimax rotation). The eigenvalue was set at conventional high values of 1.0. As shown in Table 6.11, three (3) factors with eigenvalues exceeding 1.0 were extracted. The scree plot presented in Fig 6.9 also revealed the excluded factors by indicating the cut-off point at which the eigenvalues levelled off. The total variance explained by each of the extracted factor is as follows: Factor 1 (50.585%), Factor 2 (9.225%) and Factor 3 (6.725%). This is shown in Table 6.12. Thus, the final statistics of the PCA and the extracted factors accounted for approximately 67% of the total cumulative variance.

Table 6.9: Correlation matrix of factor analysis for the level of awareness of sustainable construction practices

	C09.1	C09.2	C09.3	C09.4	C09.5	C09.6	C09.7	C09.8	C09.9	C09.10	C09.11	C09.12	C09.13	C09.14	C09.15	C09.16
C09.1	**1.000**	0.549	0.416	0.802	0.541	0.702	0.461	0.376	0.419	0.501	0.375	0.470	0.390	0.292	0.382	0.176
C09.2	0.549	**1.000**	0.434	0.460	0.570	0.527	0.687	0.455	0.562	0.480	0.466	0.443	0.515	0.398	0.424	0.356
C09.3	0.416	0.434	**1.000**	0.419	0.601	0.360	0.526	0.353	0.318	0.380	0.402	0.331	0.525	0.396	0.274	0.431
C09.4	0.802	0.460	0.419	**1.000**	0.616	0.714	0.483	0.445	0.470	0.534	0.359	0.521	0.370	0.363	0.326	0.277
C09.5	0.541	0.570	0.601	0.616	**1.000**	0.582	0.710	0.423	0.499	0.547	0.453	0.480	0.383	0.507	0.353	0.328
C09.6	0.702	0.527	0.360	0.714	0.582	**1.000**	0.596	0.373	0.610	0.610	0.511	0.567	0.372	0.481	0.462	0.209
C09.7	0.461	0.687	0.526	0.483	0.710	0.596	**1.000**	0.514	0.525	0.511	0.452	0.508	0.465	0.506	0.483	0.413
C09.8	0.376	0.455	0.353	0.445	0.423	0.373	0.514	**1.000**	0.494	0.522	0.422	0.386	0.351	0.344	0.297	0.456
C09.9	0.419	0.562	0.318	0.470	0.499	0.610	0.525	0.494	**1.000**	0.622	0.568	0.507	0.410	0.475	0.483	0.347
C09.10	0.501	0.480	0.380	0.534	0.547	0.610	0.511	0.522	0.622	**1.000**	0.603	0.609	0.434	0.531	0.449	0.399
C09.11	0.375	0.466	0.402	0.359	0.453	0.511	0.452	0.422	0.568	0.603	**1.000**	0.583	0.432	0.556	0.563	0.528
C09.12	0.470	0.443	0.331	0.521	0.480	0.567	0.508	0.386	0.507	0.609	0.583	**1.000**	0.524	0.583	0.618	0.466
C09.13	0.390	0.515	0.525	0.370	0.383	0.372	0.465	0.351	0.410	0.434	0.432	0.524	**1.000**	0.394	0.411	0.572
C09.14	0.292	0.398	0.396	0.363	0.507	0.481	0.506	0.344	0.475	0.531	0.556	0.583	0.394	**1.000**	0.535	0.594
C09.15	0.382	0.424	0.274	0.326	0.353	0.462	0.483	0.297	0.483	0.449	0.563	0.618	0.411	0.535	**1.000**	0.444
C09.16	0.176	0.356	0.431	0.277	0.328	0.209	0.413	0.456	0.347	0.399	0.528	0.466	0.572	0.594	0.444	**1.000**

Table 6.10: KMO and Bartlett's test for the level of awareness of sustainable construction practices

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.896
Bartlett's Test of Sphericity	Approx. Chi-Square	1243.265
	Df	120
	Sig.	0.000

Table 6.11: Rotated factor matrix[a] for the level of awareness of sustainable construction practices

	Factor		
	1	2	3
3D Printing (Additive Manufacturing)	**0.761**		
Industrialised Building System	**0.732**		
Building Information Modelling	**0.716**		
Internet of Things	**0.699**		
Lean Construction	**0.590**		
Design for Environment	**0.578**		
Life Cycle Costing		**0.842**	
Life Cycle Assessment		**0.821**	
Value Management		**0.792**	
Ecological economics		**0.609**	
Construction Ecology		**0.508**	
Biomimicry			**0.800**
Cradle to Cradle design			**0.651**
Blockchain Technology			**0.633**
Ecological Footprint			**0.572**
Nanotechnology			**0.454**
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalisation.a			
a. Rotation converged in 9 iterations.			

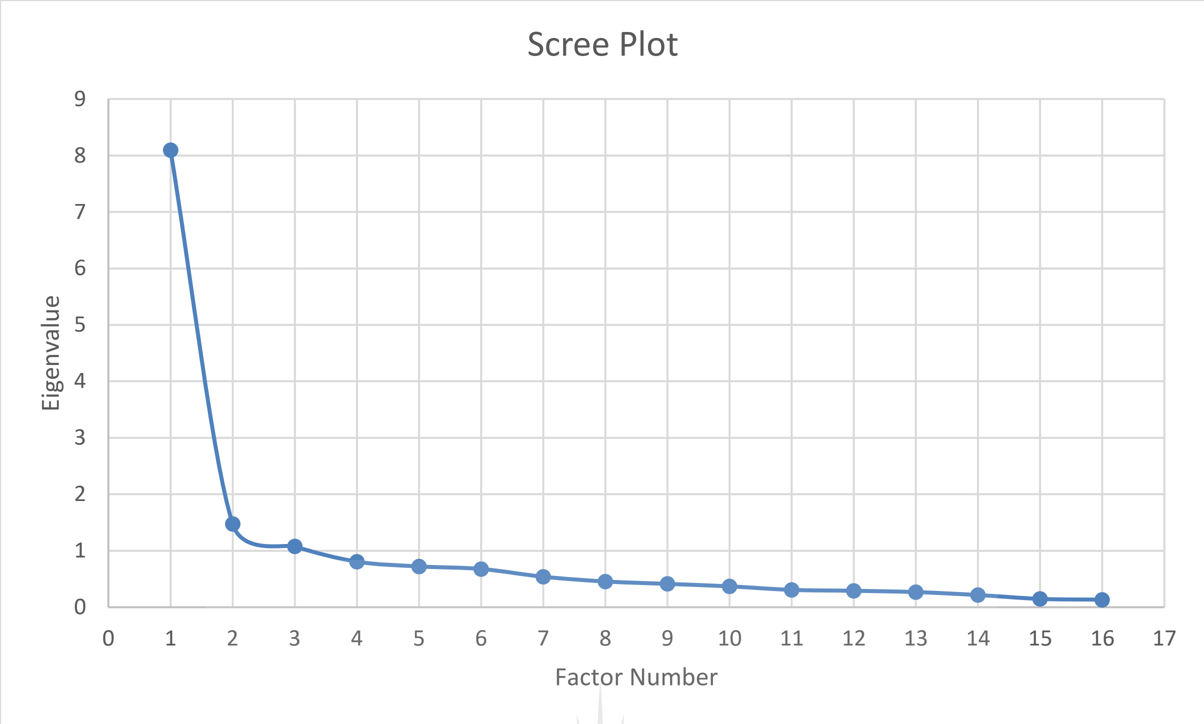


Figure 6.9: Scree plot for factor analysis for the level of awareness of sustainable construction practices

Table 6.12: Total variance explained for the level of awareness of sustainable construction practices

Factors	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	**8.094**	50.585	50.585	8.094	50.585	50.585	3.844	24.022	24.022
2	**1.476**	9.225	59.810	1.476	9.225	59.810	3.840	24.002	48.025
3	**1.076**	6.725	**66.534**	1.076	6.725	66.534	2.962	18.510	66.534
4	0.807	5.046	71.581						
5	0.723	4.518	76.099						
6	0.678	4.238	80.337						
7	0.540	3.375	83.712						
8	0.457	2.853	86.565						
9	0.413	2.584	89.149						
10	0.370	2.312	91.461						
11	0.307	1.921	93.382						
12	0.292	1.822	95.204						
13	0.268	1.678	96.882						
14	0.217	1.353	98.236						
15	0.148	0.924	99.160						
16	0.134	0.840	100.000						
Extraction Method: Principal Component Analysis.									

Principal axis factoring revealed the presence of three (3) factors with eigenvalues above one (1) as shown in Table 6.11. Based on the examination of the inherent relationships among the variables under each factor, the following interpretations were made: Factor 1 was termed **waste reducing practices**; Factor 2 **practices enhancing sustainable economics** and Factor 3 **nature inspired practices**. The names given to these factors were derived from a close examination of the variables within each of the factors. The variables contained within each of the three factors extracted are indicated below.

6.4.2.1 Factor 1: Waste reducing practices

As presented in Table 6.11, the six (6) sustainable construction practices for Factor 1 were *3D printing (additive manufacturing)* (76.1%), industrialised building system (73.2%), *building information modelling* (71.6%), Internet of Things (69.9%), lean construction (59%) and *design for environment* (57.8%). The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 6.8. This factor accounted for 50.585% of the variance.

6.4.2.3 Factor 2: Practices enhancing sustainable economics

As presented in Table 6.11, the six (6) sustainable construction practices for Factor 2 were *life cycle costing* (84.2%), *life cycle assessment* (82.1%), *value management* (79.2), *ecological economics* (60.9%) and *construction ecology* (50.8%). The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 7.8. This factor accounted for 9.225% of the variance.

6.4.2.3 Factor 3: Nature inspired practices

As presented in Table 6.11, the five (5) sustainable construction practices for Factor 3 were *biomimicry* (80%), *cradle-to-cradle design* (65.1%), *blockchain technology* (63.3%), *ecological footprint* (57.2%) and *nanotechnology* (45.4%). The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 7.8. This factor accounted for 6.725% of the variance.

6.5 SECTION D: BARRIERS TO THE ADOPTION AND IMPLEMENTATION OF SUSTAINABLE CONSTRUCTION PRACTICES

The results of section D of the questionnaire which identifies the barriers to the adoption and implementation of sustainable construction practices in the Zambian CI are presented in this section. The mean score (MS) of the questions, skewness, as well as the exploratory factor analysis (EFA) of the results, are also presented. The ranking of all the factors from the highest to the lowest is revealed through the descriptive results revealed in tabular form. Included in the table are the individual mean, standard deviation and non-parametric test results of the factors.

6.5.1 Results from Descriptive Analysis and Non- Parametric Test

The results of the MS of the questions, skewness of the data and Mann-Whitney U test are presented and discussed below in Table 6.13.

Table 6.13: Barriers to the adoption and implementation of sustainable construction practices

BARRIERS	MS	Standard Deviation	Mann-Whitney U	Asymp. Sig. (2-tailed)	RANK (R)
Lack of funds for research and development	4.07	1.089	1509.000	0.167	1
Corruption within the CI	4.02	1.253	1729.500	0.857	2
Poor implementation strategy	3.86	0.865	1745.500	0.924	3
Limited involvement of stakeholders	3.78	1.008	1397.500	0.047	4
High cost of sustainable technologies	3.73	1.143	1536.000	0.222	5
Lack of client demand for sustainable products or structures	3.66	1.154	1199.000	0.002	6
Lack of government support	3.62	1.195	1391.500	0.046	7
Stakeholders' resistance to change	3.61	1.079	1336.000	0.021	8
Lack of awareness	3.60	1.147	1738.000	0.894	9
High initial costs	3.60	1.197	1611.500	0.406	10
Lack of proper communication among stakeholders	3.57	1.004	1469.500	0.109	11
Lengthy implementation process of the new practices	3.53	1.187	1599.000	0.374	12
Lack of commitment among stakeholders	3.53	1.054	1700.500	0.739	13
Lack of incentives	3.48	1.248	1685.000	0.675	14
Limited knowledge on sustainable practices	3.38	1.281	1468.000	0.109	15
Lack of interest in the issue of sustainability	3.37	1.166	1670.500	0.604	16
Unsuitable procurement system selected for the project	3.30	1.226	1531.500	0.209	17
Lack of training and education	3.29	1.320	1613.000	0.417	18
Limited availability of sustainable products	3.25	1.108	1493.50	0.142	19
Poor integration of supply chain	3.23	1.097	1527.50	0.202	20
Absence of building codes and regulations	3.20	1.372	1456.50	0.098	21
Lack of measurement framework	3.15	1.104	1639.50	0.503	22
Unstable green market conditions	3.13	1.164	1421.00	0.063	23
Shortage of skilled personnel	2.93	1.148	1233.00	0.003	24
Lack of constructible (buildable) designs	2.86	1.300	1735.50	0.883	25

Table 6.13 reveals the respondents’ rankings of the barriers to the adoption and implementation of sustainable construction practices in the Zambian CI. The highest ranked was ‘lack of funds for research and development’ with a MS of 4.07, SD of 1.089, Mann-Whitney U 1509.000 and asymp.sig. value of 0.167, ‘corruption within the CI’ with a MS of 4.02, SD of 1.253, Mann-Whitney U 1729.500 and asymp.sig. value of 0.857 was ranked second, ‘poor implementation strategy’ with a MS of 3.86, SD of 0.865, Mann-Whitney U 1745.500 and asymp.sig. value of 0.924 was ranked third, ‘limited involvement of stakeholders’ was ranked fourth with a MS of 3.78, SD of 1.008, Mann-Whitney U 1397.500 and asymp.sig. value of 0.047, ‘high cost of sustainable technologies’ with a MS of 3.73, SD of 1.143, Mann-Whitney U 1536.000 and asymp.sig. value of 0.222 was ranked fifth, ‘lack of client demand for sustainable products or structures’ with a MS of 3.66, SD of 1.154, Mann-Whitney U 1199.000 and asymp.sig. value of 0.002 was ranked sixth, ‘lack of government support with a MS 3.62, SD of 1.195, Mann-Whitney U 1391.500 and asymp.sig. value of 0.046 was ranked seventh, ‘stakeholders’ resistance to change’ with a MS of 3.61, SD of 1.079, Mann-Whitney U 1336.000 and asymp.sig. value of 0.021 was ranked eighth and ‘lack of awareness’ with a MS of 3.60, SD 1.147, Mann-Whitney U 1738.000 and asymp.sig. value of 0.894 was ranked ninth.

In addition, ‘high initial costs’ with a MS of 3.60, SD of 1.197, Mann-Whitney U 1611.500 and asymp.sig. value of 0.406 was ranked tenth, ‘lack of proper communication among stakeholders’ with a MS of 3.57, SD of 1.004, Mann-Whitney U 1469.500 and asymp.sig. value of 0.109 was ranked eleventh, ‘lengthy implementation process of the new practices’ with a MS of 3.53, SD of 1.187, Mann-Whitney U 1599.000 and asymp.sig. value of 0.374 was ranked twelfth, lack of commitment among stakeholders with a MS of 3.53, SD of 1.054, Mann-Whitney U 1700.500 and asymp.sig. value of 0.739 was ranked thirteenth, ‘lack of incentives’ with a MS of 3.48, SD of 1.248, Mann-Whitney U 1685.000 and asymp.sig. value of 0.675 was ranked fourteenth, ‘limited knowledge on sustainable practices’ was ranked fifteenth with a MS of 3.38, SD of 1.281, Mann-Whitney U 1468.000 and asymp.sig. value of 0.109, ‘lack of interest in the issue of sustainability’ with a MS of 3.37, SD of 1.166, Mann-Whitney U 1670.500 and asymp.sig. value of 0.604 was ranked sixteenth and ‘unsuitable procurement system selected for the project’ with a MS of 3.30, SD of 1.226, Mann-Whitney U 1531.500 and asymp.sig. value of 0.209 was ranked seventeenth.

