Developing a Behaviour Change Intervention to improve the adoption and implementation of Sustainable Construction Practices by stakeholders in the South African construction industry

by

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Declaration

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Abstract

While sustainable construction has gained increasing attention internationally, there are still only limited studies that address the issue of sustainable construction in South Africa. Furthermore, the adoption and implementation of sustainable solutions in the South African construction industry is not apparent. The objective of this research study is to understand the current behaviour of construction industry stakeholders with respect to sustainable construction practices and to identify and examine the barriers and drivers of sustainable construction in the context of South Africa. This is achieved by adopting a theoretical behaviour change approach to develop an intervention strategy for improving and facilitating the shift towards adopting sustainable construction practices and principles, thereby reducing the negative impact of the development of the construction industry on the environment.

A three-phased, explanatory sequential mixed methods research design approach, guided by the Behaviour Change Wheel (BCW), was adopted in this study. In Phase One of the three-phase process to intervention design, an integrative review was conducted, and a descriptive and content analysis of the barriers and drivers of sustainable construction is presented. A total of 37 articles were reviewed, identifying 56 barriers and drivers from the integrative review, and coded against the Capability, Opportunity, Motivation – Behaviour (COM-B) model components and the Theoretical Domains Framework (TDF) domains. The barriers and drivers include: capability (knowledge, cognitive and interpersonal skills, behavioural regulation); opportunity (environmental context and resources); motivation (reinforcement, social/ professional role and identity, beliefs about consequences). This provided a theoretical basis for developing a survey questionnaire in phase two of the intervention design. Phase Two included a statistical analysis of the relevant barriers to and drivers of sustainable construction that emerged through a survey questionnaire distributed to construction industry stakeholders. Phase Three presents the three stages of the BCW design and the development of the intervention components for the intervention toolbox. Five intervention functions and 12 behaviour change techniques (BCTs) were identified as relevant to include in the intervention toolbox design to improve the engagement of sustainable construction amongst construction industry stakeholders. Semi-structured interviews were conducted with subject matter experts in the construction industry in order to evaluate the findings from Phase One and Phase Two, assess the intervention content identified which consists of the intervention functions and the BCTs, evaluate the intervention components and discuss the quality and applicability of the behaviour change intervention toolbox.

This research study provides an understanding and overview of the use of the BCW to develop a behaviour change intervention toolbox aimed at facilitating the adoption and implementation of sustainable construction practices amongst construction industry stakeholders. The BCW presents a useful framework and systematic approach to integrate multiple sources of data to inform the selection of a theory-based behaviour change intervention strategy. Construction industry stakeholders may use these strategies to design, implement and evaluate sustainable construction interventions that are feasible within the context of the built environment in South Africa.

Opsomming

Alhoewel volhoubare konstruksie internasionaal toenemend aandag kry, is daar nogsteeds net ‘n beperkte aantal studies wat die kwessie van volhoubare konstruksie in die konteks van Suid-Afrika aanspreek. Die aanvaarding en implementering van volhoubare oplossings in die Suid-Afrikaanse konstruksiebedryf is ook nie sigbaar nie. Die doel van hierdie navorsing is om die huidige gedrag van rolspelers in die konstruksiebedryf te verstaan in verband met volhoubare konstruksie praktyke. Verder word die hindernisse en drywers van volhoubare konstruksie ondersoek in die konteks van Suid-Afrika. Dit word bereik deur 'n teoretiese benadering vir gedragsverandering te gebruik om 'n intervensiestrategie te ontwikkel. Die doel van die intervensiestrategie is om die verskuiwing na die aanvaarding van volhoubare konstruksiepraktyke en -beginsels te fasiliteer en verbeter, sodat die negatiewe impak van die konstruksiebedryf op die omgewing kan verminder word.

Hierdie studie maak gebruik van 'n drie-fasige, verduidelikende opeenvolgende gemengde metodes navorsingsbenadering, gelei deur die gedragsveranderingswiel (GVW). In Fase Een van die drie-fasige intervensie-ontwerp, met behulp van 'n integrerende oorsig, was 'n beskrywende en inhoudsanalise van die hindernisse en drywers van volhoubare konstruksie uitgevoer. Altesaam was 37 artikels hersien en 56 hindernisse en drywers is geïdentifiseer uit die integrerende oorsig en gekodeer teen die Vermoë, Geleentheid, Motivering - Gedrag (VGM-G)-model-komponente en die Teoretise Domeine Raamwerk (TDR)-domeine. Die hindernisse en drywers het die volgende ingesluit: vermoë (kennis, kognitiewe en interpersoonlike vaardighede, gedragsregulering, fisieke vaardighede); geleentheid (omgewingskonteks en hulpbronne); motivering (versterking, sosiale/professionele rol en identiteit, oortuigings oor gevolge). Die resultate van die integrerende oorsig was daarna opgesom en ontwikkel in die konteks van die VGM-G-model en TDR, om 'n teoretiese basis te vorm vir die ontwikkeling van 'n vraelys in Fase Twee. In Fase Twee is 'n vraelys aan rolspelers in die konstruksiebedryf gestuur en vervolg deur 'n statistiese ontleding van die relevante hindernisse en drywers van volhoubare konstruksie. Fase drie bied aan die drie stadia van die ontwerp van die GVW en die ontwikkeling van die intervensiekomponente vir die intervensiestrategie. Vyf intervensiefunksies en 12 gedragsveranderingstegnieke (GVT’e) was geïdentifiseer as relevant om in te sluit in die intervensiestrategie om die betrokkenheid van volhoubare konstruksie onder die rolspelers in die konstruksiebedryf te verbeter. Semi-gestruktureerde onderhoude was uitgevoer om die bevindings uit Fase Een en Fase Twee te evalueer, die geïdentifiseerde intervensie-inhoud wat uit die intervensie funksies en GVT’e bestaan te ondersoek, die intervensiekomponente te evalueer en die gehalte en toepaslikheid van die gedragsveranderingsintervensie te bespreek.

Hierdie navorsingstudie bied 'n begrip van die gebruik van die GVW vir die ontwikkeling van 'n intervensiestrategie wat daarop gemik is om die aanvaarding en implementering van volhoubare konstruksiepraktyke onder die rolspelers in die konstruksiebedryf te verbeter. Die GVW bied 'n nuttige raamwerk en sistematiese benadering om verskeie inligtingsbronne te integreer om die keuse van 'n teorie-gebaseerde intervensiestrategie in te lig. Rolspelers in die konstruksiebedryf kan hierdie strategieë gebruik om volhoubare konstruksie-intervensies te ontwerp, implementeer en evalueer, wat binne die konteks van die konstruksiebedrfy uitvoerbaar is.

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“I can do all things through Christ who strengthens me.”
Philippians 4 verse 13

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Nomenclature

Acronyms

APEASE	Affordability, Practicability, Effectiveness/Cost-Effectiveness, Acceptability, Safety/Side Effects, and Equity
BCT	Behaviour Change Technique
BCTTv1	Behaviour Change Technique Taxonomy version 1
BCW	Behaviour Change Wheel
BIM	Building Information Modelling
CF	Critical Factor
CI	Construction Industry
COM-B	Capability, Opportunity, Motivation-Behaviour Model
GBCSA	Green Building Council of South Africa
SAP	Sustainability Action Plan
SDGs	Sustainable Development Goals
SC	Sustainable Construction
SME	Subject Matter Expert
SPM	Sustainable Project Management
TDF	Theoretical Domains Framework

Chapter 1
Introduction

This chapter serves as an introduction to the research study. The chapter provides a greater understanding of the research study by providing a background to the research topic and the reason for conducting the study. Five research objectives are formulated to address the research question and aim. This is followed by the research strategy adopted in this research study which highlights the trajectory of the research process and provides a guide to the research document. The scope and limitations of the research is presented and the ethical considerations for this research study is discussed.

1.1. Background to the Research

Over the past few decades, national and local governments globally have recognised that the construction industry, and specifically the built environment, is a key role player in the adoption and implementation of sustainable development. The construction industry, which includes the entire life cycle of a building project, from pre-feasibility to decommissioning and disposal, has a significant impact on the environment, economy and society (Kibert, 2007). Since the initial development of the sustainability agenda in the late 1980s, the principle of sustainable development aims to simultaneously pursue environmental, economic, and social dimensions of development. However, various authors argue that sustainable development can be interpreted and pursued within a specific context and therefore the objectives and development solutions vary (Amui, Jabbour, Jabbour, *et al.*, 2017; Bebbington, 2001; Elliott, 2006; Hjorth & Bagheri, 2006; du Plessis, Adebayo, Ebohan, *et al.*, 2002).