Furthermore, ‘lack of training and education’ with a of 3.29, SD of 1.320, Mann-Whitney U 1613.000 and asymp.sig. value of 0.417 was ranked eighteenth, ‘limited availability of sustainable products’ with a MS of 3.25, SD of 1.108, Mann-Whitney U 1493.500 and asymp.sig. value of 0.142 was ranked nineteenth, ‘poor integration of supply chain’ with a MS of 3.23, SD of 1.097, Mann-Whitney U 1527.500 and asymp.sig. value of 0.202 was ranked twentieth, ‘absence of building codes and regulation’ with a MS of 3.20, SD of 1.372, Mann-Whitney U 1456.500 and asymp.sig. value of 0.098 was ranked twenty-first, ‘lack of measurement framework’ with a MS of 3.15, SD of 1.104, Mann-Whitney U 1639.500 and asymp.sig. value of 0.503 was ranked twenty-second, ‘unstable green market conditions’ with a MS of 3.13, SD of 1.164, Mann-Whitney U 1421.000 and asymp.sig. value of 0.063 was ranked twenty-third, ‘shortage of skilled personnel’ with a MS of 2.93, SD of 1.148, Mann-Whitney U 1233.000 and asymp.sig. value of 0.003 was ranked twenty-fourth and lastly, ‘lack of constructible (buildable) designs’ with a MS of 2.86, SD of 1.300, Mann-Whitney U 1735.500 and asymp.sig. value of 0.883 was ranked twenty-fifth.

6.5.2 Results from Exploratory Factor Analysis (EFA)

The results from the EFA on the barriers to the adoption and implementation sustainable construction practices are presented in Tables 6.14 to 6.18 and Fig 6.10. The definitions of the identified variables are presented in Table 6.14.

Prior to performing the PCA, the suitability of the data for factor analysis was assessed. The inspection of the correlation matrix revealed the presence of coefficients of above 0.3 as presented in Table 6.15. As shown in Table 6.16, the KMO measure of sampling adequacy achieved a value of 0.777, exceeding the recommended minimum value of 0.6 and Bartlett’s test of sphericity was also statistically significant (less than 0.05), thus supporting the factorability of the correlation matrix.

The data was subjected to PCA (with varimax rotation). The eigenvalue was set at conventional high values of 1.0. As shown in Table 6.17, seven (7) factors with eigenvalues exceeding 1.0 were extracted. The scree plot presented in Fig 6.10 also revealed the excluded factors by indicating the cut-off point at which the eigenvalues levelled off. The total variance explained by each of the extracted factor is as follows: Factor 1 (30.384%), Factor 2 (10.237%), Factor 3 (8.688%), Factor 4 (6.425%), Factor 5 (5.157%), Factor 6 (4.589%) and Factor 7 (4.497%).

This is shown in Table 6.18. Thus, the final statistics of the PCA and the extracted factors accounted for approximately 70% of the total cumulative variance.

Table 6.14: Definition of identified barriers to the adoption and implementation of sustainable construction practices

Variable	Definition
D10.1	Lack of commitment among stakeholders
D10.2	Lack of proper communication among stakeholders
D10.3	Poor implementation strategy
D10.4	Lack of awareness
D10.5	Lack of constructible (buildable) designs
D10.6	Limited knowledge on sustainable practices
D10.7	Lack of training and education
D10.8	Shortage of skilled personnel
D10.9	Lack of measurement framework
D10.10	Limited involvement of stakeholders
D10.11	Stakeholders' resistance to change
D10.12	Lack of interest in the issue of sustainability
D10.13	Absence of building codes and regulations
D10.14	Lack of incentives
D10.15	Lack of government support
D10.16	Lack of funds for research and development
D10.17	High initial costs
D10.18	Unstable green market conditions
D10.19	Poor integration of supply chain
D10.20	Lengthy implementation process of the new practices
D10.21	Unsuitable procurement system selected for the project
D10.22	Limited availability of sustainable products
D10.23	Lack of client demand for sustainable products or structures
D10.24	Corruption within the CI
D10.25	High cost of sustainable technologies

Table 6.15: Correlation matrix of factor analysis for barriers to the adoption and implementation of sustainable construction practices

Correlation	D10.1	D10.2	D10.3	D10.4	D10.5	D10.6	D10.7	D10.8	D10.9	D10.10	D10.11	D10.12	D10.13	D10.14	D10.15	D10.16	D10.17	D10.18	D10.19	D10.20	D10.21	D10.22	D10.23	D10.24	D10.25
D10.1	**1.000**	0.510	0.454	0.247	0.236	0.193	0.198	0.179	0.223	0.477	0.465	0.538	0.335	0.164	0.443	0.056	0.263	-0.044	0.036	0.287	0.303	0.234	0.407	0.225	0.189
D10.2	0.510	**1.000**	0.415	0.400	0.346	0.283	0.294	0.140	0.394	0.402	0.249	0.279	0.185	0.226	0.234	0.245	0.225	0.191	0.301	0.217	0.182	0.178	0.308	0.190	0.293
D10.3	0.454	0.415	**1.000**	0.343	0.144	0.197	0.187	0.016	0.368	0.211	0.199	0.191	0.163	0.307	0.149	0.211	0.137	0.043	0.130	0.210	0.141	0.053	0.160	0.147	0.145
D10.4	0.247	0.400	0.343	**1.000**	0.438	0.694	0.617	0.319	0.276	0.230	0.121	0.149	0.074	0.215	0.190	0.240	0.080	0.219	0.310	0.098	0.128	0.332	0.315	0.131	0.301
D10.5	0.236	0.346	0.144	0.438	**1.000**	0.587	0.553	0.403	0.285	0.216	0.250	0.372	0.160	0.184	0.141	0.129	0.054	0.094	0.295	0.049	0.302	0.437	0.376	0.098	0.091
D10.6	0.193	0.283	0.197	0.694	0.587	**1.000**	0.776	0.489	0.358	0.270	0.154	0.238	0.195	0.290	0.142	0.213	0.132	0.366	0.432	0.247	0.221	0.394	0.315	0.145	0.144
D10.7	0.198	0.294	0.187	0.617	0.553	0.776	**1.000**	0.596	0.441	0.371	0.235	0.360	0.214	0.228	0.163	0.153	0.142	0.250	0.359	0.234	0.247	0.330	0.405	0.087	0.227
D10.8	0.179	0.140	0.016	0.319	0.403	0.489	0.596	**1.000**	0.503	0.366	0.306	0.358	0.449	0.033	0.157	0.096	0.197	0.112	0.143	0.178	0.296	0.338	0.301	0.121	0.219
D10.9	0.223	0.394	0.368	0.276	0.285	0.358	0.441	0.503	**1.000**	0.386	0.326	0.266	0.438	0.219	0.105	0.109	0.189	0.036	0.190	0.186	0.254	0.213	0.104	0.112	0.130
D10.10	0.477	0.402	0.211	0.230	0.216	0.270	0.371	0.366	0.386	**1.000**	0.362	0.436	0.350	0.321	0.397	0.179	0.296	0.124	0.143	0.293	0.209	0.249	0.383	0.180	0.263
D10.11	0.465	0.249	0.199	0.121	0.250	0.154	0.235	0.306	0.326	0.362	**1.000**	0.607	0.260	0.174	0.136	0.008	0.462	0.133	0.180	0.465	0.270	0.336	0.459	0.329	0.404
D10.12	0.538	0.279	0.191	0.149	0.372	0.238	0.360	0.358	0.266	0.436	0.607	**1.000**	0.386	0.236	0.308	0.059	0.273	0.049	0.231	0.311	0.152	0.230	0.314	0.115	0.212
D10.13	0.335	0.185	0.163	0.074	0.160	0.195	0.214	0.449	0.438	0.350	0.260	0.386	**1.000**	0.319	0.416	0.118	0.222	0.055	0.012	0.232	0.174	0.200	0.169	0.133	0.109
D10.14	0.164	0.226	0.307	0.215	0.184	0.290	0.228	0.033	0.219	0.321	0.174	0.236	0.319	**1.000**	0.249	0.445	0.300	0.241	0.246	0.358	0.078	0.303	0.244	0.064	0.137
D10.15	0.443	0.234	0.149	0.190	0.141	0.142	0.163	0.157	0.105	0.397	0.136	0.308	0.416	0.249	**1.000**	0.407	0.327	0.161	0.250	0.219	0.276	0.189	0.309	0.374	0.227
D10.16	0.056	0.245	0.211	0.240	0.129	0.213	0.153	0.096	0.109	0.179	0.008	0.059	0.118	0.445	0.407	**1.000**	0.306	0.274	0.389	0.280	0.165	0.302	0.287	0.266	0.293
D10.17	0.263	0.225	0.137	0.080	0.054	0.132	0.142	0.197	0.189	0.296	0.462	0.273	0.222	0.300	0.327	0.306	**1.000**	0.477	0.367	0.571	0.433	0.318	0.356	0.440	0.633
D10.18	-0.044	0.191	0.043	0.219	0.094	0.366	0.250	0.112	0.036	0.124	0.133	0.049	0.055	0.241	0.161	0.274	0.477	**1.000**	0.637	0.577	0.238	0.353	0.273	0.384	0.406
D10.19	0.036	0.301	0.130	0.310	0.295	0.432	0.359	0.143	0.190	0.143	0.180	0.231	0.012	0.246	0.250	0.389	0.367	0.637	**1.000**	0.509	0.231	0.348	0.349	0.310	0.241
D10.20	0.287	0.217	0.210	0.098	0.049	0.247	0.234	0.178	0.186	0.293	0.465	0.311	0.232	0.358	0.219	0.280	0.571	0.577	0.509	**1.000**	0.473	0.446	0.458	0.405	0.491
D10.21	0.303	0.182	0.141	0.128	0.302	0.221	0.247	0.296	0.254	0.209	0.270	0.152	0.174	0.078	0.276	0.165	0.433	0.238	0.231	0.473	**1.000**	0.389	0.376	0.486	0.313
D10.22	0.234	0.178	0.053	0.332	0.437	0.394	0.330	0.338	0.213	0.249	0.336	0.230	0.200	0.303	0.189	0.302	0.318	0.353	0.348	0.446	0.389	**1.000**	0.588	0.223	0.399
D10.23	0.407	0.308	0.160	0.315	0.376	0.315	0.405	0.301	0.104	0.383	0.459	0.314	0.169	0.244	0.309	0.287	0.356	0.273	0.349	0.458	0.376	0.588	**1.000**	0.192	0.482
D10.24	0.225	0.190	0.147	0.131	0.098	0.145	0.087	0.121	0.112	0.180	0.329	0.115	0.133	0.064	0.374	0.266	0.440	0.384	0.310	0.405	0.486	0.223	0.192	**1.000**	0.355
D10.25	0.189	0.293	0.145	0.301	0.091	0.144	0.227	0.219	0.130	0.263	0.404	0.212	0.109	0.137	0.227	0.293	0.633	0.406	0.241	0.491	0.313	0.399	0.482	0.355	**1.000**

Table 6.16: KMO and Bartlett's test for barriers to the adoption and implementation of sustainable construction practices

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.777
Bartlett's Test of Sphericity	Approx. Chi-Square	1609.334
	Df	300
	Sig.	0.000

Table 6.17: Rotated factor matrix [a] for barriers to the adoption and implementation of sustainable construction practices

	Factors						
	1	2	3	4	5	6	7
Limited knowledge on sustainable practices	**0.837**						
Lack of training and education	**0.802**						
Lack of constructible (buildable) designs	**0.751**						
Lack of awareness	**0.743**						
Limited availability of sustainable products	**0.459**						
Unstable green market conditions		**0.811**					
Lengthy implementation process of the new practices		**0.771**					
High initial costs		**0.676**					
Poor integration of supply chain		**0.658**					
High cost of sustainable technologies		**0.575**					
Stakeholders' resistance to change			**0.733**				
Lack of interest in the issue of sustainability			**0.709**				
Lack of commitment among stakeholders			**0.660**				
Lack of client demand for sustainable products or structures			**0.614**				
Limited involvement of stakeholders			**0.471**				
Absence of building codes and regulations				**0.737**			
Lack of measurement framework				**0.716**			
Shortage of skilled personnel				**0.607**			
Poor implementation strategy					**0.819**		
Lack of proper communication among stakeholders					**0.684**		
Lack of government support						**0.752**	
Lack of funds for research and development						**0.695**	
Lack of incentives						**0.519**	
Corruption within the construction industry							**0.696**
Unsuitable procurement system selected for the project							**0.683**
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalisation.[a]							

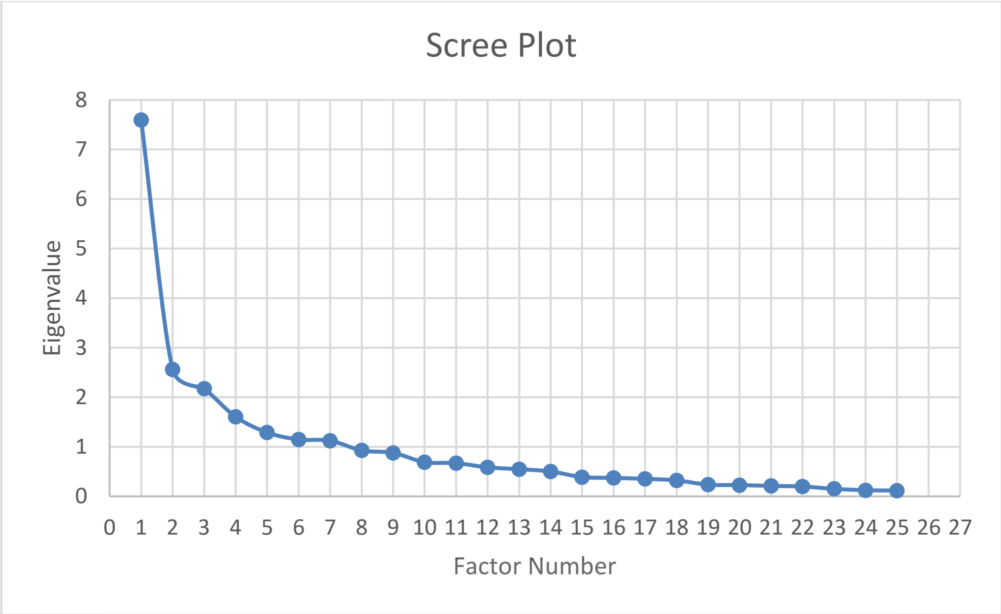


Figure 6.10: Scree plot for factor analysis for barriers to the adoption and implementation of sustainable construction practices

Table 6.18: Total variance explained for barriers to the adoption and implementation of sustainable construction practices

Factors	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	**7.596**	30.384	30.384	7.596	30.384	30.384	3.587	14.346	14.346
2	**2.559**	10.237	40.621	2.559	10.237	40.621	3.487	13.947	28.293
3	**2.172**	8.688	49.309	2.172	8.688	49.309	2.947	11.788	40.081
4	**1.606**	6.425	55.735	1.606	6.425	55.735	2.033	8.134	48.215
5	**1.289**	5.157	60.892	1.289	5.157	60.892	1.960	7.840	56.055
6	**1.147**	4.589	65.481	1.147	4.589	65.481	1.838	7.351	63.406
7	**1.124**	4.497	**69.979**	1.124	4.497	69.979	1.643	6.573	69.979
8	0.927	3.707	73.686						
9	0.878	3.511	77.196						
10	0.691	2.762	79.959						
11	0.671	2.683	82.641						
12	0.585	2.341	84.982						
13	0.549	2.196	87.178						
14	0.502	2.009	89.187						
15	0.389	1.555	90.742						
16	0.372	1.488	92.230						
17	0.354	1.416	93.646						
18	0.322	1.289	94.935						
19	0.236	0.942	95.878						
20	0.228	0.912	96.790						
21	0.211	0.842	97.632						
22	0.199	0.795	98.427						
23	0.151	0.605	99.032						
24	0.124	0.497	99.529						
25	0.118	0.471	100.000						
Extraction Method: Principal Component Analysis.									

Principal axis factoring revealed the presence of seven (7) factors with eigenvalues above 1 as shown in Table 6.17. Based on the examination of the inherent relationships among the variables under each factor, the following interpretations were made. Factor 1 was termed as **knowledge and awareness barriers**; Factor 2 was termed as **market-related barriers**, Factor 3 **stakeholder-related barriers**, Factor 4 was termed as **regulatory and manpower-related barriers**, Factor 5 was termed as **communication and implementation-related barriers**, Factor 6 was termed as **government-related** and factor 7 was termed as **corruption and procurement-related barriers**. The names given to these factors were derived from a close examination of the variables within each of the factors. The variables within each of the seven factors extracted are explained below.

6.5.2.1 Factor 1: Knowledge and awareness barriers

As presented in Table 6.17, the five (5) extracted barriers for Factor 1 were *limited knowledge on sustainable practices* (83.7%), *lack of training and education* (80.2%), *lack of constructible (buildable) designs* (75.1%), *lack of awareness* (74.3%) and *limited availability of sustainable products* (45.9%). The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 6.14. This factor accounted for 30.384 % of the variance.

6.5.2.2 Factor 2: Market-related barriers

As presented in Table 6.17, the five (5) extracted barriers for Factor 2 were *unstable green market conditions* (81.1%), *lengthy implementation process of the new practices* (77.1%), *high initial costs* (67.6%), *poor integration of supply chain* (65.8%) and *high cost of sustainable technologies* (57.5%). The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 6.14. This factor accounted for 10.237% of the variance.

6.5.2.3 Factor 3: Stakeholder-related barriers

As presented in Table 6.17, the five (5) extracted barriers for Factor 3 were *stakeholders' resistance to change* (73.3%), *lack of interest in the issue of sustainability* (70.9%), *lack of commitment among stakeholders* (66%), *lack of client demand for sustainable products or structures* (61.4%) and *limited involvement of stakeholders* (47.1%). The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 6.14. This factor accounted for 8.688% of the variance.

6.5.2.4 Factor 4: Regulatory barriers

As presented in Table 6.17, the three (3) extracted barriers for Factor 3 were *absence of building codes and regulations* (73.7%), *lack of measurement framework* (71.6%) and *shortage of skilled personnel* (60.7%) The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 6.14. This factor accounted for 6.425% of the variance.

6.5.2.5 Factor 5: Communication and implementation-related barriers

As presented in Table 6.17, the two (2) extracted barriers for Factor 5 were *poor implementation strategy* (81.9%) and *lack of proper communication among stakeholders* (68.4%). The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 6.14. This factor accounted for 5.157% of the variance.

6.5.2.6 Factor 6: Government-related barriers

As presented in Table 6.17, the three (3) extracted barriers for Factor 6 were *lack of government support* (75.2%), *lack of funds for research and development* (69.5%) and *lack of incentives* (51.9%). The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 6.14. This factor accounted for 4.589 % of the variance.

6.5.2.7 Factor 7: Corruption and procurement related barriers

As presented in Table 6.17, the two (2) extracted barriers for Factor 7 were *corruption within the construction industry* (69.6%) and *unsuitable procurement system selected for the project* (68.3%) The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 6.14. This factor accounted for 4.497 % of the variance.

6.6 SECTION E: BENEFITS OF ADOPTING AND IMPLEMENTING SUSTAINABLE CONSTRUCTION PRACTICES

The results of section E of the questionnaire which determines the benefits of adopting and implementing sustainable construction practices in the Zambian CI are presented in this section. The mean score (MS) of the questions, skewness, as well as the exploratory factor analysis (EFA) of the results, are also presented. The ranking of all the factors from the highest to the lowest is revealed through the descriptive results revealed in tabular form. Included in the table are the individual mean, standard deviation and non-parametric test results of the factors.

6.6.1 Results from Descriptive Analysis and Non- Parametric Test

The results of the MS of the questions, skewness of the data and Mann-Whitney U test are presented and discussed below.

Table 6.19: Benefits of adopting and implementing sustainable construction practices

BENEFITS	MS	Standard Deviation	Mann-Whitney U	Asymp. Sig. (2-tailed)	(R)
Reduced energy consumption	3.99	1.032	1546.000	0.231	1
Promotes the use of local sustainable materials	3.97	1.075	1619.500	0.428	2
Improves site health and safety	3.92	1.049	1535.500	0.214	3
Improves the overall quality of life	3.91	1.012	1671.000	0.615	4
Reduced waste generation	3.91	1.128	1654.500	0.552	5
Increased use of green construction materials	3.90	0.999	1588.500	0.339	6
Reduced emission of greenhouse gases	3.89	1.074	1754.000	0.963	7
Improved water quality	3.89	1.043	1533.500	0.211	8
Increased demand for green construction materials	3.87	1.020	1582.500	0.320	9
Increased protection of ecosystem	3.86	1.023	1633.000	0.474	10
Creates market for green products and services	3.85	1.042	1556.500	0.260	11
Improved air quality	3.80	1.090	1612.000	0.410	12
Enhances sustainable economic growth	3.76	0.928	1545.000	0.237	13
Reduced reliance on non-renewable resources	3.76	1.037	1491.000	0.137	14
Improved building performance	3.69	1.053	1660.500	0.580	15
Enhances project quality	3.67	1.000	1663.000	0.586	16
Optimises life-cycle economic performance	3.67	1.048	1666.500	0.598	17
Reduction in the structure’s carbon footprint	3.62	1.023	1686.000	0.673	18
Higher customer satisfaction	3.60	1.147	1694.000	0.707	19
Enhances project efficiency	3.57	1.028	1597.500	0.366	20
Reduced operating costs	3.52	1.137	1693.500	0.706	21
Reduction in maintenance costs	3.48	1.173	1722.500	0.826	22
Positively impacts property value	3.46	1.022	1676.500	0.640	23
Increased productivity of building occupant	3.45	1.021	1622.500	0.440	24
Enhances competitiveness	3.33	1.087	1736.500	0.886	25
Reduction in construction time	3.19	1.195	1593.000	0.347	26

Table 6.19 reveals the respondents' rankings of the benefits of adopting and implementing sustainable construction practices. The highest ranked was 'reduced energy consumption' with a MS of 3.99 and standard deviation (SD) of 1.032, Mann-Whitney U 1546.000 and asymp.sig. value of 0.231 'promotes the use of local sustainable materials' with a MS of 3.97, SD of 1.075, Mann-Whitney U 1619.500 asymp.sig. value of 0.428was ranked second, 'improves site health and safety' with a MS of 3.92, SD of 1.049, Mann-Whitney U 1535.500 and asymp.sig. value of 0.214 was ranked third, 'improves the overall quality of life' with a MS of 3.91 and SD of 1.012, Mann-Whitney U 1671.000 and asymp.sig. value of 0.615was ranked fourth, with a MS of 3.91, SD of 1.128, Mann-Whitney U1654.500 and asymp.sig. value of 0.552 'reduced waste generation' was ranked fifth, 'increased use of green construction materials' with a MS of 3.90, SD of 0.999 Mann-Whitney U 1588.500 and asymp.sig. value of 0.339was ranked sixth, reduced emission of greenhouse gases with MS of 3.89, SD of 1.074 Mann-Whitney U 1754.000 and asymp.sig. value of 0.963 was ranked seventh, 'improved water quality' with a MS 3.89, SD of 1.043 Mann-Whitney U 1533.500 and asymp.sig. value of 0.211 was ranked eighth and 'increased demand for green construction materials' with a MS of 3.87, SD of 1.020, Mann-Whitney U 1582.500 and asymp.sig. value of 0.320 was ranked ninth.

In addition, 'increased protection of ecosystem' with a MS of 3.86, SD of 1.023, Mann-Whitney U 1633.000 and asymp.sig. value of 0.474 was ranked tenth, 'creates market for green products and services' with a MS of 3.85 and SD of 1.042 Mann-Whitney U 1556.500 and asymp.sig. value of 0.260 was ranked eleventh, 'improved air quality' with a MS of 3.80, SD of 1.090, Mann-Whitney U 1612.000 and asymp.sig. value of 0.410 was ranked twelfth, 'enhances sustainable economic growth' with a MS of 3.76 and SD of 0.928 Mann-Whitney U 1545.00 and asymp.sig. value of 0.237 was ranked thirteenth, 'reduced reliance on non-renewable resources' with a MS of 3.76, SD of 1.037, Mann-Whitney U 1491.000 and asymp.sig. value of 0.137 was ranked fourteenth, 'improved building performance' with a MS of 3.69 and SD of 1.053 Mann-Whitney U 1660.50 and asymp.sig. value of 0.580 was ranked fifteenth, 'enhances project quality' with a MS of 3.67 and SD of 1.000, Mann-Whitney U 1663.00 and asymp.sig. value of 0.568 was ranked sixteenth and 'optimises life-cycle economic performance' with a MS of 3.67, SD of 1.048, Mann-Whitney U 1666.50 and asymp.sig. value of 0.598 was ranked seventeenth.

Furthermore, 'reduction in the structure's carbon footprint' with a MS of 3.62 and SD of 1.023, Mann-Whitney U 1686.00 and asymp.sig. value of 0.673 was ranked eighteenth, 'higher customer satisfaction' with a MS of 3.60 and SD of 1.147, Mann-Whitney U 1694.00 and asymp.sig. value of 0.707 was ranked nineteenth, 'enhances project efficiency' with a MS of 3.57 and SD 1.028, Mann-Whitney U 1597.50 and asymp.sig. value of 0.366 was ranked twentieth, 'reduced operating costs' with a MS of 3.52, SD of 1.137, Mann-Whitney U 1693.50 and asymp.sig. value of 0.706 was ranked twenty-first, 'reduction in maintenance costs' with a MS of 3.48, SD of 1.173, Mann-Whitney U 1722.50 and asymp.sig. value of 0.826 was ranked twenty-second, 'positively impacts property value' with a mean value of 3.46, SD of 1.022, Mann-Whitney U 1676.50 and asymp.sig. value of 0.640 was ranked twenty-third, 'increased productivity of building occupant' with a MS of 3.45, SD of 1.021 Mann-Whitney U 1622.50 and asymp.sig. value of 0.440 was ranked twenty-fourth, 'enhances competitiveness' with a MS of 3.33, SD of 1.087, Mann-Whitney U 1736.50 and asymp.sig. value of 0.886 was ranked twenty-fifth and 'reduction in construction time' with a MS of 3.19, SD of 1.195 Mann-Whitney U 1593.00 and asymp.sig. value of 0.374 was ranked twenty-sixth.

6.6.2 Results from Exploratory Factor Analysis

The results from the EFA on the adverse impacts of construction activities are presented in Tables 6.20 to 6.24 and Fig 6.11. The definitions of the identified variables are presented in Table 6.20.

Prior to performing the PCA, the suitability of the data for factor analysis was assessed. Inspection of the correlation matrix revealed the presence of coefficients of above 0.3 as presented in Table 6.21. As shown in Table 6.22, the KMO measure of sampling adequacy achieved a value of 0.908, exceeding the recommended minimum value of 0.6 and Bartlett's test of sphericity was also statistically significant (less than 0.05), thus supporting the factorability of the correlation matrix.

The data was subjected to PCA (with varimax rotation). The eigenvalue was set at conventional high values of 1.0. As shown in Table 6.24, four (4) factors with eigenvalues exceeding 1.0 were extracted. The scree plot presented in Fig 6.11 also revealed the excluded factors by indicating the cut-off point at which the eigenvalues levelled off. The total variance explained by each of the extracted factor is as follows: Factor 1 (51.667%), Factor 2 (9.066%), Factor 3 (5.369%) and Factor 4 (4.613%). This is shown in Table 7.25. Thus, the final statistics of the

PCA and the extracted factors accounted for approximately 71% of the total cumulative variance.

Table 6.20: Definition of identified benefits of adopting and implementing sustainable construction practices

Variable	Definition
E11.1	Reduced waste generation
E11.2	Reduced energy consumption
E11.3	Improved air quality
E11.4	Improved water quality
E11.5	Reduced emission of greenhouse gases
E11.6	Increased protection of ecosystem
E11.7	Reduced reliance on non-renewable resources
E11.8	Reduction in the structure's carbon footprint
E11.9	Increased demand for green construction materials
E11.10	Increased use of green construction materials
E11.11	Improved building performance
E11.12	Increased productivity of building occupant
E11.13	Reduction in construction time
E11.14	Positively impacts property value
E11.15	Reduction in maintenance costs
E11.16	Reduced operating costs
E11.17	Enhances competitiveness
E11.18	Enhances sustainable economic growth
E11.19	Creates market for green products and services
E11.20	Optimises life-cycle economic performance
E11.21	Enhances project efficiency
E11.22	Enhances project quality
E11.23	Higher customer satisfaction
E11.24	Improves site health and safety
E11.25	Improves the overall quality of life
E11.26	Promotes the use of local sustainable materials

Table 6.21: Correlation matrix of factor analysis for benefits of adopting and implementing sustainable construction practices