The construction industry has a unique position to create value by improving the quality of life of society and thereby positively contributing to sustainable development. Although the conventional approach to the built environment is driven by cost, quality and performance criteria, sustainable design and construction aims to additionally minimise resource depletion, minimise environmental degradation and create a healthy built environment (Kibert, 2016). Sustainable construction (SC), although lacking a general definition and therefore lacking a universal approach (Ahn, Pearce, Wang, *et al.*, 2013; Ofori, 2015; du Plessis *et al.*, 2002), has been highlighted in documents such as the Agenda 21 for Sustainable Construction published by the International Council for Research and Innovation in Building and Construction (CIB). The purpose of this document was to provide guidance for all national agendas on a global scale to implement SC research and development strategies to overcome issues and challenges of sustainable development within the construction industry (du Plessis *et al.*, 2002). Responses to the SC agenda has however varied amongst the different contexts of countries.

Although SC has been studied by authors in both developed and developing countries who recognise the need to develop and implement SC agendas (Ahn *et al.*, 2013; AlSanad, 2015; Brennan & Cotgrave, 2014; Chan, Darko & Ameyaw, 2017; Darko, Zhang & Chan, 2017; Häkkinen & Belloni, 2011; Ismail, Idris, Nasir, *et al.*, 2012; Marchman & Clarke, 2011; Saleh & Alalouch, 2015), only a few researchers (Aigbavboa, Ohiomah & Zwane, 2017; du Plessis, 2007a) have conducted studies which extends the concept of SC to South Africa. In 2002, du Plessis prepared a discussion document named the "Agenda 21 for Sustainable Construction in Developing Countries" (A21 SCDC) which sought to present a sector and developing country response to the challenge of sustainable development. It also aimed to highlight the implications of sustainability in the built environment in a regional context and to suggest the principles and strategy for action for the developing world in partnership with the developed world. The objectives of this agenda aimed to provide a framework that can be used to guide research and development (R&D) in developing countries and to promote the exchange of learning of SC within the developing world. Du Plessis further investigated an action plan for sustainability in the African context in 2005 to emphasise that there is a process required to create an international agenda for sustainable building and construction to recognise the regional and local differences. du Plessis (2007a) argues that developing countries will become the platform for infrastructural and industrial development and therefore the construction sector in these countries has a critical role to play in responding to the sustainable agenda. The A21 SCDC strategy developed a broad framework to guide the development of a response to the opportunity within sustainable development for the construction sector.

Although numerous strategies were further developed as stated by Dalal-Clayton & Bass (2012), there has been very little impact of such strategies as a result of lack of integration between frameworks and key decision-makers, limited links between policies and practical applications, a narrow base of participation from multiple stakeholders, and many strategies lack clear and concise priorities and achievable targets (du Plessis, 2007a). Another study conducted by Sebake (2008) on architect's as stakeholders in the built environment emphasised the challenges faced by professionals in the implementation of sustainability principles during the development of building projects. The study recognised that any strategies to sustainable building projects must be dealt with at the initial stages of a project and include both architect's as well as the rest of the professional team such as engineers and contractors. In doing so, the clients brief can be formulated and developed by taking advantage of all participants' competencies and prerequisites to ensure a sustainable build and minimise silo design and development and clashes later in the project. Windapo (2014) employed a qualitative research approach conducting 13 interviews with stakeholders in the construction industry to assess what motivates the adoption of green buildings by clients and evaluate the role of the Green Building Council of South Africa (GBCSA) and green building regulations. The thematic analysis found that green building is at an early stage of development in South Africa and that rising energy costs and the GBCSA's Green Star rating system was the primary drivers of green building.

Windapo (2014) noted that these drivers have not changed since 2006, which is nearly a decade since the publication of the article and highlighted that the drivers of green building were mainly financially driven and not necessarily to protect the environment. Evidence of this is substantiated by the case studies which suggests that competitive advantage and corporate image were key drivers to achieving Green Star status. Therefore, the author concludes that without the economic benefit which green buildings provide its' clients and developers, and with a lack of government regulations to support green building construction, a limited number of clients and developers would drive green building projects forward for the sole purpose of environmental sustainability. An empirical study done by Aigbavboa, Ohiomah & Zwane (2017) on the "lazy view" of construction professionals in the South African construction industry suggests that the following reasons were the key challenges facing the construction industry in a bid to achieve sustainable construction: additional cost of building sustainable buildings, a limited understanding of the benefits of sustainable construction and lastly, the lack of mobilisation of sustainable construction resources to support technological changes in the industry.

1.1.1. Research Rationale

In a global context, the built environment plays a significant role in most economies and contributes significantly to global warming as it consumes a large proportion of global resources, contributes to environmental degradation and climate change (Department of Environmental Affairs, 2011a,b). The relationship between the built environment and its role in climate change is its dimension of consumption of materials and resources. The built environment is one of the primary energy consumers contributing between 30-40% of global energy use, 20-30% of greenhouse gas emissions, and approximately 40% of the materials which enter the global economy annually, is converted to building material components (Department of Environmental Affairs, 2011b).

The environmental impacts of designing and constructing buildings include but is not limited to i) the use of energy and water, ii) raw material extraction which increases the loss of biodiversity, and iii) clearing of vegetation on sites for new infrastructure builds (Department of Environmental Affairs, 2011b). Africa is projected to be one of the continents that are most severely impacted by the effects of climate change due to multiple stresses and low adaptive capacity (Department of Environmental Affairs & Tourism, 2008). South Africa is no different, as electricity consumption of buildings alone accounts for nearly a quarter of the country's carbon emissions (Department of Environmental Affairs, 2011a). The freshwater resources in South Africa are at a critical point as evident in drought-stricken regions such as the Western Cape which faces potential long-term water restrictions to reduce the demand on the municipal water supply (Reddick & Fundikwa, 2018). In an attempt to supply both access to basic services and infrastructure whilst simultaneously maintaining reliable supply to high-end users and ongoing economic activities, the demand for development has placed additional pressure on already strained infrastructure and resources (Department of Environmental Affairs, 2011a).

According to Climate Transparency (2018) who publish the Brown to Green Report[1] annually, there has been developments within green policy in South Africa such as the 2018 Integrated Resource Plan which boosts renewable energy until 2030 and the carbon tax bill which was approved in February 2019, which covers at least 75% of greenhouse gas emissions. However, South Africa, along with Australia and Indonesia who have the highest emission intensity in the power sector, has also taken steps backwards by continuing to build coal power plants until 2024 (Climate Transparency, 2018) and lack clear strategies to phase out coal. Although there has been a shift towards adopting a green approach towards buildings, since the establishment of the GBCSA in 2007, professional stakeholders in the built environment have been reluctant to pursue greening of buildings in their design and construction methodologies. In a study conducted by Coetzee & Brent (2015), it was found that the perception amongst key stakeholders in the built environment was that the additional costs associated with the design of sustainable buildings are too high. The results of the study, however, indicated that the perceived cost of sustainable design and construction was more than double what the actual cost was. This highlights one of the barriers towards effectively adopting and implementing SC, which is discussed further in Chapter 2.5. In addition to this, the lack of regulations and policies which govern SC in many developing countries has made it less likely for stakeholders in the industry to adopt SC practices (Aghimien, Aigbavboa, Oke, *et al.*, 2018; Djokoto, Dadzie & Ohemeng-Ababio, 2014; Foong, Mitchell, Wagstaff, *et al.*, 2017; Suliman & Omran, 2009). Although there are regulations and frameworks available in South Africa, such as the Green Economy Accord, National Greening Framework and the Green Building Council which certifies green buildings, Simpeh & Smallwood (2015) suggest that the adoption of sustainable practices in the South African construction industry has been slow due to conflicting regulations and stakeholders who fear the liability and litigation when it comes to the performance of new sustainable products and systems. The current legislation is generally voluntary and prescriptive, which further reduces the transition towards a more sustainable approach to the multiple phases of the building life cycle (Ametepey, Aigbavboa & Ansah, 2015; Gan, Zuo, Ye, *et al.*, 2015; Mousa, 2015). Assessing the current awareness amongst built environment stakeholders along with their perceptions is critical to identify and understand the barriers towards a more sustainable built environment in the South African context. By identifying these barriers, it allows key decision-makers to look at possible solutions to overcome these barriers and work towards driving the SC agenda forward.