Correlation	E11.1	E11.2	E11.3	E11.4	E11.5	E11.6	E11.7	E11.8	E11.9	E11.10	E11.11	E11.12	E11.13	E11.14	E11.15	E11.16	E11.17	E11.18	E11.19	E11.20	E11.21	E11.22	E11.23	E11.24	E11.25	E11.26
E11.1	**1.000**	0.808	0.764	0.666	0.592	0.633	0.483	0.479	0.492	0.469	0.463	0.394	0.368	0.423	0.420	0.456	0.334	0.477	0.502	0.520	0.494	0.443	0.361	0.448	0.478	0.563
E11.2	0.808	**1.000**	0.747	0.621	0.618	0.648	0.593	0.490	0.501	0.496	0.545	0.395	0.316	0.466	0.358	0.398	0.304	0.421	0.483	0.494	0.511	0.502	0.423	0.465	0.474	0.521
E11.3	0.764	0.747	**1.000**	0.780	0.609	0.671	0.534	0.486	0.488	0.512	0.541	0.432	0.404	0.493	0.414	0.441	0.385	0.450	0.461	0.541	0.578	0.507	0.475	0.578	0.575	0.558
E11.4	0.666	0.621	0.780	**1.000**	0.602	0.544	0.488	0.404	0.437	0.442	0.511	0.511	0.328	0.442	0.414	0.466	0.410	0.495	0.427	0.474	0.551	0.505	0.544	0.438	0.547	0.513
E11.5	0.592	0.618	0.609	0.602	**1.000**	0.776	0.652	0.632	0.591	0.629	0.518	0.474	0.331	0.339	0.238	0.344	0.250	0.480	0.562	0.505	0.445	0.483	0.421	0.388	0.455	0.469
E11.6	0.633	0.648	0.671	0.544	0.776	**1.000**	0.740	0.676	0.640	0.609	0.519	0.480	0.394	0.386	0.318	0.461	0.302	0.418	0.554	0.497	0.438	0.472	0.417	0.444	0.475	0.477
E11.7	0.483	0.593	0.534	0.488	0.652	0.740	**1.000**	0.709	0.658	0.647	0.507	0.430	0.363	0.385	0.374	0.401	0.312	0.439	0.526	0.490	0.455	0.506	0.475	0.453	0.373	0.504
E11.8	0.479	0.490	0.486	0.404	0.632	0.676	0.709	**1.000**	0.617	0.545	0.465	0.393	0.431	0.483	0.263	0.321	0.380	0.410	0.575	0.431	0.380	0.452	0.412	0.348	0.398	0.372
E11.9	0.492	0.501	0.488	0.437	0.591	0.640	0.658	0.617	**1.000**	0.830	0.539	0.422	0.495	0.455	0.378	0.402	0.419	0.535	0.658	0.477	0.403	0.444	0.449	0.376	0.421	0.456
E11.10	0.469	0.496	0.512	0.442	0.629	0.609	0.647	0.545	0.830	**1.000**	0.607	0.514	0.417	0.433	0.379	0.380	0.372	0.527	0.692	0.521	0.417	0.464	0.441	0.386	0.465	0.551
E11.11	0.463	0.545	0.541	0.511	0.518	0.519	0.507	0.465	0.539	0.607	**1.000**	0.716	0.481	0.572	0.484	0.503	0.458	0.440	0.395	0.416	0.548	0.554	0.580	0.463	0.454	0.451
E11.12	0.394	0.395	0.432	0.511	0.474	0.480	0.430	0.393	0.422	0.514	0.716	**1.000**	0.519	0.545	0.465	0.513	0.402	0.376	0.405	0.448	0.476	0.429	0.551	0.436	0.479	0.375
E11.13	0.368	0.316	0.404	0.328	0.331	0.394	0.363	0.431	0.495	0.417	0.481	0.519	**1.000**	0.721	0.625	0.535	0.608	0.324	0.361	0.472	0.503	0.495	0.526	0.494	0.520	0.359
E11.14	0.423	0.466	0.493	0.442	0.339	0.386	0.385	0.483	0.455	0.433	0.572	0.545	0.721	**1.000**	0.648	0.588	0.615	0.352	0.414	0.481	0.581	0.578	0.567	0.506	0.528	0.375
E11.15	0.420	0.358	0.414	0.414	0.238	0.318	0.374	0.263	0.378	0.379	0.484	0.465	0.625	0.648	**1.000**	0.825	0.581	0.448	0.289	0.460	0.536	0.524	0.563	0.496	0.489	0.544
E11.16	0.456	0.398	0.441	0.466	0.344	0.461	0.401	0.321	0.402	0.380	0.503	0.513	0.535	0.588	0.825	**1.000**	0.555	0.440	0.261	0.423	0.554	0.567	0.625	0.487	0.501	0.514
E11.17	0.334	0.304	0.385	0.410	0.250	0.302	0.312	0.380	0.419	0.372	0.458	0.402	0.608	0.615	0.581	0.555	**1.000**	0.529	0.393	0.574	0.533	0.602	0.604	0.480	0.530	0.420
E11.18	0.477	0.421	0.450	0.495	0.480	0.418	0.439	0.410	0.535	0.527	0.440	0.376	0.324	0.352	0.448	0.440	0.529	**1.000**	0.639	0.650	0.534	0.539	0.453	0.370	0.531	0.605
E11.19	0.502	0.483	0.461	0.427	0.562	0.554	0.526	0.575	0.658	0.692	0.395	0.405	0.361	0.414	0.289	0.261	0.393	0.639	**1.000**	0.599	0.327	0.374	0.337	0.352	0.418	0.460
E11.20	0.520	0.494	0.541	0.474	0.505	0.497	0.490	0.431	0.477	0.521	0.416	0.448	0.472	0.481	0.460	0.423	0.574	0.650	0.599	**1.000**	0.636	0.622	0.474	0.554	0.618	0.629
E11.21	0.494	0.511	0.578	0.551	0.445	0.438	0.455	0.380	0.403	0.417	0.548	0.476	0.503	0.581	0.536	0.554	0.533	0.534	0.327	0.636	**1.000**	0.844	0.695	0.596	0.614	0.593
E11.22	0.443	0.502	0.507	0.505	0.483	0.472	0.506	0.452	0.444	0.464	0.554	0.429	0.495	0.578	0.524	0.567	0.602	0.539	0.374	0.622	0.844	**1.000**	0.771	0.597	0.583	0.551
E11.23	0.361	0.423	0.475	0.544	0.421	0.417	0.475	0.412	0.449	0.441	0.580	0.551	0.526	0.567	0.563	0.625	0.604	0.453	0.337	0.474	0.695	0.771	**1.000**	0.638	0.637	0.518
E11.24	0.448	0.465	0.578	0.438	0.388	0.444	0.453	0.348	0.376	0.386	0.463	0.436	0.494	0.506	0.496	0.487	0.480	0.370	0.352	0.554	0.596	0.597	0.638	**1.000**	0.654	0.562
E11.25	0.478	0.474	0.575	0.547	0.455	0.475	0.373	0.398	0.421	0.465	0.454	0.479	0.520	0.528	0.489	0.501	0.530	0.531	0.418	0.618	0.614	0.583	0.637	0.654	**1.000**	0.757
E11.26	0.563	0.521	0.558	0.513	0.469	0.477	0.504	0.372	0.456	0.551	0.451	0.375	0.359	0.375	0.544	0.514	0.420	0.605	0.460	0.629	0.593	0.551	0.518	0.562	0.757	**1.000**

Table 6.22: KMO and Bartlett's test for benefits of adopting and implementing sustainable construction practices

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.908
Bartlett's Test of Sphericity	Approx. Chi-Square	2777.097
	Df	325
	Sig.	0.000

Table 6.23: Rotated factor matrix[a] for benefits of adopting and implementing sustainable construction practices

	Factors			
	1	2	3	4
Positively impacts property value	**0.777**			
Reduction in maintenance costs	**0.764**			
Reduction in construction time	**0.760**			
Reduced operating costs	**0.736**			
Higher customer satisfaction	**0.686**			
Enhances competitiveness	**0.654**			
Increased productivity of building occupant	**0.613**			
Improved building performance	**0.588**			
Enhances project quality	**0.570**			
Enhances project efficiency	**0.557**			
Improves site health and safety	**0.504**			
Increased demand for green construction materials		**0.793**		
Increased use of green construction materials		**0.770**		
Creates market for green products and services		**0.733**		
Reduction in the structure's carbon footprint		**0.718**		
Reduced reliance on non-renewable resources		**0.669**		
Increased protection of ecosystem		**0.631**		
Reduced emission of greenhouse gases		**0.622**		
Improved air quality			**0.778**	
Reduced energy consumption			**0.763**	
Reduced waste generation			**0.745**	
Improved water quality			**0.704**	
Enhances sustainable economic growth				**0.710**
Optimises life-cycle economic performance				**0.685**
Promotes the use of local sustainable materials				**0.671**
Improves the overall quality of life				**0.593**
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalisation.[a]				

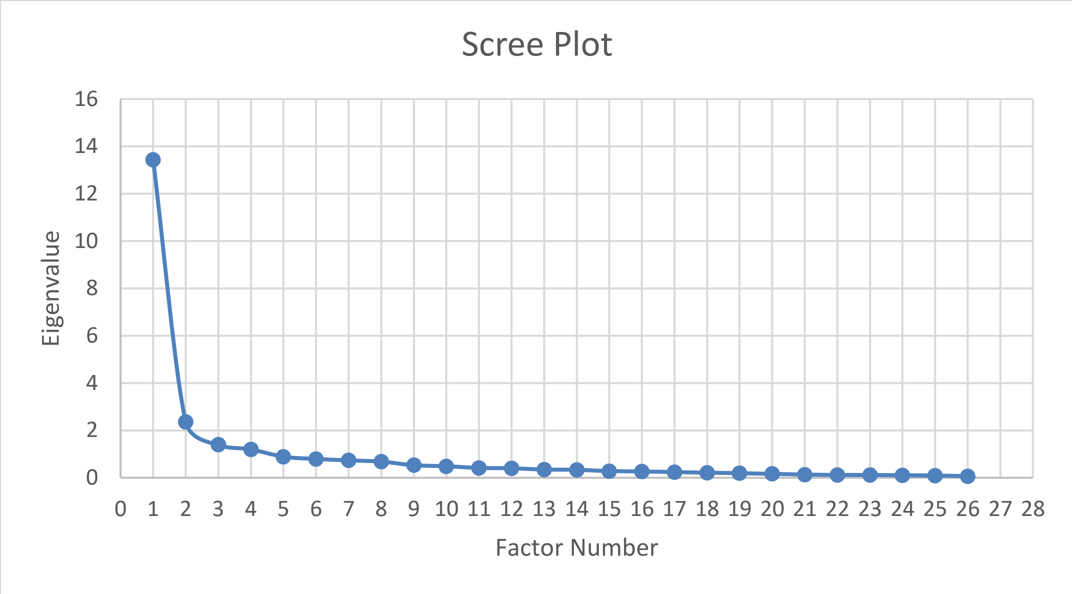


Figure 6.11: Scree plot for factor analysis for benefits of adopting and implementing sustainable construction practices

Table 6.24: Total variance explained for benefits of adopting and implementing sustainable construction practices

Factors	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	**13.433**	51.667	51.667	13.433	51.667	51.667	5.755	22.135	22.135
2	**2.357**	9.066	60.733	2.357	9.066	60.733	4.767	18.336	40.471
3	**1.396**	5.369	66.102	1.396	5.369	66.102	4.350	16.729	57.200
4	**1.199**	4.613	**70.715**	1.199	4.613	70.715	3.514	13.516	70.715
5	0.888	3.414	74.129						
6	0.794	3.055	77.184						
7	0.735	2.826	80.009						
8	0.680	2.617	82.626						
9	0.530	2.037	84.664						
10	0.485	1.867	86.531						
11	0.417	1.604	88.134						
12	0.399	1.536	89.670						
13	0.348	1.339	91.009						
14	0.334	1.286	92.296						
15	0.282	1.085	93.381						
16	0.267	1.027	94.407						
17	0.239	0.920	95.327						

18	0.214	0.822	96.150						
19	0.192	0.739	96.888						
20	0.165	0.633	97.522						
21	0.135	0.520	98.041						
22	0.119	0.458	98.500						
23	0.119	0.456	98.956						
24	0.108	0.415	99.371						
25	0.095	0.364	99.735						
26	0.069	0.265	100.000						
Extraction Method: Principal Component Analysis.									

Principal axis factoring revealed the presence of four (4) factors with eigenvalues above 1 as shown in Table 6.23. Based on the examination of the inherent relationships among the variables under each factor, the following interpretations were made. Factor 1 was termed as **project benefits**; Factor 2 was termed as **green material benefits**; Factor 3 **improved resource optimisation** and Factor 4 was termed as **sustainable economy**. The names given to these factors were derived from a close examination of the variables within each of the factors. The constituent indicators of each of the four factors extracted are explained below.

6.6.2.1 Factor 1: Project benefits

As presented in Table 6.23, the eleven (11) extracted benefits for Factor 1 were *positively impacts property value* (77.7%), *reduction in maintenance costs* (76.4%), *reduction in construction time* (76.0%), *reduced operating costs* (73.6%), *higher customer satisfaction* (68.6%), *enhances competitiveness* (65.4%), *increased productivity of building occupant* (61.3%), *improved building performance* (58.8%), *enhances project quality* (57.0%), *enhances project efficiency* (55.7%) and *improves site health and safety* (50.4%). The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 6.20. This factor accounted for 51.667% of the variance.

6.6.2.2 Factor 2: Green material benefits

As presented in Table 6.23, the seven (7) extracted benefits for Factor 2 were *increased demand for green construction materials* (79.3%), *increased use of green construction materials* (77.0%), *creates market for green products and services* (73.3%), *reduction in the structure's carbon footprint* (71.8%), *reduced reliance on non-renewable resources* (66.9%), *increased* *protection of ecosystem* (63.1%), *reduced emission of greenhouse gases* (62.2%).The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 6.20. This factor accounted for 9.066% of the variance.

6.6.2.3 Factor 3: Resource optimisation

As presented in Table 6.23, the four (4) extracted benefits for Factor 3 were *improved air quality* (77.8%), *reduced energy consumption* (76.3%), *reduced waste generation* (74.5%) and *improved water quality* (70.4%). The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 6.20. This factor accounted for 5.369% of the variance.

6.6.2.4 Factor 4: Sustainable economy

As presented in Table 6.23, the four (4) extracted benefits for Factor 4 were *enhances sustainable economic growth* (71%), *optimises life-cycle economic performance* (68.5%), *promotes the use of local sustainable materials* (67.1%) *and improves the overall quality of life* (59.3%). The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 6.20. This factor accounted for 5.369% of the variance.

6.7 SECTION F: DRIVERS TO THE ADOPTION AND IMPLEMENTATION OF SUSTAINABLE CONSTRUCTION PRACTICES IN ZAMBIA

This section presents the results of section F of the questionnaire which determines the drivers to the adoption and implementation of sustainable construction practices in the Zambian CI. The mean score (MS) of the questions, skewness, as well as the exploratory factor analysis (EFA) of the results, are presented. The ranking of all the factors from the highest to the lowest is revealed through the descriptive results revealed in tabular form. Included in the table are the individual mean, standard deviation and non-parametric test results of the factors.

6.7.1 Results from Descriptive Analysis and Non- Parametric Test

The results of the MS of the questions, skewness of the data and Mann-Whitney U test are presented and discussed below.

Table 6.25: Drivers for the adoption and implementation of sustainable construction practices

DRIVERS	MS	Standard Deviation	Mann-Whitney U	Asymp. Sig. (2-tailed)	RANK (R)
Government support	4.31	0.901	1734.500	0.875	1
Development of sustainability measurement standards	4.28	0.846	1523.000	0.173	2
Training of skilled and unskilled workers in Sustainable Development	4.26	0.821	1499.000	0.130	3
Continuous professional development in Sustainable Development	4.24	0.814	1716.000	0.792	4
Enforcement of implementation standards	4.23	0.898	1729.500	0.850	5
Inclusion of sustainable practices in university syllabi	4.21	0.902	1737.500	0.889	6
Increased client and stakeholder awareness	4.20	0.778	1713.000	0.782	7
Increased funding for research and development	4.19	0.894	1593.000	0.336	8
Formulation of implementation policies and regulations	4.11	1.019	1573.500	0.298	9
Increased client demand	4.10	0.885	1681.500	0.652	10
Efficient market for green products and services	4.06	0.846	1744.000	0.918	11
Improved efficiency of sustainable products and services	4.04	0.837	1663.000	0.580	12
Increased supply of green materials	4.03	0.862	1727.000	0.836	13
Introduction of economic incentives	4.02	0.881	1667.500	0.595	14
Change in the organisational and stakeholder attitude	4.01	0.904	1553.000	0.234	15
Improved multi-disciplinary communication	3.93	0.888	1629.500	0.448	16
Continued improvement of existing practices	3.80	1.028	1663.000	0.568	17

Table 6.25 reveals the respondents' rankings of the drivers of adopting and implementing sustainable construction practices. 'Government support' with a of 4.31, SD of 0.901, Mann-Whitney U 1734.50 and asymp.sig. value of 0.875 was the highest ranked, 'development of sustainability measurement standards' with a MS of 4.28, SD of 0.846, Mann-Whitney U 1523.00 and asymp.sig. value of 0.173 was ranked second, 'training of skilled and unskilled workers in sustainable development' with a MS of 4.26, SD of 0.821, Mann-Whitney U 1499.00 and asymp.sig. value of 0.130 was ranked third, 'continuous professional development in sustainable development' with a MS of 4.24, SD of 0.814, Mann-Whitney U 1716.00 and asymp.sig. value of 0.792 was ranked fourth, 'enforcement of implementation standards' with a MS of 4.23, SD of 0.898, Mann-Whitney U 1729.50 and asymp.sig. value of 0.850 was ranked fifth, 'inclusion of sustainable practices in university syllabi' with a MS of 4.21, SD of 0.902, Mann-Whitney U 1737.50 and asymp.sig. value of 0.889 was ranked sixth, 'increased client and stakeholder awareness' with a MS 4.20, SD of 0.778, Mann-Whitney U 1713.00 and asymp.sig. value of 0.782 was ranked seventh, 'increased funding for research and development' with a MS of 4.19, SD of 0.894, Mann-Whitney U 1593.00 and asymp.sig. value of 0.336 was ranked eighth and 'formulation of implementation policies and regulations' with

a MS 4.11, SD of 1.019 Mann-Whitney U 1573.50 and asymp.sig. value of 0.298 was ranked ninth.

In addition, ‘increased client demand’ with a MS of 4.10, SD of 0.885, Mann-Whitney U 1681.50 and asymp.sig. value of 0.652 was ranked tenth, ‘efficient market for green products and services’ with a MS of 4.06, SD of 0.846, Mann-Whitney U 1744.00 and asymp.sig. value of 0.918 was ranked eleventh, ‘improved efficiency of sustainable products and services’ with a MS of 4.04, SD of 0.837, Mann-Whitney U 1663.00 and asymp.sig. value of 0.580 was ranked twelfth, ‘increased supply of green materials’ with a MS of 4.03, SD of 0.862, Mann-Whitney U 1727.00 and asymp.sig. value of 0.836 was ranked thirteenth, ‘introduction of economic incentives’ with a MS of 4.02, SD of 0.881, Mann-Whitney U 1553.00 and asymp.sig. value of 0.234 was ranked fourteenth, ‘change in the organisational and stakeholder attitude’ with a MS of 4.01, SD of 0.904, Mann-Whitney U 1553.00 and asymp.sig. value of 0.234 was ranked fifteenth, ‘improved multi-disciplinary communication’ with a MS of 3.93, SD of 0.888, Mann-Whitney U 1629.50 and asymp.sig. value of 0.448 was ranked sixteenth and ‘continued improvement of existing practices’ with a MS of 3.80, SD of 1.028 Mann-Whitney U 1663.00 and asymp.sig. value of 0.568 was ranked seventeenth.

6.7.2 Results from Exploratory Factor Analysis

The results from the EFA on the adverse impacts of construction activities are presented in Tables 6.26 to 6.30 and Fig 6.12. The definitions of the identified variables are presented in Table 6.26.

Table 6.26: Definition of identified drivers to the adoption and implementation of sustainable construction practices

Variable	Definition
F12.1	Formulation of implementation policies and regulations
F12.2	Continuous professional development in Sustainable Development
F12.3	Training of skilled and unskilled workers in Sustainable Development
F12.4	Inclusion of sustainable practices in university syllabi
F12.5	Increased client and stakeholder awareness
F12.6	Increased client demand
F12.7	Introduction of economic incentives
F12.8	Increased funding for research and development
F12.9	Continued improvement of existing practices
F12.10	Improved multi-disciplinary communication
F12.11	Increased supply of green materials

F12.12	Change in the organisational and stakeholder attitude
F12.13	Government support
F12.14	Efficient market for green products and services
F12.15	Improved efficiency of sustainable products and services
F12.16	Enforcement of implementation standards
F12.17	Development of sustainability measurement standards

Prior to performing the PCA, the suitability of the data for factor analysis was assessed. Inspection of the correlation matrix revealed the presence of coefficients of above 0.3 as presented in Table 6.27. As shown in Table 6.28, the KMO measure of sampling adequacy achieved a value of 0.901, exceeding the recommended minimum value of 0.6 and Bartlett's test of sphericity was also statistically significant (less than 0.05), thus supporting the factorability of the correlation matrix.

The data was subjected to PCA (with varimax rotation). The eigenvalue was set at conventional high values of 1.0. As shown in Table 6.29, three (3) factors with eigenvalues exceeding 1.0 were extracted. The scree plot presented in Fig 6.12 also revealed the excluded factors by indicating the cut-off point at which the eigenvalues levelled off. The total variance explained by each of the extracted factor is as follows: Factor 1 (52.648%), Factor 2 (7.921%) and Factor 3 (6.420%). This is shown in Table 6.30. Thus, the final statistics of the PCA and the extracted factors accounted for approximately 67% of the total cumulative variance.

Table 6.27: Correlation matrix of factor analysis for drivers to the adoption and implementation of sustainable construction practices

Correlation	F12.1	F12.2	F12.3	F12.4	F12.5	F12.6	F12.7	F12.8	F12.9	F12.10	F12.11	F12.12	F12.13	F12.14	F12.15	F12.16	F12.17
F12.1	**1.000**	0.707	0.608	0.461	0.515	0.346	0.403	0.631	0.471	0.437	0.438	0.322	0.603	0.357	0.373	0.578	0.550
F12.2	0.707	**1.000**	0.710	0.482	0.474	0.403	0.479	0.552	0.484	0.468	0.543	0.424	0.518	0.484	0.495	0.536	0.588
F12.3	0.608	0.710	**1.000**	0.549	0.565	0.339	0.508	0.540	0.652	0.602	0.653	0.398	0.425	0.525	0.585	0.467	0.620
F12.4	0.461	0.482	0.549	**1.000**	0.493	0.222	0.380	0.442	0.395	0.461	0.469	0.292	0.416	0.460	0.459	0.490	0.615
F12.5	0.515	0.474	0.565	0.493	**1.000**	0.464	0.586	0.433	0.454	0.497	0.533	0.491	0.419	0.535	0.495	0.526	0.519
F12.6	0.346	0.403	0.339	0.222	0.464	**1.000**	0.400	0.311	0.286	0.239	0.342	0.350	0.355	0.434	0.485	0.418	0.305
F12.7	0.403	0.479	0.508	0.380	0.586	0.400	**1.000**	0.594	0.515	0.466	0.630	0.560	0.389	0.509	0.503	0.496	0.471
F12.8	0.631	0.552	0.540	0.442	0.433	0.311	0.594	**1.000**	0.618	0.536	0.496	0.550	0.655	0.466	0.509	0.512	0.564
F12.9	0.471	0.484	0.652	0.395	0.454	0.286	0.515	0.618	**1.000**	0.700	0.642	0.517	0.302	0.413	0.404	0.374	0.447
F12.10	0.437	0.468	0.602	0.461	0.497	0.239	0.466	0.536	0.700	**1.000**	0.737	0.649	0.336	0.423	0.504	0.351	0.476
F12.11	0.438	0.543	0.653	0.469	0.533	0.342	0.630	0.496	0.642	0.737	**1.000**	0.636	0.370	0.598	0.663	0.481	0.577
F12.12	0.322	0.424	0.398	0.292	0.491	0.350	0.560	0.550	0.517	0.649	0.636	**1.000**	0.463	0.496	0.469	0.364	0.375
F12.13	0.603	0.518	0.425	0.416	0.419	0.355	0.389	0.655	0.302	0.336	0.370	0.463	**1.000**	0.464	0.443	0.636	0.547
F12.14	0.357	0.484	0.525	0.460	0.535	0.434	0.509	0.466	0.413	0.423	0.598	0.496	0.464	**1.000**	0.697	0.559	0.613
F12.15	0.373	0.495	0.585	0.459	0.495	0.485	0.503	0.509	0.404	0.504	0.663	0.469	0.443	0.697	**1.000**	0.515	0.684
F12.16	0.578	0.536	0.467	0.490	0.526	0.418	0.496	0.512	0.374	0.351	0.481	0.364	0.636	0.559	0.515	**1.000**	0.731
F12.17	0.550	0.588	0.620	0.615	0.519	0.305	0.471	0.564	0.447	0.476	0.577	0.375	0.547	0.613	0.684	0.731	**1.000**

Table 6.28: KMO and Bartlett's test for drivers to the adoption and implementation of sustainable construction practices

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.901
Bartlett's Test of Sphericity	Approx. Chi-Square	1449.666
	Df	136
	Sig.	0.000

Table 6.29: Rotated factor matrix [a] for drivers to the adoption and implementation of sustainable construction practices

	Factors		
	1	2	3
Formulation of implementation policies and regulations	**0.837**		
Government support	**0.712**		
Continuous professional development in sustainable development	**0.696**		
Enforcement of implementation standards	**0.670**		
Development of sustainability measurement standards	**0.658**		
Increased funding for research and development	**0.612**		
Inclusion of sustainable practices in university syllabi	**0.587**		
Improved multi-disciplinary communication		**0.845**	
Continued improvement of existing practices		**0.801**	

Increased supply of green materials		**0.740**	
Change in the organisational and stakeholder attitude		**0.672**	
Training of skilled and unskilled workers in sustainable development		**0.568**	
Introduction of economic incentives		**0.527**	
Efficient market for green products and services			**0.720**
Increased client demand			**0.717**
Improved efficiency of sustainable products and services			**0.695**
Increased client and stakeholder awareness			**0.518**
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalisation.[a]			

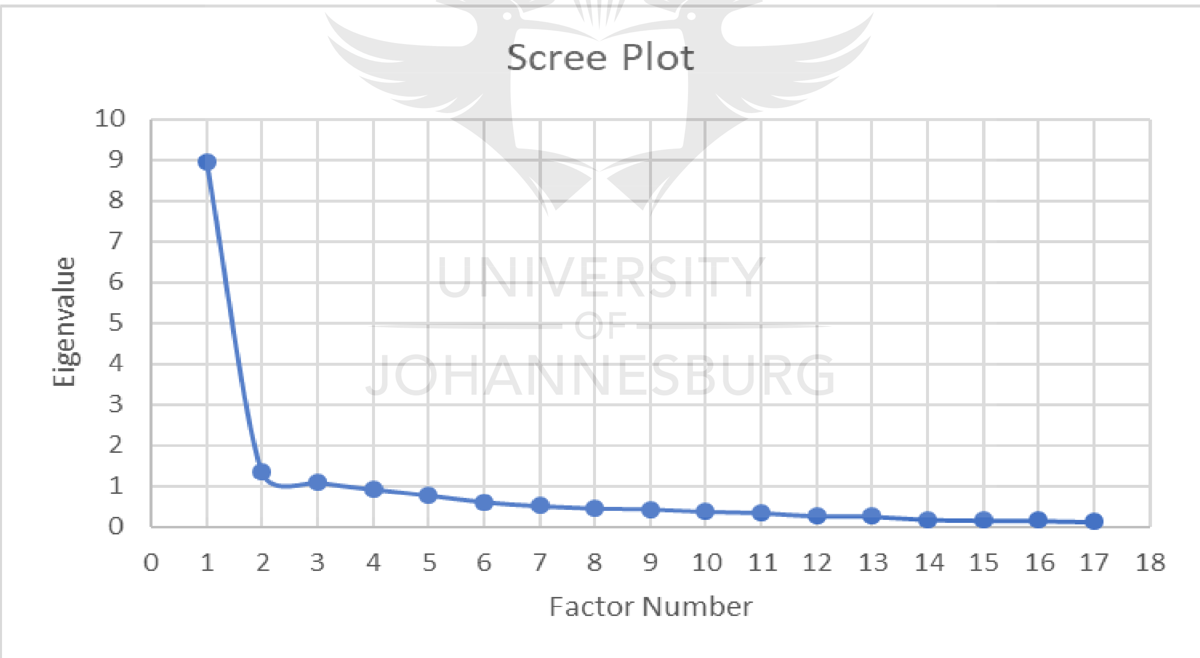


Figure 6.12: Scree plot for factor analysis of drivers to the adoption and implementation of sustainable construction practices

Table 6.30: Total variance explained for drivers to the adoption and implementation of sustainable construction practices

Factors	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	**8.950**	52.648	52.648	8.950	52.648	52.648	4.264	25.083	25.083
2	**1.347**	7.921	60.569	1.347	7.921	60.569	3.930	23.120	48.203
3	**1.091**	6.420	**66.989**	1.091	6.420	66.989	3.194	18.786	66.989
4	0.927	5.454	72.443						
5	0.777	4.572	77.015						
6	0.615	3.616	80.631						
7	0.521	3.068	83.699						
8	0.460	2.706	86.404						
9	0.436	2.566	88.971						
10	0.379	2.230	91.201						
11	0.345	2.029	93.229						
12	0.267	1.572	94.802						
13	0.260	1.527	96.329						
14	0.182	1.068	97.397						
15	0.161	0.946	98.344						
16	0.155	0.910	99.254						
17	0.127	0.746	100.000						
Extraction Method: Principal Component Analysis.									

Principal axis factoring revealed the presence of three (3) factors with eigenvalues above 1 as shown in Table 6.29. Based on the examination of the inherent relationships among the variables under each factor, the following interpretations were made. Factor 1 was termed as **academic and government-related drivers**; Factor 2 was termed **stakeholder development** and Factor 3 **market conditions and improved awareness**. The names given to these factors were derived from a close examination of the variables within each of the factors. The constituent indicators of each of the three factors extracted are explained below.

6.7.2.1 Factor 1: academic and government-related drivers

As presented in Table 6.29, the seven (7) extracted drivers for Factor 1 were *formulation of implementation policies and regulations* (83.7%), *government support* (71.2%), *continuous professional development in sustainable development* (69.6%), *enforcement of implementation standards* (67%), *development of sustainability measurement standards* (65.8%), *increased funding for research and development* (61.2%) and *inclusion of sustainable practices in university syllabi* (58.7%). The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 6.26. This factor accounted for 52.648% of the variance.

6.7.2.2 Factor 2: stakeholder development

As presented in Table 6.29, the six (6) extracted drivers for Factor 2 were *improved multi-disciplinary communication* (84.5%), *continued improvement of existing practices* (80.1%), *increased supply of green materials* (74%), *change in the organisational and stakeholder attitude* (67.2%), *training of skilled and unskilled workers in Sustainable Development* (56.8%) and *introduction of economic incentives* (52.7%). The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 6.26. This factor accounted for 7.921 % of the variance.

6.7.2.3 Factor 3: market conditions and improved awareness

As presented in Table 6.29, the four (4) extracted drivers for Factor 3 were *efficient market for green products and services* (72%), *increased client demand* (71.7%), *improved efficiency of sustainable products and services* (69.5%) and *increased client and stakeholder awareness* (51.8%). The number in parenthesis indicates the respective factor loadings while the definitions of these variables are shown in Table 6.26. This factor accounted for 6.420% of the variance.

6.8 RESULTS FROM EMPIRICAL AND THEORETICAL RESULTS

This section presents the findings of the reliability tests that were conducted. As discussed in Chapter Five, a value of 0.7 was adopted as this research study's Cronbach's alpha as it indicated that the coefficients have a good internal consistency. Table 6.31 reveals the Cronbach's alpha values for the empirical and theoretical reliabilities for the adverse impacts of construction activities, level of awareness of sustainable construction practices, barriers, benefits and drivers to the adoption and implementation of sustainable construction practices. Not all the coefficients have Cronbach's alpha above the adopted value of 0.70. However, they were considered acceptable for the study. This was determined by carrying out an additional test known as the mean inter-item correlation. Cronbach alpha values, as observed by Pallant (2016:23), rely on the number of items in the scale. A smaller number of items in a scale (usually less than 10) results in a lower Cronbach's alpha value. In such instances, Pallant advised that it is better to report on the mean inter-item correlation which should be in the range of 0.2 – 0.4. Thus, the results of the mean inter-item correlation indicate that the variables are within the acceptable range.

Table 6.31: Empirical and theoretical reliabilities

Empirical	Theoretical	No. of items	Cronbach's alpha	Mean inter-item correlation
Adverse impacts of construction activities				
Environmental degrading impacts		13	0,949	
Decreased human health and productivity		4	0,874	
Resource depletion and pollution		5	0,844	
	Adverse impacts of construction activities	23	0,953	
Level of awareness of sustainable construction practices				
Waste reducing practices		6	0,881	
Practices enhancing sustainable economics		5	0,885	
Nature inspired practices.		5	0,810	
	Sustainable construction practices	16	0,933	
Barriers to the adoption and implementation of sustainable construction practices				
Knowledge and awareness barriers		5	0,842	
Market-related barriers		5	0,828	
Stakeholder-related barriers		5	0,800	
Regulatory and manpower-related barriers		3	0,722	
Communication and implementation-related barriers		2	0,568	0,415
Government-related		3	0,635	0,367
Corruption and procurement-related barriers		2	0,655	0,486
	Barriers to the adoption and implementation of sustainable construction practices	25	0,902	
Benefits of adopting and implementing sustainable construction practices				
Stakeholder benefits		11	0,934	
Economic and environmental benefits		7	0,927	
Resource usage		4	0,916	
Sustainable economy		4	0,873	
	Benefits of adopting and implementing sustainable construction practices	23	0,962	
Drivers to the adoption and implementation of sustainable construction practices				
Academic and government-related drivers		7	0,900	
Stakeholder development		6	0,897	
Market conditions and improved awareness		4	0,811	
	Drivers to the adoption and implementation of sustainable construction practices	17	0,942	

6.9 CONCLUSION

This chapter presented the research study's findings. The interpretations of the results were in the form of tables, graphs and charts. These results are discussed in the next chapter.