In light of the above, this research aims to contribute to the existing literature by addressing two key aspects in relation to SC in South Africa. Firstly, the understanding and perceptions of stakeholders with regards to SC, and how this is promoted amongst stakeholders to evaluate the barriers and drivers of adopting and implementing SC. Secondly, the research aims to use behaviour change theory to provide a theoretical approach to analysing the barriers and drivers to the adoption and implementation of SC at the building construction project level, and to develop a behaviour change toolbox to provide an intervention strategy for behaviour change in the construction industry.

[1] The Brown to Green report is published by Climate Transparency in conjunction with which provides an overview of the G20 countries in which South Africa is listed, and whether – and how well they are doing in transitioning towards a low-carbon economy.

1.2. Research Question

What is the current perception and awareness of sustainable construction by professional stakeholders in the built environment in South Africa, and how can behaviour change theory be used to guide the development of an intervention to improve the adoption and implementation of sustainable construction?

1.3. Research Aim and Objectives

The aim of this research is to contribute towards increasingly effective and efficient adoption and implementation of sustainable construction practices within the context of the South African construction industry. The objectives that support the achievement of this aim are defined below:

i. Investigate the concept of sustainable development and how it is applied within the construction industry (RO-1).
ii. Evaluate the current legislation and policies that govern sustainable construction in South Africa (RO-2).
iii. Identify the drivers and barriers of sustainable construction adoption and implementation amongst construction industry stakeholders (RO-3).
iv. Investigate the perception of barriers and drivers of sustainable construction by construction industry stakeholders in South Africa (RO-4).
v. Develop a behaviour change intervention by identifying the components and/or strategies that can be used by construction industry stakeholders to facilitate the adoption and implementation of sustainable construction through a sustainable project management[2] process (RO-5).

1.4. Research Strategy

The research strategy adopted in this study has four phases as highlighted in Figure 1-1. The research study adopted a nonlinear path and each of the research phases and the research approaches used to address the various research objectives are discussed in Chapter 4. The outcomes of the research from each phase are discussed in the remaining chapters.

[2] Sustainable project management (SPM) encompasses the planning, monitoring and controlling of project delivery and support processes which considers the economic, environmental and social aspects of the life cycle of project resources, processes, deliverables and effects (Chawla *et al.*, 2018).

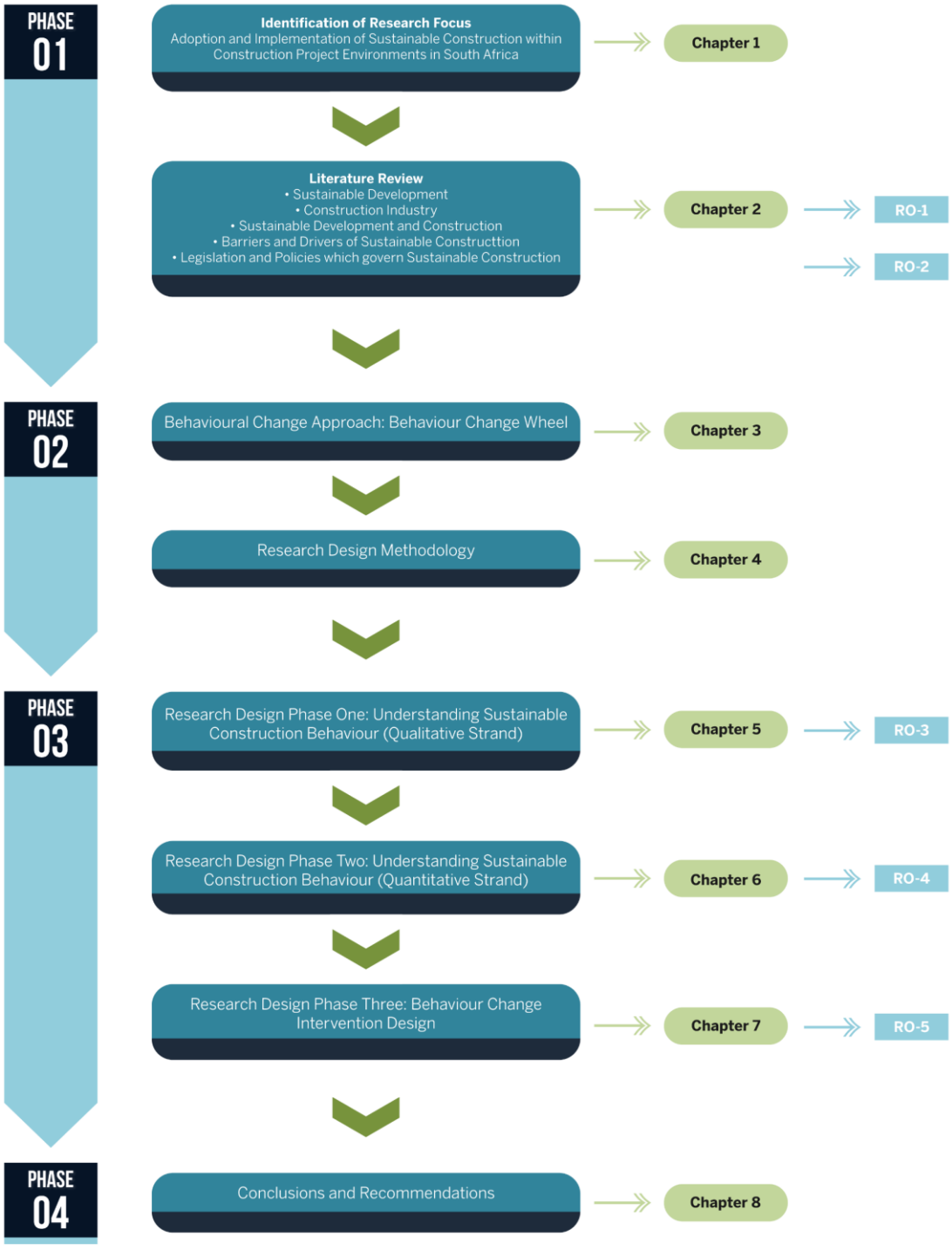

Figure 1-1: Research Strategy

1.5. Scope and Limitations of the Study

The scope of this research study will focus on the construction industry in the South Africa. The construction industry in the context of this study includes only a portion of the whole building life cycle[3] where a specific building project is the outcome. This will entail the design and development phase of the whole building life cycle. A specific focus will be placed on organisations within the built environment that are key stakeholders during the design and development phase of a building project. Organisations will include architectural firms, engineering consultancies (built environment specialists such as structural, civil, mechanical, and electrical engineers), contractors, and quantity surveying firms. The study will therefore not include clients such as private investors or government organisations or project management consultants. This will however not affect the validity of the study as multiple other key stakeholders' perceptions and views will be addressed. The behaviour change toolbox developed in this research study will be applicable to all stakeholders involved in the design and development phase of the project life cycle.

The findings from this study should be interpreted and understood with the following limitations in mind:

i. Although the study aimed to seek the perceptions of all construction industry stakeholders, structural and civil engineers represented 67.6% of the sample. The findings of the research related to the targeted Theoretical Domains Framework (TDF) domains should therefore be interpreted as such, however it is deemed to be transferrable to other stakeholder groups.
ii. Sustainable construction is a broad and complex concept which encompasses a variety of principles, practices, methods, processes, systems and technologies. This study therefore focused on sustainable project management as an area to improve the adoption and implementation of sustainable construction.
iii. Due to time and cost constraints, and lack of access to organisations, the application of the toolbox could not be tested in industry or be evaluated against a case study.
iv. There were limitations and challenges with recruitment of participants in both Phase Two and Phase Three of the design of the toolbox. Nonetheless, participants who responded provided sufficient contextual data which helped to achieve the aims and objectives of this research study.

[3] Whole building life cycle refers to all the life cycle phases of the building: pre-feasibility studies, conceptual design, raw material procurement, manufacturing, design and development, construction, operation and decommissioning (Garcia-Ceballos *et al.*, 2018).

1.6. Ethical Implications of the Research

The ethical implications of research can be divided into four key areas of consideration. The first consideration is whether the research study is harmful to those who participate in the study. In this research study, participants will not be exposed to any experiments or chemicals which may physically harm them. The researcher will also ensure that the confidentiality and anonymity of participants and their organisations are maintained throughout the study. This will be achieved through the generalization of groups of participants such as the years of experience in their field. Participants will also be grouped based on their role in the construction industry (contractors, architects etc.). Furthermore, the participation in the research study is voluntary and participants will be allowed to withdraw from the research study at any point without affecting the study. It is important that the principle of informed consent is applied within the research environment as it primarily focuses on the views and perceptions of the participants. According to Bryman *et al.* (2017), there are two main reasons why the principle of informed consent might not be as easy to implement. Firstly, the researcher might fear that they would contaminate the answers to questions of prospective participants by giving them all the background information. Secondly, the ethnographic researcher is in contact with many people and therefore it is not practical to ensure that everyone has an opportunity for informed consent.

For the purpose of this study, the researcher will provide participants with sufficient information and background to the study so that participants can make an informed decision about whether or not to participate in the study. Bryman *et al.* (2017) state that the researcher has a responsibility not to intrude, violate or disrespect the beliefs and values of participants for the aim of addressing the research objectives. The researcher will ensure that the privacy of the participants is not invaded and that participants can freely choose whether to answer certain questions or not. Furthermore, the researcher will include a fair representation of participants with different levels of expertise in their field, various disciplines within the construction industry, as well as multiple organisations.

1.7. Conclusion: Chapter 1

Chapter 1 introduces the research study by discussing the background to the research and presenting the five research objectives which will support the aim of the research. Secondly, the four phases to the research development and strategy is provided and the scope and limitations of the study is addressed. Lastly, the key ethical considerations for this research study are identified and discussed.

Chapter 2
Sustainable Development and the Construction Industry

The key focus area of this research study is to investigate the adoption and implementation of sustainable construction (SC) within the construction industry in South Africa. This research draws from two main bodies of literature: i) Sustainable Development, and ii) Construction Industry as shown in Figure 2-1. Although the existing literature regarding sustainable development has been broadly analysed in many other countries, limited research exists which places sustainable development at the forefront of the construction industry in South Africa. This poses a concern with regards to how the construction industry in South Africa is currently addressing sustainable development challenges and adopting sustainable practices to ensure the sustainability of the industry as well as that of the environment, economy, and society. On the other hand, the terms “sustainable development” and “construction” are complex concepts as illustrated in the literature which needs to be understood for the development of effective approaches to sustainability (Elliott, 2006). Furthermore, the literature has brought about various terms which bring sustainable development and construction together which further hinders the understanding of these two terms (du Plessis, 2007a). This chapter of the literature review aims to firstly address the concept of sustainable development. Secondly, it aims to understand the diverse perspectives and interpretations of the construction industry and the role it plays in influencing and achieving sustainable development. Lastly, a review of the concept of SC is discussed. Chapter 2 addresses the first and second objectives of this research (RO-1: *Investigate the concept of sustainable development and how it is applied within the construction industry*; and RO-2: *Evaluate the current legislation and policies which govern sustainable construction in South Africa*).

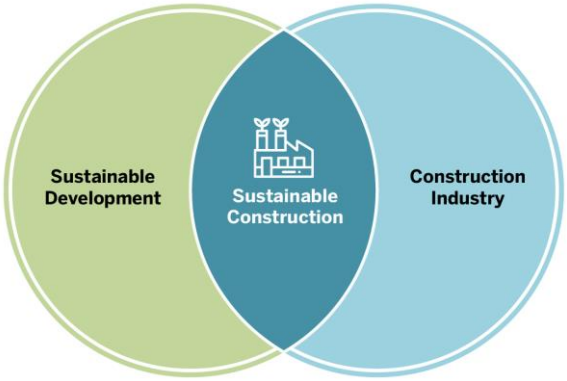

Figure 2-1: Main Bodies of Literature

2.1. The Concept of Sustainable Development

The concept and definition of sustainable development was published for the first time in the Brundtland Report in 1987. The definition of sustainable development which is still commonly used is "*to ensure that development meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED 1987, p. 16). There are, however, several definitions of sustainable development by various authors and organisations such as: "*improving the quality of human life while living within the carrying capacity of supporting ecosystems*" (IUCN, UNEP & WWF 1991, p. 10); and "*determined to promote economic and social progress for their peoples, taking into account the principle of sustainable development and within the context of the accomplishment of the international market and of reinforced cohesion and environmental protection, and to implement policies ensuring that advances in economic integration are accompanied by parallel progress in other fields*" (Amsterdam Treaty 1997, p. 7).

It is evident in the literature that various definitions of sustainable development are used and the principles of these definitions are applied accordingly. du Plessis *et al.* (2002) state that the various sectors within society interpret and pursue sustainability and sustainable development within their specific context. In addition to this, Bebbington (2001) argues that the meaning of a concept cannot be defined without considering the underlying assumptions made by individuals when developing meaning. The concept of sustainable development therefore needs to emerge from various stakeholders with diverse perspectives. According to Kates *et al.* (2005), this would lead to the reconciliation of different and opposing values and goals with regards to sustainable development which would develop new insights and mutual action to achieve multiple goals simultaneously. Amui *et al.* (2017) also emphasise that multidisciplinary integration and collaboration is necessary to advance and develop sustainable solutions. Due to the variations in definitions of sustainable development, this research study aims to understand the concept of sustainable development and how it is applied as opposed to defining the concept.

2.1.1. Theory of Sustainable Development

Throughout the literature, most of the definitions of sustainable development encompass three interdependent pillars: environmental, economic, and social. In 1987, Ed Barbier developed what he described as an analytical approach to view sustainable development: interaction amongst the three pillars which are contained in interlocking circles as shown in Figure 2-2. Furthermore, each of the pillars has their own human-ascribed objectives and the primary objective of sustainable development is to then maximise each of these goals across the three pillars. However, Barbier (1987) highlights that in order to maximise these objectives and achieve sustainable development, trade-offs are required: decisions regarding what is to be sustained at a specific point in time, how this will be pursued, and recognising at what cost to individuals and groups sustainable development can be achieved. Redclift (2005) further emphasises that sustainable development can be approached in various ways which are based on how people define their needs. This often excludes the possible needs of others which can have a long-term effect on the sustainability of peoples' livelihoods.

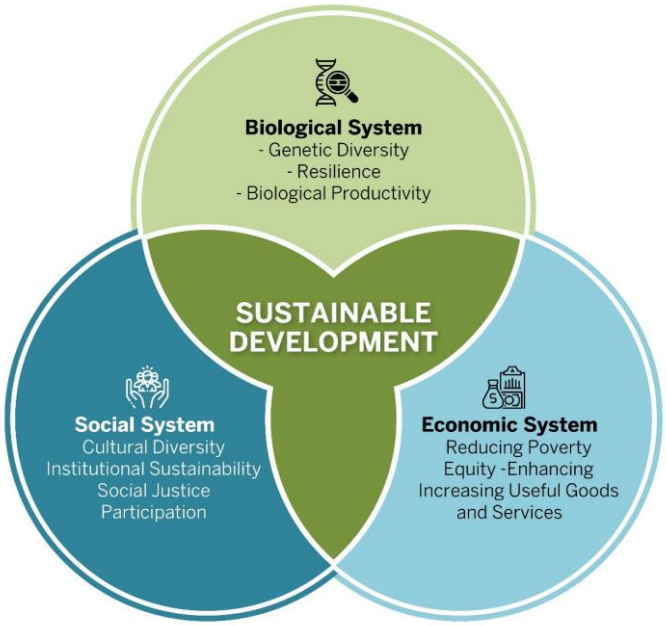

Figure 2-2: Three-pillar sustainable development model (Barbier, 1987)

Although this three-pillar approach is widely used, it has received some criticism in literature. Gibson (2006) argues that sustainability cannot be defined by actions within each of the spheres but by the relationships between them. He further states that the three-pillars as depicted in the model are recognized as being interdependent and interconnected. However, in real-world applications, there has been limited effective integration of the three pillars because it limits thinking beyond the conventional administrative, academic and technical confines (Gibson, 2006). He criticises the model for two main reasons. Firstly, the three-pillar model emphasises the categories of the three pillars which potentially compete with one another leaving minimal room for balance. Secondly, the concept of sustainability highlights the linkages between objectives amongst the elements which might have been at odds. This conflicts with the divisions created by the three-pillars. Additionally, Lehtonen (2004) has raised four criticisms of the three-pillar model. Firstly, the political critique of the three-pillar approach is that it enables government and other institutions to validate its own objectives within the concept of sustainable development and thereby maintaining the current status quo. Secondly, the three-pillar model strengthens the notion that the economy is detached from the society within which human activities are embedded which is a false consensus. Lehtonen's (2004) third criticism of the three-pillar approach is that it does not give guidance on how to deal with the trade-offs and synergies between the conflicting objectives of the economy, environment, and society. Finally, he argues that the three pillars of sustainable development hold different positions in a hierarchy because they are not qualitatively equal. Lehtonen (2004) therefore developed the bio-economy model of sustainable development which has each of the elements of sustainable development circumscribed by one another as shown in Figure 2-3. This model emphasises that economic activities should be in the service of society while also conserving the biophysical systems necessary for society to sustain its existence (Lehtonen, 2004).