CHAPTER SEVEN

DISCUSSION OF FINDINGS

7.1 CHAPTER INTRODUCTION

This chapter discussed the findings from the data analysis in relation to the research questions. Furthermore, the findings are discussed with reference to the literature reviewed in chapters 2, 3, 4 and 5. This is carried out with the purpose of establishing that the research questions have been answered based on the data analysed in Chapter Six. In addition, the results in relation to the research question have been presented together with the relevant data as required.

7.2 RESEARCH QUESTION ONE

RQ1: What are the adverse impacts of construction activities in Zambia?

7.2.1 Findings

Results from the descriptive and exploratory factor analysis were used to answer this research question. Included are the results of the non-parametric test.

Based on the findings, 'increased energy consumption was ranked first with a MS of 3.62, SD of 0.999, Mann-Whitney U 1678.50 and asymp.sig. value of 0.644; 'deforestation' was ranked second with a MS of 3.42, SD of 1.067, Mann-Whitney U 1587.000 and asymp.sig. value of 0.337; 'climate change' was ranked third with a MS of 3.32, SD of 1.054, Mann-Whitney U 1648.500 and asymp.sig. value of 0.529; 'generation of excessive waste' was ranked fourth with a MS of 3.31, SD of 1.107, Mann-Whitney U 1737.000 and asymp.sig. value of 0.889; 'depletion of non-renewable material resources' was ranked fifth with a MS of 3.11, SD of 1.097, Mann-Whitney U 1720.000 and asymp.sig. value of 0.817; 'degradation of the ecosystem' was ranked sixth with MS of 3.25, SD of 1.023, Mann-Whitney U 1717.000 and asymp.sig. of 0.803; 'increased land pollution' was ranked seventh with a MS 3.16, SD of 1.031, Mann-Whitney U 1687.000 and asymp.sig. of 0.680. The least ranked were 'acid rains' at twenty-first with a MS of 2.35, SD of 1.036, Mann-Whitney U 1327.000 and asymp.sig. value of 0.017; 'decreased productivity level of building occupants' was ranked twenty-second with a MS of 2.31, SD of 1.092, Mann-Whitney U 1361.500 and asymp.sig. value of 0.026 and lastly, 'declined health of building occupants' was ranked twenty-third with a MS 2.29, SD of 0.940, Mann-Whitney U 1553.000 and asymp.sig. value of 0.244.

From the factor analysis results, adverse impacts were grouped into three factors, namely ‘environmental degrading impacts’ (MS= 3.12 and SD of 1.047), ‘decreased human health and productivity’ (MS= 2.39 and SD of 0.998) and lastly, ‘resource depletion and pollution’ (MS= 2.99 and SD of 1.028).

The Mann-Whitney U results indicated that there were two variables below the minimum accepted two-tailed significance value of 0.05. These are acid rains and decreased productivity levels of building occupants.

7.2.2 Discussion

From exploratory factor analysis, the findings of this research are in tandem with the publications of Kibert (2016:52) and the EIA Guidelines for the Construction Sector in Zambia (2016:2). These publications indicated that the adverse impacts of construction activities are damage to sensitive eco-systems, soil erosion, interference with wildlife movement, loss of valuable agricultural lands, displacement of people, deforestation, desertification, soil erosion, toxic waste, climate change, eutrophication, depletion of fisheries, destruction of the ecosystem, depletion of the ozone layer, and water, air and land pollution. On the other hand, despite the alarming statistics and the number of publications on the variables termed resource depletion and pollution were found to be least significant. This finding contradicts the studies of several scholars who established that construction activities consume a large percentage of the natural resources (Du Plessis, 2002:14; Baloi, 2003:337; Dixon (2010:2). Furthermore, production and maintenance of the various structures that we work or live in consumes a lot of energy, contributes to the emission of harmful gases and also pollutes the various water bodies.

Several notable points were picked up from the descriptive results. The first is that with mean values below 3, the respondents indicated that the following were not adverse impacts of construction activities: increased water pollution, ozone depletion, degradation of waterways, declined health of construction workers, transformation of habitable land into deserts, loss of marine life, acid rains, decreased productivity level of building occupants and declined health of building occupants. From these results, two stood out, namely ‘decreased productivity level of building occupants’ and ‘declined health of building occupants’ as these are not in line with the studies conducted by Pearce (2012:5) and Zarghami et al (2018:107). These scholars established that the internal air quality of a building has an impact on the occupants’ health, comfort and productivity. Additionally, humans are prone to health problems, several of which are termed as respiratory-related illnesses, and these are traced to construction activities or products of the same.

From the non-parametric test, there was a statistical difference in opinion between the respondents working for the public and the private sectors on the variables ‘acid rains’ and ‘decreased productivity level of building occupants’. This is established from the two-tailed significance value below 0.05 for each of the variables.

7.2.3 Implications of the study

From the discussion, it is evident that some of the findings are consistent with the theoretical review on the adverse impacts of construction activities on the environment. This can be attributed to lack of awareness and understanding or lack of interest or alarm in the degradation of the environment. Therefore, it is pertinent that sensitisation on the effects of all activities, not only those construction- related, should be publicised for the purpose of a harmonious existence, not only presently but also for the generations to come.

7.3 RESEARCH QUESTION TWO

RQ2: What is the level of awareness of sustainable construction practices amongst the professionals in the Zambian CI?

7.3.1 Findings

In response to the question of the respondents’ level of awareness of sustainable construction practices, the following findings were used.

The findings from the descriptive analysis were as follows: 3D Printing (additive manufacturing)’ was ranked first with a of 3.70, SD of 1.285, Mann-Whitney U 1596.500 and asymp.sig. value of 0.368, ‘value management’ with a MS of 3.48, SD of 1.294, Mann-Whitney U 1565.500 and asymp.sig. value of 0.287 was ranked second, ‘design for environment’ with a MS of 3.37, SD of 1.312, Mann-Whitney U 1640.500 and asymp.sig. value of 0.467was ranked third, ‘building information modelling’ with a MS of 3.34, SD of 1.388, Mann-Whitney U 1622.500 and asymp.sig. value of 0.450 was ranked fourth, ‘life cycle costing’ with a MS of 3.22, SD of 1.519, Mann-Whitney U 1640.500 and asymp.sig. value of 0.505 was ranked fifth, ‘Internet of Things’ with a MS of 3.09, SD of 1.483, Mann-Whitney U 1680.000 and asymp.sig. value of 0.655 was ranked sixth and ‘lean construction’ with a MS of 3.06, SD of

1.462, Mann-Whitney U 1392.500 and asymp.sig. value of 0.043 was ranked seventh. At the rear end of the list was ‘nanotechnology’ with a MS of 2.17, SD of 1.264, Mann-Whitney U 1574.500 and asymp.sig. value of 0.312 ranked fourteenth ‘cradle-to-cradle design’ with a MS of 2.11, SD of 1.241, Mann-Whitney U 1476.500 and asymp. sig. value of 0.118 was ranked fifteenth and lastly, ‘biomimicry’ with a MS of 1.63, SD of 0.902, Mann-Whitney U 1476.000 and asymp. sig. value of 0.116 was ranked sixteenth.

From the factor analysis results, three factors were identified and termed. These factors were also ranked as follows ‘waste reducing practices’ with MS of 3.24 and SD of 1.364 was ranked first, ‘practices enhancing sustainable economics’ with MS of 2.92 and SD of 1.338 was ranked second and third was ‘nature inspired practices’ with a MS of 2.12 and SD of 1.202.

The result of the Mann-Whitney U showed that the variable ‘lean construction’ had a value below the minimum accepted two-tailed significance value of 0.05.

7.3.2 Discussion

The results of the descriptive analysis indicate that there is a low level of awareness amongst the Zambian construction professionals on the sustainable construction practices that have emerged in other parts of the world. This is deduced from the high number of variables with a mean value less than three (3), namely life cycle assessment, industrialised building system, construction ecology, ecological economics, ecological footprint, blockchain technology, nanotechnology, cradle to cradle design and biomimicry. This finding is similar to that of an earlier study conducted in Zambia by James and Matipa (2004:1362). The low level of awareness could be attributed to the level of ambiguity surrounding some practices as indicated by Sev and Ezel (2014:894-895) in their study of nanotechnology.

The results of the EFA indicated that the highest ranked was a factor termed as ‘waste reducing practices’ and contained the following variables: 3D printing (additive manufacturing), industrialised building system, building information modelling, internet of things, lean construction and design for environment. The name emanated from the literature review which showed that these practices focus on waste reduction, not only in material but also construction time. Implementation of these practices would result in environmental and economic benefits. It is interesting to note that there is a similarity in the findings of the descriptive and exploratory factor analysis. This is evident in the low ranking of “Biomimicry” one of variables that falls under nature inspired factors.

The results of the non-parametric indicated that there was a statistical difference in opinion between the respondents working for the public and the private sectors. This difference was in the variable 'lean construction' which had a two-tailed significance value below 0.05.

Furthermore, the findings indicate that there is a knowledge deficit on sustainability even though the biographical results indicate that most of the respondents have university degrees with a significant year of experience. Thus, there is an urgent need to disseminate information on sustainability through inclusion in university syllabi, training (both theoretical and practical) and workshops for professionals and any other suitable platform for all stakeholders. This study will serve as a useful tool in enhancing sustainability in the ZCI.

7.3.3 Implications of the study

The findings are consistent with literature obtained from other parts of the world which attributes one of the major barriers to the adoption of sustainable construction practices to be lack of awareness. Furthermore, the findings from the exploratory factor analysis indicate that the practices will promote the three pillars of sustainability by aiding the reduction of construction waste, enhancing the creation of structures inspired by nature and at the same time opening up markets for sustainable products. It is therefore important that there should be increased sensitisation amongst the professional on the various practices as it is through them that clients will come to learn of these practices, and this will aid increased demand for sustainable structures. This task should not be left to the Zambian professionals, but the government should also take an active role with other regulatory organisations to enable the realisation of the country's vision 2030.

7.4 RESEARCH QUESTION THREE

RQ3: What are the barriers to the adoption and implementation of sustainable construction practices in the Zambian CI?

7.4.1 Findings

The results obtained from the descriptive and exploratory analysis are presented below. Included are the results of the non-parametric test.

From the descriptive analysis, the highest ranked barrier was 'lack of funds for research and development' with a of 4.07, SD of 1.089, Mann-Whitney U 1509.000 and asymp.sig. value of

0.167, ‘corruption within the CI’ with a MS of 4.02, SD of 1.253, Mann-Whitney U 1729.500 and asymp.sig. value of 0.857 was ranked second, ‘poor implementation strategy’ with a MS of 3.86, SD of 0.865, Mann-Whitney U 1745.500 and asymp.sig. value of 0.924 was ranked third, ‘limited involvement of stakeholders’ was ranked fourth with a MS of 3.78, SD of 1.008, Mann-Whitney U 1397.500 and asymp.sig. value of 0.047, ‘high cost of sustainable technologies’ with a MS of 3.73, SD of 1.143, Mann-Whitney U 1536.000 and asymp.sig. value of 0.222 was ranked fifth, ‘lack of client demand for sustainable products or structures’ with a MS of 3.66, SD of 1.154, Mann-Whitney U 1199.000 and asymp.sig. value of 0.002 was ranked sixth, ‘lack of government support’ with a MS 3.62, SD of 1.195, Mann-Whitney U 1391.500 and asymp.sig. value of 0.046 was ranked seventh, at the bottom of the table ‘unstable green market conditions’ with a MS of 3.13, SD of 1.164, Mann-Whitney U 1421.000 and asymp.sig. value of 0.063 was ranked twenty-third, ‘shortage of skilled personnel’ with a MS of 2.93, SD of 1.148, Mann-Whitney U 1233.000 and asymp.sig. value of 0.003 was ranked twenty-fourth and lastly, ‘lack of constructible (buildable) designs’ with a MS of 2.86, SD of 1.300, Mann-Whitney U 1735.500 and asymp.sig. value of 0.883 was ranked twenty-fifth.

Seven factors were established through the factor analysis. The highest ranked was ‘government-related barriers’(MS=3.72 and SD = 1.177), the second was ‘communication and implementation-related barriers’ (MS=3.71 and SD=0.935), ‘corruption and procurement-related barriers’ (MS=3.66 and SD=1.239) was the third, the fourth was ‘stakeholder-related barriers’(MS=3.59 and SD = 1.092), ‘market-related barriers’(MS = 3.44 and SD = 1.157) was the fifth, ‘regulatory and manpower-related barriers’ (MS=3.10 and SD =1.208) was the sixth, and ‘knowledge and awareness barriers’ (MS=2.70 and SD = 1.232) was the seventh.

The result of the Mann-Whitney U showed that the variables ‘limited involvement of stakeholders’, ‘high cost of sustainable technologies’, ‘lack of client demand for sustainable products or structures’, ‘lack of government support’ and ‘stakeholders’ resistance to change’ had values below the minimum accepted two-tailed significance value of 0.05.

7.4.2 Discussion

The findings of this study from the exploratory factor analysis indicated that the major barriers to the adoption and implementation of sustainable construction practices (SCP) are limited knowledge on sustainable practices, lack of training and education, lack of constructible (buildable) designs and lack of awareness. These agree with the studies of Khosrowshahi and

Arayici (2012:623) on BIM use in the UK. Their study found that the uptake of BIM is inhibited due to most firms not being familiar with it. In addition, Luvara and Mwemezi (2017:12) in their study of VM identified a lack of awareness of this practice by professionals and lack of trained VM managers in the CI as the barriers to its adoption. Similarly, Aghimien et al. (2018:822) found that the client's lack of awareness of the existence of VM and the benefits that can be derived from it as the major barrier to its adoption. In contrast, from their study of IBS, Khosshnava et al. (2014:1641,1646) established that the major barrier to its adoption was the lack of policy implementation. Other governance-related barriers were found to be lack of building codes and standards, lack of assessment, lack of incentives and lack of understanding about sustainability issues. Similarly, from their study, Ayarkwa et al. (2012:9) posited that barriers to the adoption of lean construction were regulatory authorities' intervention and inconsistency in policies and lack of standardisation. Though not the highest in order of importance, stakeholder-related barriers are critical to the adoption of SCPs. This is because with CI being client-driven their demand for sustainable structures will drive the adoption of SCPs.

From the descriptive analysis results, the following were the highest ranked variables: lack of funds for research and development, corruption within the CI, poor implementation strategy and limited involvement of stakeholders. With regard to the barrier pertaining to the lack of funds for research and development, Teshnizi (2018:177), in a study on life cycle costing (LCA), established that one of the major barriers to its implementation is that stakeholders are deterred by the time and financial resources required to conduct the study. Studies by Abdullah et al. (2009:5-7), Marhani et al. (2013:96-97), Sahil (2016:11) and Ankrah et al. (2015:53-55) posited that poor communication and implementation strategies, corruption and the stakeholders 'attitude were the major barriers to the adoption of SCP.

The result of the non-parametric test indicates that there was a statistical difference in the opinion of the professionals working in the public and the private sectors seen in the two-tailed significance value for all the barriers that were less than 0.05 ($p < 0.05$). The variables in question were limited involvement of stakeholders, high cost of sustainable technologies, lack of client demand for sustainable products or structures, lack of government support and stakeholders' resistance to change.