He states that the hierarchy of the three elements can change depending on its importance in specific circumstances. The environment might therefore not always be the most significant element, as long as the social and economic elements do not undermine the environment (Dempsey, Bramley, Power, *et al.*, 2011; Lehtonen, 2004).

Figure 2-3: Bio-economy model of sustainable development (Lehtonen, 2004)

In addition to this, Hjorth & Bagheri (2006) argues that the single and multi-purpose approach to sustainable development needs to be adjusted to an approach which is more integrative and holistic. Their view is that sustainable development is a continuous process which cannot be defined by fixed goals and how they will be achieved, but by "an approach to create change". Although several authors have made a connection between economic growth and sustainable development, Holden *et al.* (2014: p. 131) derived four primary dimensions from the Brundtland Report: "*safeguarding long-term ecological sustainability, satisfying basic human needs, and promoting intragenerational and intergenerational equity*". From this logic, Holden *et al.* (2014) infer that economic growth is not one of the primary dimensions of sustainable development which is in contrast to the three-pillar model which focuses on the balance between environmental, social, and economic issues. Holden *et al.* (2014) argue that economic growth is a means to fulfil and achieve the four primary dimensions, but not a primary dimension in its own right. Therefore, it can be implied that the government will be required to shift away from the notion that economic growth will lead to sustainable development. Despite the fact that most of the initial research which contributed to the definition of sustainable development came from the economics and environmental science fields, the social aspect has garnered more focus in recent work (Elliott, 2006). Dempsey *et al.* (2011) for example, highlights that social sustainability has emerged from the sustainability debate as a theme which has two core dimensions to consider.

Firstly, *social equity* is embedded in social justice, how resources are allocated and the equality of condition which seeks to reduce or eliminate the material inequalities amongst individuals or households in a society (Dempsey *et al.*, 2011). This is reflected in the definitions of sustainable development which aim to meet the needs of the present and future generations as well as redress the inequalities of condition. The second dimension, *sustainability of community*, focuses on the continued feasibility, well-being and functionality of the society which is incorporated in the term 'community'. Dempsey *et al.* (2011) state that there are five measurable aspects of sustainability of community which is linked to the built environment namely:

i. *"social interaction/social networks in the community"*
   Social interaction and networks refer to the layout, density and what the extent of mixed land use is in a street or neighbourhood.
ii. *"participation in collective groups and networks in the community"*
   The participation of individuals in a community is dependent on how mixed the various land uses are and how dense the area is. This will ensure that there is a greater variety of activities in which residents can participate. However, the accessibility of community facilities may influence the participation of individuals in certain activities.
iii. *"community stability"*
   Although Dempsey *et al.* (2011) could not identify a direct link between community stability and the built environment, it can be argued that the decision to reside in or move out of a neighbourhood may be linked to: a) the perception of quality and maintenance of the built environment, b) how accessible services and facilities are and c) the size and type of houses in relation to which stage in their lives the residents are (e.g. single or married with children).
iv. *"pride/sense of place"*
   The built environment and how people develop a sense of attachment to that built environment is shared by residents of a specific neighbourhood. This creates a unique order and way of doing things which allows the neighbourhood to be differentiated from another.
v. *"safety and security"*
   The condition of the built environment and whether or not it is being maintained could potentially have psychological effects on how people perceive their safety.

It is evident that although there is no generic uniform understanding of sustainable development in literature, most definitions emphasise the tension between the goals of environmental protection and economic development with economic goals having primacy. Most authors agree that there are discrepancies around the meaning of sustainable development, what it aims to achieve and how these aims should be achieved. According to Robinson (2004), the lack of a definition is an important opportunity for engagement as a specific definition can exclude individuals and organisations whose views are not represented in such a definition. Elliott (2006: p. 10) further argues that the "*attractiveness (and the 'dangers')*" of the concept of sustainable development potentially manifests itself in the various ways in which it is interpreted and how it is used to support various interests and causes. Coupled with this, is the importance of understanding what the term "needs" mean to different people.

Society is therefore able to create and define their own “needs” within certain contexts and groups (which could be interpreted as “wants”), without satisfying the basic needs of others (Elliott, 2006). Elliott (2006) further emphasizes that to understand the concept of sustainable development, the political nature of sustainable development in practice has to be understood. In addition to this, an understanding of how the solutions which are proposed and the choices and trade-offs which are made, can carry different costs for different people. It is therefore imperative that the changes in thinking about what constitutes sustainable development, what is to be sustained and how to achieve this is identified, to realise the opportunities as well as challenges to effectively implement sustainable development.

2.1.2. Other terminologies linked to Sustainable Development

Following the understanding of sustainable development, it is important to note the different terminologies often referred to in literature alongside sustainable development. These terminologies include concepts such as sustainability, sustainable growth, environmental sustainability, and the green economy.

Sustainability

The Brundtland report which first popularised the concept of sustainable development uses a managerial and more incremental approach to sustainable development. This is favoured by government and private organisations who adopt the term sustainable development in similar contexts to which NGOs and academics adopt the term sustainability. Bell & Morse (2008) emphasise this by arguing that the sustainable component of the sustainable development paradigm[4], varies in meaning based on who uses the term and in what context. Robinson (2004) argues that the division on the terminology of the two terms is a cause of concern to NGOs and environmentalists as development is seen as being synonymous with growth, and therefore sustainable development means to better, but not to challenge continued economic growth. Based on this view, it can be inferred that the term sustainability focuses on what is important, which is the ability of mankind to continue to live within environmental constraints.

The sustainability argument is that it emphasises the questions related to values and fundamental changes in individual attitudes and perceptions towards nature, whereas the sustainable development argument takes what is believed to be a more pragmatic and collective approach, focused on gaining efficiency and improvements in technology (Robinson, 2004). Jabareen (2008) further echoes these arguments by highlighting that ‘sustainability’ is labelled as an environmental logo and ‘development’, as an economic logo. According to Jabareen (2008), there is a paradox between the terms sustainability and development. ‘Sustainability’ is perceived as representing a part of a process or state that can be maintained indefinitely, whereas ‘development’ means adjusting the environment which exploits the natural environment and exhausts natural resources (Jabareen, 2008).

[4] Sustainable Development Paradigm – “Paradigms are theoretical and philosophical frameworks within which we derive theories, laws and generalisations.”(Bell & Morse, 2008) The sustainable development paradigm therefore acts as a framework within which we derive theories, laws and assumptions about the environment, society and the economy.

Additionally, Diesendorf (2000) considers sustainability as the end goal of the process of sustainable development. Although the concept of sustainability was originally adopted in ecological research (which describes sustainability as the potential an ecosystem has to exist over time without any changes), when the term development was added as research evolved, the concept would no longer only be viewed from an environmental perspective, but from a societal and economic perspective as well. The concept of sustainable development therefore aims to moderate the paradox between the two terms as it is believed to be able to cope with the environmental crisis without affecting the current economic relationships of authorities. In other words, capitalism and ecology are not deemed to be a paradox under the banner of sustainable development as the "limits to growth" have become manageable and negotiable. Furthermore, Kuhlman & Farrington (2010) state that the term sustainable development can be used when the potential impact of a proposed policy, project or programme is assessed and which leads to better well-being and has a positive or neutral effect on the state of natural resources for future generations.

Sustainable Growth

In the 1960s, economic growth took precedence in development thinking discussions and applying modern scientific and technical knowledge was viewed as the way in which to achieve prosperity in the underdeveloped world (Elliott, 2006). During this time, development problems of the underdeveloped world were assumed to be solved rapidly through the transfer of technology, finance and experience from developed countries. Elliott (2006) further explains that although the empirical evidence[5] concerning economic growth indicates that change has been achieved, the 'development' was not distributed evenly amongst the populations of these nations. Additionally, Hopwood *et al.* (2005) highlight that the ambiguity in the Brundtland Report allows organisations and governments to favour sustainability without challenging their current course, which uses the reports support for rapid growth to justify the phrase 'sustainable growth'. This allows capitalism to use economic growth as its solution to poverty, in other words, if the economy continues to grow, eventually everyone in society will benefit (Hopwood *et al.*, 2005). Similarly, Daly & Townsend (1993) criticise the term 'sustainable growth' as an oxymoron where the economy, as a subsystem of the earth's ecosystem, is finite and therefore its growth is not sustainable. Daly & Townsend (1993) therefore argue that the term 'sustainable development' makes sense for the economic system if it is understood as "development without growth" (qualitative and not quantitative improvements). On the other hand, Hopwood *et al.* (2005) state that development is identified along with growth, and economic growth is seen as part of the solution. Robinson (2004) supports Hopwood *et al.*'s (2005) statement that development should be seen as synonymous with growth and therefore sustainable development means that it improves but does not challenge economic growth. Bebbington (2001) however views the conflict between economic growth and development as being central to the concept of sustainable development.

[5] Empirical evidence referred to here is based on the gross national product (GDP) which is used as a measure of economic growth or performance of a specific country or region.

The nature of economic growth and how human development is experienced both influences the business practices in industry as business is seen as the catalyst which provides growth for economies and consequently providing development for those who are consumers of their products and services. Bebbington (2001) further argues that the role which economic growth plays in both driving and restricting business' practices with regards to sustainability, may be seen as the reason why organisations fail to engage in sustainable development practices. This is an important element to consider as the current goal of corporate activity is to pursue profits through the expanded levels of economic growth.

Environmental Sustainability

According to Lozano (2008), many definitions of sustainable development in literature have focused primarily on environmental sustainability, which has usually been developed by scientists who rarely considered the importance of social aspects (e.g. poverty, illiteracy, human rights, corruption) and how they interact with economic and environmental aspects. This could be ascribed to the fact that the economy and society rely on the integrity of environmental processes as the environment provides society and economies with a life support system and resources (Diesendorf, 2000). In addition to this, the concept of sustainable development as stated by Holden *et al.* (2014), emphasises long-term environmental sustainability, which is also referred to as "narrow sustainability". As noted by Elliott (2006), environmental justice has become a critical part of discussions about the meaning of and how sustainable development is practiced. Environmental justice encompasses environmental protection, how environmental issues (e.g climate change and pollution) and environmental benefits (e.g access to open green space) are distributed across societies and environmental management strategies and the nature of how public involvement could influence decision-making (Elliott, 2006).

Green Economy

Since the Green Economy Initiative (GEI) launched by the United Nations (UN) Environment, the concept of the green economy was placed on the 2012 Rio+20 agenda and recognised as a tool to achieve sustainable development (UNEP, 2011a). In an attempt to find effective approaches to sustainable development, a green economy has been proposed by UN organisations and donors as a 'triple-win' solution. An inclusive green economy according to UNEP (2011a) is one that is low carbon, resource efficient and socially inclusive. Green economy initiatives aim to decouple economic growth from environmental degradation (UNEP, 2011b), in other words, the consumption of resources and environmental impacts should be dissociated from economic growth (Department of Environmental Affairs, 2011a). These actions aim to address the drivers of economic, social and environmental decline by integrating and realigning economies in ways that accommodate environmental and social costs. ten Brink *et al.* (2012) however highlights that a transition towards a green economy requires radical changes to existing governance institutions, markets, and approaches. This transition will therefore follow different paths in different countries as it depends on the country's domestic context, its natural resources, and socio-economic priorities.

By integrating multiple stakeholders from both economic and environmental perspectives, organisations such as UNEP aim to encourage greater adoption and political support than was present for earlier sustainable development initiatives (Swainson & Mahanty, 2018). From the discussions in Sections 2.1.1 and 2.1.2, the concept of sustainable development and its constituents are complex, varying in nature and the context in which it is used and by whom. Even so, it is possible to understand that there is a dynamic relationship between the economic, social and environmental dimensions of sustainable development and this could inform the actions, practices and decision-making of all stakeholders involved. While the conceptual development of sustainable development continues, the principles of sustainable development are implemented at various levels within industries. Therefore, the next section aims to explore one of the applications of sustainable development; sustainable development in the construction industry.

2.2. Interpretation of the Construction Industry

The construction industry as highlighted in the literature is one of the industries which contributes significantly to the socio-economic growth and development of developing countries (Jamilus, Ismail & Aftab, 2013; Ofori, 2015; du Plessis, 2007a). It is therefore important to investigate and understand the characteristics and requirements of the construction industry to develop solutions which reduce the impact of construction activities on society and the environment (AlSanad, 2015; Shi, Zuo, Huang, *et al.*, 2013; Yilmaz & Bakis, 2015). The term construction is however a complex concept which varies in terms of the scope and meaning (Ofori, 2015; du Plessis, 2007a).

2.2.1. Defining Construction

Kibert (2007) argues that the physical boundaries of construction are extensive and includes the energy and water consumed during all phases of the product and building life cycle. Pearce (2003) further states that the definitions of construction vary according to the focus, which could be the focus on contractors and alternatively, subcontractors, professional management as well as design and engineering professionals. According to Irurah's (2001) contribution to the Agenda 21 for Sustainable Construction in Developing Countries (du Plessis *et al.*, 2002), construction can be described as:

i. site activities;
ii. the building project life cycle;
iii. a sector of the economy; and
iv. the mechanism used to create human settlements and infrastructure.

The first interpretation of construction which is the most commonly used (du Plessis, 2007a), provides the simplest level of viewing construction as the site activities which lead to the realisation of a construction project (e.g. building, road or dam). This view however ignores all other phases of the building life cycle (e.g. feasibility, planning and decommissioning) and excludes stakeholders involved in these phases such as material manufacturers, suppliers and facility managers who form an integral part of the construction industry. Furthermore, intervention is limited at this level of construction as not all key role players are included.

As this research focuses on SC in a broader context, a much broader interpretation of construction is required which includes all the aspects above. The second interpretation of construction which views construction as the complete project life cycle also incorporates the first interpretation. It encompasses the construction stages before (e.g. feasibility, site identification), during (e.g. design and technical documentation) and post-construction (which includes operation, occupation and demolition). While this definition does provide a more comprehensive outline of the activities forming part of the construction environment, it is still limited (du Plessis, 2007b). The life cycle of most construction materials, equipment and components begins before the conventional project life cycle and ends after the project life cycle is over which highlights the limitation of the second interpretation. For this reason, the third interpretation places the construction industry within the economy as a sector. du Plessis (2007b) identifies the construction industry as forming a vital supply chain within the economy which is linked to the extraction of raw materials, assembly of components on a construction site, occupation of buildings, demolition of buildings as well as the management and disposal of waste. Hillebrandt (1985) also argues that due to the size and high level of employment within the construction industry in most countries (du Plessis, 2007b), the activity within the industry or lack thereof has an effect on the economy. In the same way, it can be expected that the state of the economy could affect the construction industry (Hillebrandt, 1985).

To encompass all of the above interpretations which focus mainly on the biophysical and economic elements of sustainability in the built environment, du Plessis *et al.* (2002) developed a broad definition of construction which incorporates the abovementioned interpretations: "*The broad process/mechanism for the realisation of human settlements and the creation of infrastructure that supports development. This includes the extraction and beneficiation of raw materials, the manufacturing of construction materials and components, the construction project life cycle from feasibility to deconstruction, and the management and operation of the built environment*."

2.2.2. Impacts of the Construction Industry

Globally, construction industry activities affect the environment through its energy consumption, land use, waste generation, resource depletion and various forms of pollution (Esin & Cosgun, 2007; Ortiz, Pasqualino & Castells, 2010; Osmani, Glass & Price, 2008; Yu, Poon, Wong, *et al.*, 2013). These activities and their impacts are generally considered across the whole building life cycle and highlights the key role the construction industry plays in achieving sustainability. The five main impact categories of the construction industry are discussed below.