7.4.3 Implications of the study

The literature reviewed was consistent with the findings of this study. This is evidenced in the exploratory factor analysis results which revealed limited knowledge on sustainable practices, lack of training and education, and lack of awareness as the barriers to the adoption SCPs. Improved knowledge and awareness of SCPs by the various stakeholders will go a long way in promoting its adoption. Furthermore, stakeholders need to take an active role in promoting SCPs through mediums such as enactment of policies, workshops, learning institutions and continuous development programmes. In addition, proper guidelines on these practices need to be published and distributed and the ambiguities that surround some of the practices with regards to their impact on human health and the environment need to be cleared. Above all, a change in attitude by the various stakeholders would aid the attainment of a sustainable existence.

7.5 RESEARCH QUESTION FOUR

RQ4: What are the benefits of adopting and implementing sustainable construction practices in the Zambian CI?

7.5.1 Findings

To aid the response to the research question, the results from the descriptive and exploratory analysis are presented below. Included are the results of the non-parametric test.

From the descriptive analysis, the highest ranked benefit of adopting and implementing sustainable construction practices was 'reduced energy consumption' with a of 3.99, standard deviation (SD) of 1.032, Mann-Whitney U 1546.000 and asymp.sig. value of 0.231 'promotes the use of local sustainable materials' with a MS of 3.97, SD of 1.075, Mann-Whitney U 1619.500 asymp.sig. value of 0.428 was ranked second, 'improves site health and safety' with a MS of 3.92, SD of 1.049, Mann-Whitney U 1535.500 and asymp.sig. value of 0.214 was ranked third, 'improves the overall quality of life' with a MS of 3.91 and SD of 1.012, Mann-Whitney U 1671.000 and asymp.sig. value of 0.615was ranked fourth, with a MS of 3.91, SD of 1.128, Mann-Whitney U1654.500 and asymp.sig. value of 0.552 'reduced waste generation' was ranked fifth, 'increased use of green construction materials' with a MS of 3.90, SD of 0.999 Mann-Whitney U 1588.500 and asymp.sig. value of 0.339was ranked sixth and 'reduced emission of greenhouse gases' with MS of 3.89, SD of 1.074 Mann-Whitney U 1754.000 and asymp.sig. value of 0.963 was ranked seventh. 'Increased productivity of building occupant' with a MS of 3.45, SD of 1.021 Mann-Whitney U 1622.50 and asymp.sig. value of 0.440 was ranked twenty-fourth, 'enhances competitiveness' with a MS of 3.33, SD of 1.087, Mann-Whitney U 1736.50 and asymp.sig. value of 0.886 was ranked twenty-fifth and 'reduction in construction time' with a MS of 3.19, SD of 1.195 Mann-Whitney U 1593.00 and asymp. sig. value of 0.374 was ranked twenty-sixth.

The results from the exploratory analysis indicated that four factors were identified and termed. The highest in ranking was 'resource optimisation' (MS=3.90 and SD = 1.074), 'sustainable economy' (MS=3.83 and SD=1.016) was second, third in rank is 'green material benefits' and the last was 'project benefits' (MS=3.21 and SD=0.974).

The result of the Mann-Whitney U showed that all the variables had values above the minimum accepted two-tailed significance value of 0.05.

7.5.2 Discussion

The findings from the descriptive statistics indicate that the major benefits of adopting and implementing sustainable construction practices (SCPs) are reduced energy consumption, promoting the use of local sustainable materials, improved site health and safety and improved overall quality of life. These findings are similar to those obtained from the exploratory analysis which lists improved air quality, reduced energy consumption, reduced waste generation and improved water quality as the major benefits. These results are all in agreement with the work of Oke et al. (2017:3842) and Sev and Ezel (2014:894) who posited that nanotechnology, and an SCP which focuses on enhancing the functionality of traditional construction materials would aid the reduction of material carbon emissions, result in energy saving, reduced reliance on non-renewable resources and reduced waste generation. In addition, Aghimien et al. (2018:3125) in their study established that VM would contribute to SC through the promotion of the use of local sustainable materials in construction.

The findings from the non-parametric test indicate that the professionals from both the public and private sectors had the same opinion on the benefits of adopting and implementing sustainable construction practices. This is because all the two-tailed significance values are greater than the minimum of 0.05.

7.5.3 Implications of the study

From the exploratory factor analysis results, SCPs has the potential to provide environmental, economic and social benefits which are the pillars of sustainability. This is evidenced in the variables from the two highest ranked factors, namely improved air quality, reduced energy consumption, reduced waste generation, improved water quality, enhances sustainable economic growth, optimises life-cycle economic performance, promotes the use of local sustainable materials and improves the overall quality of life. Promotion of these practices will drive the preservation of the scarce resources in Zambia, improve the livelihood of its citizens and aid the attainment of a sustainable economy.

7.6 RESEARCH QUESTION FIVE

RQ5: What are the drivers to the adoption and implementation of sustainable construction practices in the Zambian CI?

7.6.1 Findings

The results below from the descriptive and exploratory analysis were utilised to answer this research question. Included are the results of the non-parametric test.

From the descriptive analysis, ‘government support’ with a MS of 4.31, SD of 0.901, Mann-Whitney U 1734.50 and asymp.sig. value of 0.875 was the highest ranked, ‘development of sustainability measurement standards’ with a MS of 4.28, SD of 0.846, Mann-Whitney U 1523.00 and asymp.sig. value of 0.173 was ranked second, ‘training of skilled and unskilled workers in sustainable development’ with a MS of 4.26, SD of 0.821, Mann-Whitney U 1499.00 and asymp.sig. value of 0.130 was ranked third, ‘continuous professional development in sustainable development’ with a MS of 4.24, SD of 0.814, Mann-Whitney U 1716.00 and asymp.sig. value of 0.792 was ranked fourth, ‘enforcement of implementation standards’ with a MS of 4.23, SD of 0.898, Mann-Whitney U 1729.50 and asymp.sig. value of 0.850 was ranked fifth, ‘inclusion of sustainable practices in university syllabi’ with a MS of 4.21, SD of 0.902, Mann-Whitney U 1737.50 and asymp.sig. value of 0.889 was ranked sixth and ‘increased client and stakeholder awareness’ with a MS of 4.20, SD of 0.778, Mann-Whitney U 1713.00 and asymp.sig. value of 0.782 was ranked seventh. At the bottom of the table was ‘change in the organisational and stakeholder attitude’ with a MS of 4.01, SD of 0.904, Mann-Whitney U 1553.00 and asymp.sig. value of 0.234 ranked fifteenth, ‘improved multi-disciplinary communication' with a MS of 3.93, SD of 0.888, Mann-Whitney U 1629.50 and asymp.sig. value of 0.448 was ranked sixteenth and 'continued improvement of existing practices' with a MS of 3.80, SD of 1.028 Mann-Whitney U 1663.00 and asymp.sig. value of 0.568 was ranked seventeenth.

The factor analysis results indicated that there were three factors identified and termed. These factors were ranked as follows 'academic and government-related drivers' with a MS of 4.22 and SD of 0.896, ' market conditions and improved awareness' with a MS of 4.10 and SD of 0.837 and the last with a MS of 4.01 and SD of 0.898 was 'stakeholder development'.

The Mann-Whitney U results indicate that there were no variables below the minimum accepted two-tailed significance value of 0.05.

7.6.2 Discussion

The results of the descriptive analysis indicated that the adoption of sustainable construction practices can be promoted through government support, development of sustainability measurement standards, training of skilled and unskilled workers in sustainable development and continuous professional development in sustainable development. From the exploratory factor analysis, the results show that formulation of implementation policies and regulations, government support, continuous professional development in sustainable development, enforcement of implementation standards, development of sustainability measurement standards, increased funding for research and development and inclusion of sustainable practices in university syllabi are the main drivers of the adoption of SCPs. These findings agree with the study conducted by Oke and Aigbavboa (2017:179) in which it was established that the main driver of the adoption of SCPSs is through the formulation of the necessary and appropriate guidelines and regulations. Similarly, Ayarkwa, (2012:10) posited that government agencies should embark on formulating applicable policies that could provide critical support to make lean methods feasible. In contrast, Opoku (2014:126) observed that with the CI being a client driven one, their increased awareness and subsequent demand would result in the construction of sustainable buildings.

With no variable with a two-tailed significance value less than 0.05 for all the drivers of sustainable construction practices, it can be deduced that there were no statistical differences in the opinion of the professionals working for either the public or the private sector.

7.6.3 Implications of the study

The research findings revealed that the active involvement of the government and the various regulatory bodies would enhance sustainability in Zambia. This responsibility does not rest on the government alone but also on the private sector as they can also encourage the adoption of sustainability in Zambia through participation in training and continuous development for workers and professionals. Most importantly, all stakeholders should support the dissemination of information on sustainability to the students through inclusion in school and university curricula and in the practical training sessions.

7.7 CONCLUSION

The results obtained from the respondents on the evaluation of SCPs in the ZCI were presented and analysed based on the research questions and the literature reviewed.

In the next chapter, the research objectives are reviewed in relation to the study's findings. This chapter also includes recommendations in relation to the objectives of the study.

CHAPTER EIGHT

CONCLUSIONS AND RECOMMENDATIONS

8.1 CHAPTER INTRODUCTION

This section of the study presents and discusses the conclusion and recommendations of the research study in relation to the study's objectives. The chapter ends with a general conclusion drawn from the conclusions of each research objective. Below are the research objectives followed by an explanation of how these objectives were met.

a. To identify the adverse impacts of construction activities in the Zambian construction industry.
b. To assess the level of awareness of sustainable construction practices amongst the professionals in the Zambian construction industry.
c. To identify the barriers to the adoption and implementation of sustainable construction practices in the Zambian construction industry.
d. To determine the benefits of adopting and implementing sustainable construction practices in the Zambian construction industry.
e. To identify the drivers of the adoption and implementation of sustainable construction practices in the Zambian construction industry

8.2 CONCLUSIONS

8.2.1 Conclusion for Research Objective 1

- *To identify the adverse impacts of construction activities in the Zambian construction industry*

Review of literature revealed that that the adverse impacts of construction activities are soil erosion, pollution of surface and underground water, landslides, climate change, damage to sensitive eco-systems, interference with wildlife movement, loss of valuable agricultural lands, displacement of people, demographic changes, accelerated urbanisation, deforestation, desertification, toxic waste, climate change, eutrophication, depletion of fisheries, destruction of ecosystem, depletion of the ozone layer, water, air and land pollution, high energy use and associated emissions of greenhouse gases, extraction and consumption of renewable and non-renewable natural resources, disruption of communities and animal habitation.

Results from the questionnaire survey indicated that increased energy consumption, deforestation, climate change, generation of excessive waste, depletion of non-renewable material resources, degradation of the ecosystem, increased land pollution, land degradation, depletion of non-renewable energy resources and increased air pollution were the highest ranked adverse impacts of construction activities in Zambia. In addition, the results from the factor analysis found that environmental degradation, decreased human health and productivity and lastly resource depletion and pollution are the adverse impacts of construction activities in Zambia. Therefore, it can be concluded that from both the review of literature and the findings that the objective was fulfilled.

8.2.2 Conclusion for Research Objective 2

- *To assess the level of awareness of sustainable construction practices amongst the professionals in the Zambian construction industry*

From the primary data, the following sustainable construction practices were identified: lean construction, biomimicry, nanotechnology, ecological economics, life cycle costing, life cycle assessment, building information modelling, value management, ecological footprint, design for the environment, construction ecology, industrialised building systems, cradle to cradle design, internet of things, 3D printing (additive manufacturing) and blockchain technology.

The questionnaire results revealed that there is a low level of awareness of sustainable construction practices in the Zambian construction industry (ZCI). Despite this, the seven (7) highest ranked practices were 3D printing (additive manufacturing), value management, design for environment, building information modelling, life cycle costing, Internet of Things and lean construction. From the factor analysis results, the practices identified were waste reducing practices, practices enhancing sustainable economics and nature-inspired practices. Therefore, the research objective was achieved.

8.2.3 Conclusion for Research Objective 3

- *To identify the barriers to the adoption and implementation of sustainable construction practices in the Zambian construction industry*

The numerous barriers to the adoption and implementation of sustainable construction practices were categorised and reduced into the following: management barriers (a lack of commitment and attentiveness exhibited by top management in construction organisations) technical barriers (absence of benchmarks, inappropriateness of the existing tools and methodologies, inadequate training and education, lack of awareness amongst the professionals), attitude barriers (resistance to new technology, lack of collaboration amongst development stakeholders, preference for conventional technologies and products), government barriers (lack of policy implementation, lack of building codes and standards, lack of incentives), financial barriers (high initial costs and the competitive nature of the built environment) and other barriers (possible health risks, lack of understanding of approaches, procurement practices, political and social instability).

The questionnaire survey results indicated that top highest ranked barrier to the adoption and implementation of sustainable construction practices are lack of funds for research and development, corruption within the CI, poor implementation strategy, limited involvement of stakeholders, high cost of sustainable technologies, lack of client demand for sustainable products or structures, lack of government support, stakeholders' resistance to change, lack of awareness and high initial costs. The results of the factor analysis results revealed that government-related barriers, communication and implementation-related barrier, corruption and procurement-related barriers, stakeholder-related barriers, market-related barriers, regulatory and manpower-related barriers and knowledge and awareness barriers are hampering the adoption and implementation of sustainable construction practices (SCPs) in Zambia. It can therefore be concluded that the research objective was met.

8.2.4 Conclusion for Research Objective 4

- *To determine the benefits of adopting and implementing sustainable construction practices in the Zambian construction industry*

From literature, the benefits that can be drawn from the adoption and implementation of SCPs fall into three categories, namely environmental (reduced material carbon emissions, energy saving, reduced reliance on non-renewable resources), economic (elimination of unnecessary designs, reduced waste and defects, enhanced value) and social benefits (maintenance of biodiversity and the ecosystem, improved physical health).

The results of the questionnaire survey identified that the ten significant benefits of sustainable construction practices are reduced energy consumption, promotion of the use of local sustainable materials, improved site health and safety, improved overall quality of life, reduced waste generation, increased use of green construction materials, reduced emissions of greenhouse gases, improved water quality, increased demand for green construction materials and increased protection of ecosystem. From the exploratory analysis, the four factors that outline the benefits of sustainable construction practices in the ZCI are project benefits, green material benefits, resource optimisation and sustainable economy. Thus, the objective was achieved from both the literature and the questionnaire results.

8.2.5 Conclusion for Research Objective 5

- *To identify the drivers of the adoption and implementation of sustainable construction practices in the Zambian construction industry*

Through literature, it was revealed that the following can promote the adoption of SCPs in Zambia, namely the formulation of the necessary and appropriate guidelines and regulations; collaboration of multiple disciplines; inclusion of the various practices in the current university syllabi; organisation of networks, workshops and events; training for professionals; increased client and stakeholder awareness; increased client demand; introduction of economic incentives for projects that adopt sustainable goals; and continued research on emerging technologies.

The highest ranked drivers from the questionnaire survey results were government support, development of sustainability measurement standards, training of skilled and unskilled workers in sustainable development, continuous professional development in sustainable development, enforcement of implementation standards, inclusion of sustainable practices in university syllabi, increased client and stakeholder awareness, increased funding for research and development, formulation of implementation policies and regulations and increased client demand. The results of the factor analysis indicated that academic and government-related drivers, stakeholder development, market conditions and improved awareness are the factors that will drive the adoption and implementation of sustainable construction practices in Zambia. With these results, it can therefore be concluded that the research objective was met.