Resources

Globally, the construction industry sector is one of the largest consumers of natural resources. The impact of the material extraction, material consumption and construction activities imposes a loss of biological diversity in certain regions, fragmentation of natural ecosystems and destruction of natural green areas (Akadiri, Chinyio & Olomolaiye, 2012; Kibert, 2016; Yilmaz & Bakis, 2015). Willmott Dixon (2010) states that even though most construction materials are common to many construction sites, the practical extent to which materials can be recycled is limited due to the fragmented nature of development.

Akadiri, Chinyio & Olomolaiye (2012) and Pullen *et al.* (2012) suggest that optimising the reuse and recycling of demolition materials can reduce the impact on the environment as it eliminates the process of extracting and supplying new construction materials. Furthermore, stakeholders involved in the project initiation and design phases where the selection of materials are of importance should consider incorporating sustainable materials to minimise the impact on the environment.

Energy

The built environment is one of the largest consumers of energy, accounting for approximately 40% of the global primary energy demand (Hong, Koo, Kim, *et al.*, 2015). Buildings can no longer only be assessed during the operational phase to indicate their energy performance. The whole life cycle of the building needs to be taken into consideration as energy consumption starts at the production of materials required for the construction phase (Garcia-Ceballos, de Andres-Díaz & Contreras-Lopez, 2018; Karunasena, Rathnayake & Senarathne, 2016; Rohracher, 2001). Ghaffarianhoseini *et al.* (2013) and Robichaud & Anantatmula (2011) state that due to the high level of energy consumed in the construction sector, the effects on the environment is substantial as can be seen with global warming, climate change, lack of energy resources, challenges with new energy supplies, and ozone layer deterioration. Several authors suggest that there is an urgent need for the built environment to assess the energy consumption level of buildings and provide innovative solutions to reduce the built environment's role in global energy consumption (Dwaikat & Ali, 2016; Ghaffarianhoseini *et al.*, 2013; Robichaud & Anantatmula, 2011). Sustainable building practices along with new energy strategies are required to drastically reduce energy consumption and increase the potential to adopt the use of renewable energy sources (Kibert, 2007; Robichaud & Anantatmula, 2011).

Land

All development which is undertaken by the construction industry requires planning permission due to the impact the construction of a building has on the environment. The interaction of land use, the spatial planning system and the construction industry has an extensive range of environmental issues which need to be addressed. Rapid urban development and agricultural expansion due to an increased population have resulted in a loss of capacity for the natural soil to absorb exceptional levels of rainfall which has become more intense, concentrated and erratic. This is clearly demonstrated by the recent floods in 2018 which have displaced many families and have caused a significant loss of life in areas such as Kerala, India (Agence France-Presse, 2018). Kibert (2016) emphasises that sustainable land use should be based on the premise that land is a precious and finite resource, and the development thereof should be minimised. Willmott Dixon (2010) and Kibert (2016) therefore suggest that effective spatial planning and the design of buildings and their landscapes has an important role to play to absorb these excessive new rainfall spikes, which in turn reduces the strain on the current engineered drainage and river systems. Furthermore, land can also be recycled, restored and reused which facilitates land conservation and promotes economic and social revitalisation (Kibert, 2016).

Water

With the rate at which the current global economy is developing, the exhaustion of potable water resources is becoming a critical environmental issue which cannot be ignored (Akadiri *et al.*, 2012; Kibert, 2016). Global warming which triggers climate change and unpredictable weather patterns further limit access and availability to water. As a result, the conservation and protection of existing groundwater and surface water supplies is crucial since only a small percentage of the earth's hydrologic cycle yields potable water. Kibert (2016) argues that once this water has been contaminated, it becomes an expensive and almost impossible exercise to try to reverse the damage. According to the McKinsey & Company report as referenced by Kibert (2016), the global demand for water will exceed its supply by 40% in 2030 and 42% of this water demand would be from just four countries: China, India, Brazil and South Africa.

In South Africa, rainwater is the largest source of water and at 490mm on average per annum, it is half of the world average. As shown in Figure 2-4, South Africa's large population and highly variable rainfall makes it more water scarce than two of its neighbouring countries (Botswana and Namibia), as well as a few other global countries (Colvin, Muruven, Lindley, *et al.*, 2016). The recent drought in the Western Cape has placed a significant strain on water resources and has led to severe water restrictions to reduce the demand, which affects all citizens living and working in the provinces. With water scarcity being a significant challenge, drought resilience measures need to be promoted to reduce the reliance on rainwater (Reddick & Fundikwa, 2018). Reddick & Fundikwa (2018) suggest that sustainable measures to reduce water consumption can be related to water metering and monitoring, water efficiency, water reuse, and alternative water supplies such as desalinated seawater.

The impact of the construction industry on the environment is specifically noticeable when looking at the utilisation of water resources. The overall consumption of water is not only present during the operation of buildings. Water is consumed throughout the whole building life cycle and includes the extraction, production, manufacturing, and delivery of construction materials to site; the construction of new buildings; their operations and maintenance. With the limited available water resources, which impacts development and construction in many areas of the world, the use of potable water for whole building life cycle activities should be avoided and alternative methods and strategies should be incorporated into the design (Akadiri *et al.*, 2012; Pocock, Steckler & Hanzalova, 2016). However, as noted by Bardhan (2011), there is still a lack of progress in water resource management in the construction and operation of buildings as the amount of water used per unit area of construction remains largely undocumented.

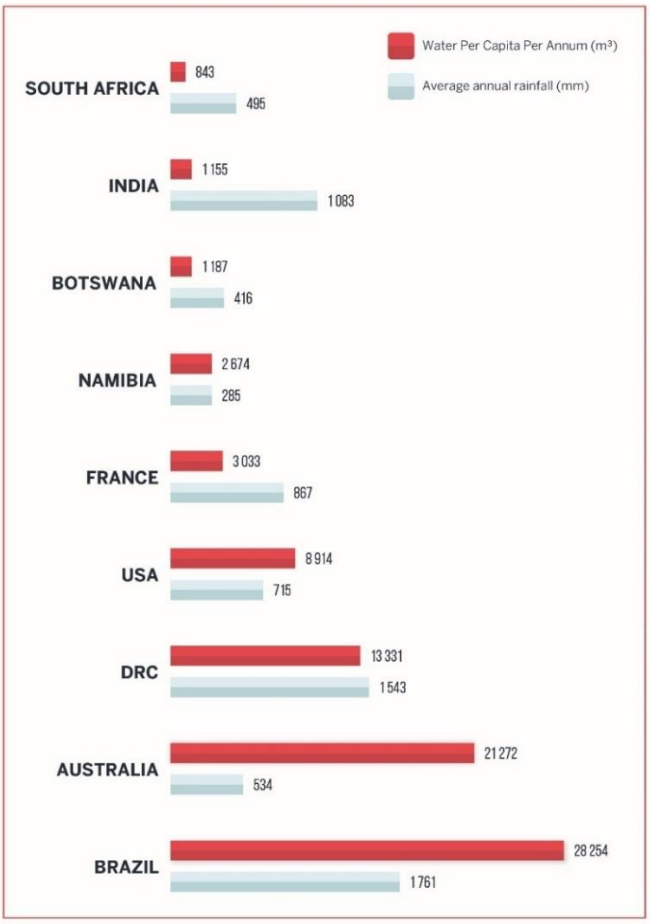

Figure 2-4: Water availability per person per annum in selected countries (Colvin *et al.*, 2016)

Waste

The construction industry generates a significant amount of waste in most countries which has a direct impact on productivity, loss of material and project completion times which results in loss of revenue (Esin & Cosgun, 2007; Jamilus *et al.*, 2013). Large amounts of construction and demolition waste (CDW) generated also adds strain to the capacity of existing landfill sites and have led to environmental concerns related to pollution (Esin & Cosgun, 2007; Yu *et al.*, 2013). In a study conducted by (Yu *et al.*, 2013), the concentration of CDW to total waste generated in various countries are relatively high as shown in Table 2-1. In countries such as Denmark, Australia, Germany, Japan and Netherlands, it can be argued that although the production of construction and demolition waste is high, a large percentage of this waste is recycled as indicated in Figure 2-5. According to Ortiz, Pasqualino & Castells (2010), if CDW is managed properly, it has a high recovery potential as 80% can be recycled, even though most countries only recycle small proportions of this waste. In South Africa specifically, despite the high financial and societal costs linked to landfilling, only 16% of CDW is recycled. The recovery, processing and application of CDW creates a large prospect for the crushing industry from a supply perspective, as well as a demand in road materials both in the public and private sectors (GreenCape, 2016).