8.3 GENERAL RESEARCH CONCLUSIONS

The main essence of this study was to evaluable SCPs in the ZCI. This was accomplished by establishing the level of awareness of SCPs and identifying the barriers to, and drivers and benefits of adopting and implementing SCPs in the ZCI. In addition, the study also identified the adverse impacts of construction activities in Zambia. Thus, the following conclusions were established from the research study:

- There are several impacts of construction activities that can be described as adverse. These have an impact on the continued existence of humanity. Increased sensitisation on the impacts identified and many more cannot be over-emphasised.
- The number of innovative practices that can enhance sustainability in the CI is not limited to the ones identified in this study. Studies have shown that these practices will not only protect the ecosystem but will aid business operations and opportunities and will enable an improved livelihood. Therefore, these practices contribute meaningfully to the three pillars of sustainability. The low awareness of these practices amongst the professionals can be mitigated through training, workshops, inclusion in schools and university syllabi and a change of mind set.
- The adoption of sustainable construction practices in the ZCI is hampered by several obstacles. The majority are government related, indicating that this institution needs to take the lead in the adoption of SCPs. The responsibility, however, should not be left to this institution alone to implement these practices. Other stakeholders need to participate in the promotion of not only a sustainable CI but also a sustainable way of life.
- With Zambia reeling from the effects of daily power cuts, the country will stand to benefit from the adoption of these practices through reduced energy usage, reduced material wastage, improved air and water quality. The SCPS will also promote the utilisation of sustainable local materials. Thus, the adoption and implementation of SCPS will aid the attainment of sustainability in all spheres.
- As the saying goes, “A journey of a thousand miles begins with the first step”, though the attainment of a sustainable construction industry is a mammoth task, this can be achieved by increased awareness through the dissemination of information on various platforms. These platforms are workshops, training and continuous development for workers and professionals, as well as the inclusion of sustainability courses in university syllabi and roadshows. The information needs to reach the wider population as this fight is not only for the CI but for the rest of mankind in order to maintain our existence.

8.4 RECOMMENDATIONS

With the rapid rate at which the environment is degrading, the issue of sustainability is one which the various nations are striving to address; hence this study's evaluation of sustainable construction practice in the ZCI industry. This evaluation was achieved through the identification of the barriers to, and drivers and benefits of SCPs. It also assessed the level of awareness of SCPs. It is from these that the following are recommended:

- Awareness amongst the various stakeholders in the construction should be encouraged through training, workshops, roads shows and the inclusion of sustainability courses in the university syllabi. In these platforms, information on the adverse impacts of construction activities should be disseminated so that the benefits of the SCPS can be appreciated.
- The government should spearhead the adoption and subsequent implementation of the SCPS through the introduction of policies and incentives promoting their adoption,
- The government should develop a framework for the adoption of SCPs. This should be coupled with regulations that will ensure that SCPS are implemented.
- The government should enhance collaboration with the various stakeholders to ensure that regulation that would enable the various SC practices to be implemented are enforced.
- Professional training and education should be stimulated through continuous professional development. In addition, the professionals should be encouraged to keep abreast with the various trends that would enhance sustainable in the ZCI.

8.5 GENERAL RESEARCH CONCLUSIONS

The study recommends the following as areas of possible further research:

- Future research should be done on the development of a framework for the adoption and implementation of SCPs in the ZCI.
- An extensive study should be done on how the practices such as nanotechnology can be used to improve the various construction materials in Zambia.
- A study should be conducted on how the benefits of SCPs can be maximized in construction project delivery in Zambia.

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APPENDIX 1: Cover Letter

University of Johannesburg
Department of Construction Management and Quantity Surveying
Doornfontein, 2028

August 2019

Dear Sir/Madam

LETTER OF INVITATION FOR RESEARCH SURVEY

The department of Construction Management and Quantity Surveying at the University of Johannesburg is undertaking a research project titled: ***AN EVALUATION OF SUSTAINABLE CONSTRUCTION PRACTICES IN THE ZAMBIAN CONSTRUCTION INDUSTRY*** as a pre-requisite for the completion of a Magister Technologiae (MTech) degree course in Construction Management.

To this end, we kindly request that you complete the following short questionnaire that should take no longer than 15 minutes of your time. Your response is of the utmost importance to us.

Please do not enter your name or contact details on the questionnaire as it remains anonymous. Should you have any queries or comments regarding this survey, you are welcome to contact me telephonically at +27 79 869 0139 or email me at chandamusenga.cm@gmail.com or Mr. Olusegun Oguntona telephonically at: +27 74 207 6075 or via email: architectoguntona12@gmail.com or Prof. C.O. Aigbavboa telephonically at: +27 11 559 6398 or via email: caigbavboa@uj.ac.za

Thank you in advance

C. MUSENGA

APPENDIX 2: Questionnaire

QUESTIONNAIRE ON AN EVALUATION OF SUSTAINABLE CONSTRUCTION PRACTICES IN THE ZAMBIAN CI

INSTRUCTIONS:
PLEASE ANSWER THE FOLLOWING QUESTIONS BY CROSSING (X) ON THE APPROPRIATE BLOCK OR WRITE DOWN YOUR ANSWER IN THE SPACE PROVIDED.

APPENDIX 2: QUESTIONNAIRE

QUESTIONNAIRE ON AN EVALUATION OF SUSTAINABLE CONSTRUCTION PRACTICES IN THE ZAMBIAN CONSTRUCTION INDUSTRY

INSTRUCTIONS:
PLEASE ANSWER THE FOLLOWING QUESTIONS BY CROSSING (X) ON THE APPROPRIATE BLOCK OR WRITE DOWN YOUR ANSWER IN THE SPACE PROVIDED.

SECTION A - BACKGROUND INFORMATION

This section of the questionnaire refers to background or biographical information. Although we are aware of the sensitivity of the questions in this section, the information will allow us to compare groups of respondents. Once again, we assure you that your response will remain anonymous. Your co-operation is appreciated.

1. What is your highest educational qualification?

Grade 12	1
Certificate	2
Diploma	3
Bachelor's Degree	4
Master's Degree	5
Doctorate	6

2. What is your professional affiliation?

Architect	1
Quantity Surveyor	2
Civil Engineer	3
Construction Manager	4
Construction Project Manager	5
Project Manager	6
Mechanical Engineer	7
Electrical Engineer	8
Land Surveyor	9
Town Planner	10

3. How many years of experience do you have in the construction industry?

0 – 5 years	1
6 – 10 years	2
11– 15 years	3
16- 20 years	4
More than 20 years	5

4. Which of the following do you currently work for?

Public/Government Organisation	1
Private Organisation	2

5. State the province in which you are mainly working. *(Choose only 1 option)*

Central	1
Copperbelt	2
Eastern	3
Luapula	4
Lusaka	5
Muchinga	6
Northern	7
North- Western	8
Southern	9
Western	10

6. State the number of construction projects you have you been involved in the last 12 months.

None	1
1- 2 projects	2
3- 4 projects	3
5- 6 projects	4
7- 8 projects	5
More than 8 projects	6

7. How many sustainable construction projects have you been involved in to date?

None	1
1- 2 projects	2
3- 4 projects	3
5- 6 projects	4
7- 8 projects	5
More than 8 projects	6

SECTION B: ADVERSE IMPACTS OF CONSTRUCTION ACTIVITIES

This section of the questionnaire identifies the adverse impacts of construction activities in Zambia.

Please indicate your answers by using the following 5-point scale where:

1 = No extent; 2 = Small extent; 3 = Moderate extent; 4 = Large extent; 5 = Very large extent

6. To what extent are the following adverse impacts of construction activities in Zambia?

	Adverse impacts of construction activities	**To no extent**	**Small extent**	**Moderate extent**	**Large extent**	**Very large extent**
1	Depletion of non- renewable energy resources	1	2	3	4	5
2	Depletion of non-renewable material resources	1	2	3	4	5
3	Soil erosion	1	2	3	4	5
4	Increased air pollution	1	2	3	4	5
5	Loss of marine life	1	2	3	4	5
6	Climate change	1	2	3	4	5
7	Degradation of the ecosystem	1	2	3	4	5
8	Transformation of habitable land into deserts	1	2	3	4	5
9	Increased land pollution	1	2	3	4	5
10	Deforestation	1	2	3	4	5
11	Habitat destruction	1	2	3	4	5
12	Increased water pollution	1	2	3	4	5
13	Irreversible transformation of valuable land	1	2	3	4	5
14	Disruption of natural ecosystem	1	2	3	4	5
15	Increased energy consumption	1	2	3	4	5
16	Generation of excessive waste	1	2	3	4	5
17	Ozone depletion	1	2	3	4	5
18	Land degradation	1	2	3	4	5
19	Degradation of waterways	1	2	3	4	5
20	Acid rains	1	2	3	4	5
21	Decreased productivity level of building occupants	1	2	3	4	5
22	Declined health of building occupants	1	2	3	4	5
23	Declined health of construction workers	1	2	3	4	5

SECTION C- LEVEL OF AWARENESS OF SUSTAINABLE CONSTRUCTION PRACTICES

This section of the questionnaire assesses the level of awareness of sustainable construction practices in the Zambia construction industry.

Please indicate your answers using the following 5-point scale:

1 = Not At All Aware; 2 = Slightly Aware; 3 = Somewhat Aware; 4 = Moderately Aware;

5 = Very Aware

7. To what extent are you aware of the following sustainable construction practices in the Zambia construction industry?

	Sustainable Construction Practices	**Not At All Aware**	**Slightly Aware**	**Somewhat Aware**	**Moderately Aware**	**Very Aware**
1	Life Cycle Costing	1	2	3	4	5
2	Construction Ecology	1	2	3	4	5
3	Biomimicry	1	2	3	4	5
4	Life Cycle Assessment	1	2	3	4	5
5	Ecological economics	1	2	3	4	5
6	Value Management	1	2	3	4	5
7	Ecological Footprint	1	2	3	4	5
8	Nanotechnology	1	2	3	4	5
9	Design for Environment	1	2	3	4	5
10	Lean Construction	1	2	3	4	5
11	Industrialised Building System	1	2	3	4	5
12	Building Information Modelling	1	2	3	4	5
13	Cradle to Cradle design	1	2	3	4	5
14	Internet of Things	1	2	3	4	5
15	3D Printing (Additive Manufacturing)	1	2	3	4	5
16	Blockchain Technology	1	2	3	4	5

SECTION D: BARRIERS TO ADOPTING AND IMPLEMENTING SUSTAINABLE CONSTRUCTION PRACTICES

This section of the questionnaire identifies the barriers to the adoption and implementation of sustainable construction practices in the Zambia construction industry.

Please indicate your answers by using the following 5-point scale where:

1 = No extent; 2 = Small extent; 3 = Moderate extent; 4 = Large extent; 5 = Very large extent

8. To what extent are the following barriers to the adoption and implementation of sustainable construction practices in the Zambian construction industry?

	Barriers to the adoption of sustainable construction practices	**To no extent**	**Small extent**	**Moderate extent**	**Large extent**	**Very large extent**
1	Lack of commitment among stakeholders	1	2	3	4	5
2	Lack of proper communication among stakeholders	1	2	3	4	5
3	Poor implementation strategy	1	2	3	4	5
4	Lack of awareness	1	2	3	4	5
5	Lack of constructible (buildable) designs	1	2	3	4	5
6	Limited knowledge on sustainable practices	1	2	3	4	5
7	Lack of training and education	1	2	3	4	5
8	Shortage of skilled personnel	1	2	3	4	5
9	Lack of measurement framework	1	2	3	4	5
10	Limited involvement of stakeholders	1	2	3	4	5
11	Stakeholders' resistance to change	1	2	3	4	5
12	Lack of interest in the issue of sustainability	1	2	3	4	5
13	Absence of building codes and regulations	1	2	3	4	5
14	Lack of incentives	1	2	3	4	5
15	Lack of government support	1	2	3	4	5
16	Lack of funds for research and development	1	2	3	4	5
17	High initial costs	1	2	3	4	5
18	Unstable green market conditions	1	2	3	4	5
19	Poor integration of supply chain	1	2	3	4	5
20	Lengthy implementation process of the new practices	1	2	3	4	5
21	Unsuitable procurement system selected for the project	1	2	3	4	5
22	Limited availability of sustainable products	1	2	3	4	5
23	Lack of client demand for sustainable products or structures	1	2	3	4	5
24	Corruption within the construction industry	1	2	3	4	5
25	High cost of sustainable technologies	1	2	3	4	5

SECTION E- BENEFITS OF ADOPTING AND IMPLEMENTING SUSTAINABLE CONSTRUCTION PRACTICES

This section of the questionnaire explores the benefits of adopting and implementing sustainable construction practices in Zambia.

Please indicate your answers by using the following 5-point scale where:

1 = No extent; 2 = Small extent; 3 = Moderate extent; 4 = Large extent; 5 = Very large extent

9. To what extent are the following benefits of adopting and implementing sustainable construction practices in the Zambian construction industry?

	Benefits of adopting sustainable construction practices	**To no extent**	**Small extent**	**Moderate extent**	**Large extent**	**Very large extent**
1	Reduced waste generation	1	2	3	4	5
2	Reduced energy consumption	1	2	3	4	5
3	Improved air quality	1	2	3	4	5
4	Improved water quality	1	2	3	4	5
5	Reduced emission of greenhouse gases	1	2	3	4	5
6	Increased protection of ecosystem	1	2	3	4	5
7	Reduced reliance on non-renewable resources	1	2	3	4	5
8	Reduction in the structure's carbon footprint	1	2	3	4	5
9	Increased demand for green construction materials	1	2	3	4	5
10	Increased use of green construction materials	1	2	3	4	5
11	Improved building performance	1	2	3	4	5
12	Increased productivity of building occupant	1	2	3	4	5
13	Reduction in construction time	1	2	3	4	5
14	Positively impacts property value	1	2	3	4	5
15	Reduction in maintenance costs	1	2	3	4	5
16	Reduced operating costs	1	2	3	4	5
17	Enhances competitiveness	1	2	3	4	5
18	Enhances sustainable economic growth	1	2	3	4	5
19	Creates market for green products and services	1	2	3	4	5
20	Optimises life-cycle economic performance	1	2	3	4	5
21	Enhances project efficiency	1	2	3	4	5
22	Enhances project quality	1	2	3	4	5
23	Higher customer satisfaction	1	2	3	4	5
24	Improves site health and safety	1	2	3	4	5
25	Improves the overall quality of life	1	2	3	4	5
26	Promotes the use of local sustainable materials	1	2	3	4	5

SECTION F- DRIVERS TO THE ADOPTION AND IMPLEMENTATION OF SUSTAINABLE CONSTRUCTION PRACTICES

This section of the questionnaire explores the drivers to the adoption and implementation of sustainable construction practices in Zambia.

Please indicate your answers by using the following 5-point scale where:

1 = No extent; 2 = Small extent; 3 = Moderate extent; 4 = Large extent; 5 = Very large extent

10. To what extent will the following promote the adoption and implementation of sustainable construction practices within the Zambian construction industry?

	Drivers to the adoption of sustainable construction practices	**To no extent**	**Small extent**	**Moderate extent**	**Large extent**	**Very large extent**
1	Formulation of implementation policies and regulations	1	2	3	4	5
2	Continuous professional development in Sustainable Development	1	2	3	4	5
3	Training of skilled and unskilled workers in Sustainable Development	1	2	3	4	5
4	Inclusion of sustainable practices in university syllabi	1	2	3	4	5
5	Increased client and stakeholder awareness	1	2	3	4	5
6	Increased client demand	1	2	3	4	5
7	Introduction of economic incentives	1	2	3	4	5
8	Increased funding for research and development	1	2	3	4	5
9	Continued improvement of existing practices	1	2	3	4	5
10	Improved multi-disciplinary communication	1	2	3	4	5
11	Increased supply of green materials	1	2	3	4	5
12	Change in the organisational and stakeholder attitude	1	2	3	4	5
13	Government support	1	2	3	4	5
14	Efficient market for green products and services	1	2	3	4	5
15	Improved efficiency of sustainable products and services	1	2	3	4	5
16	Enforcement of implementation standards	1	2	3	4	5
17	Development of sustainability measurement standards	1	2	3	4	5

Thank you for your co-operation in completing this questionnaire.