Table 2-1: Percentage of Construction Waste Generated in comparison to Total Waste Generated (Department of Environmental Affairs, 2011b; Yu *et al.*, 2013)

Country	% CDW to Total Waste
Australia	44
Brazil	15
Denmark	25-50
Finland	14
France	25
Germany	19
Japan	36
Italy	30
Netherlands	26
Norway	30
South Africa	20
Spain	70
United Kingdom	Over 50
United States of America	29

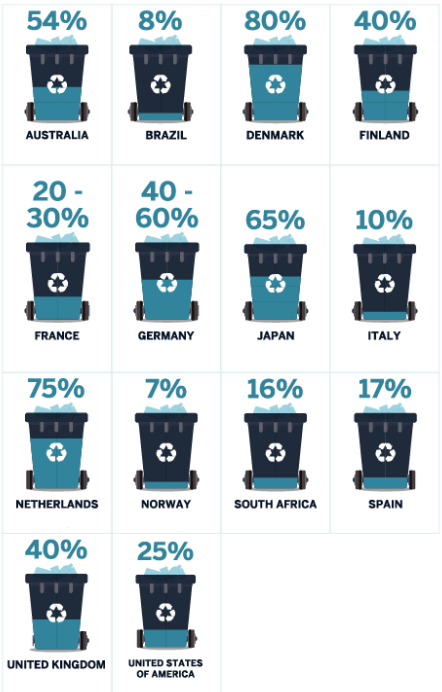

Figure 2-5: Percentage of Waste Recycled for selected Countries (Yu *et al.*, 2013)

2.3. Sustainable Construction

In order for the construction industry to effectively contribute to sustainable development, a more holistic definition of sustainable construction (SC) is required (Pearce, 2003). The debate about SC has been hindered by the perceived ambiguity, conflicting nature of the concept and terminologies associated with it (du Plessis *et al.*, 2002). Attempts at developing a generally accepted definition for SC has been unsuccessful thus far (Hill & Bowen, 1997; Ofori, 2015; du Plessis, 2007a). Furthermore, du Plessis *et al.* (2002) explains that the concept of SC extends beyond environmental sustainability. It embraces the contribution of economic and social sustainability, which highlights the value creation by improving the quality of life of society. This view is supported by Kibert (2016) who states that conventional design and construction would typically only focus on cost, performance objectives and quality objectives. However, sustainable design and construction adds three additional criteria which includes: minimising resource depletion, minimising environmental degradation and creating a healthy built environment. Analysis of the literature revealed different terms related to SC such as ‘green building’, ‘sustainable building’ and ‘high-performance building’. Authors have used these terms interchangeably with SC. It is therefore important to distinguish the differences and potential similarities.

Sustainable buildings can be defined as having an efficient use of water, energy, materials and have a reduced impact on health as well as the environment throughout its life-cycle (Berardi, 2013). According to the GBCSA, a “green building” can be defined as a resource-efficient, energy-efficient, and environmentally responsible building. Green building focuses on the environmental sustainability associated with sustainable development and is therefore viewed as a subset of sustainable buildings (Kibert, 2007). Ahn *et al.* (2011) further state that green buildings can be used as a path which the construction industry can use to work towards adopting sustainability. Green buildings are representative of the structures designed and constructed to address environmental concerns whereas sustainable construction incorporates economic and social concerns as well. High-performance buildings is a form of green buildings which has a single focus on the energy performance of buildings (Kibert, 2016). Another term which is often used with sustainability in the context of buildings is “smart buildings” or “smart construction”. However, these terms are not similar to sustainable buildings or sustainable construction as it refers to the responsiveness of the building through information technology and control systems (Bell & Morse, 2008). Based on the literature, the most suitable and holistic term to discuss the application of sustainable development in the construction industry is sustainable construction. This research study will therefore adopt the term sustainable construction. The literature reveals various definitions of sustainable construction which is listed in Table 2-2.

Table 2-2: Definitions of Sustainable Construction

Authors	Definition
Hill & Bowen (1997, p. 225)	"*Creating a healthy built environment using resource-efficient, ecologically-based principles*."
Huovila & Koskela, (1998, p. 2)	"*Sustainable construction is the response of the building sector to the challenge of sustainable development*."
du Plessis *et al.* (2002, p. 6)	"*A holistic process aiming to restore and maintain harmony between the natural and the built environments and create settlements that affirm human dignity and encourage economic equity*."
Al-Yami & Price (2006, p.1)	"*Sustainable construction is broadly taken to signify the responsibility of the construction industry for the efficient use of natural resources, minimisation of any negative impact on the environment as well as satisfaction of human needs and improvement of the quality of life*."
Kibert (2007, p.1)	"*Sustainable construction may best be defined as how the construction industry together with its product the 'built environment', among many sectors of the economy and human activity, can contribute to the sustainability of the earth including its human and non-human inhabitants*."
Shen *et al.* (2009, p.1)	"*Sustainable construction practice refers to various methods in the process of implementing construction projects that involve less harm to the environment (i.e. prevention of waste production), increased reuse of waste in the production of construction material (i.e. waste management), beneficial to the society, and profitable to the company*."
Robichaud & Anantatmula (2011, p. 49)	"*a philosophy and associated project and construction management practices that seek to: i) minimize or eliminate impacts on the environment, natural resources, and non-renewable energy sources to promote the sustainability of the built environment; ii) enhance the health, wellbeing and productivity of occupants and whole communities; iii) cultivate economic development and financial returns for developers and whole communities; and iv) apply life cycle approaches to community planning and development*."
Tan, Shen & Yao (2011, p. 227)	"*It is the application of the principles of sustainable development to the comprehensive construction cycle from the extraction of raw materials, through the planning, design and construction of buildings and infrastructure, until their final deconstruction and management of the resultant waste*."
AlSanad (2015, p. 971)	"*The main focus of sustainable construction remains on the well-being of the community with regard to environmental, social and economic problems*."
Khalfan *et al.* (2015, p.941)	"*Sustainable construction can be best described as a subset of sustainable development, which encircles matters such as tendering, site planning and organisation, material selection, recycling, and waste minimisation*."
(Yilmaz & Bakis, 2015, p. 2258)	"*Sustainable construction is the application of sustainable development principles to a building life cycle from planning the construction, constructing, mining raw material to production and becoming construction material, usage, destruction of construction, and management of wastes*."
(Aghimien, Adegbembo, *et al.*, 2018, p. 34)	"*sustainability in construction can be said to be a way of finding a balance between economic, environmental and social factors in the design, construction, use and maintenance of buildings*"

Even with the lack of a general definition of sustainable construction as evident in Table 2-2, there are key features of sustainable construction which could be identified. These key features include:

i. It considers the whole building project life cycle which involves all stakeholders throughout the project phases.
ii. Environmental protection, growth of the economy in a sustainable manner as well as the quality of life of individuals and communities all need to work in harmony to achieve sustainability.
iii. It encompasses both technological and non-technological solutions related to social and economic sustainability.
iv. The needs of present and future stakeholders have to be addressed.

2.3.1. Whole Building Life Cycle

As discussed in Section 2.2, the physical boundaries of the construction industry are extensive. To consider the sustainability of this sector, sustainability objectives should be embedded within the whole life cycle of the building so that it can be considered for decision making at each of the stages of the life cycle (Huovila & Koskela, 1998). Previous research on sustainable construction has indicated that the traditional or conventional project life cycle of a building typically includes project initiation, design and development, construction and project termination (Bennett, 2003; Pinto & Prescott, 1988). However, Sev (2009) argues that this approach does not address the sustainability concerns related to the procurement and manufacturing of materials, operations and maintenance as well as the reuse and recycling of buildings well after their design lifetime. This view is supported by Pearce (2003) who writes that good design and construction does not end once the building is erected but also includes the provision of services over the building lifetime. Hence, it is therefore imperative that the definition of sustainable construction incorporates the whole life cycle of a building as illustrated in Figure 2-6 and not only the project life cycle. By drawing on the concept of a life cycle approach, Hill & Bowen (1997) recognises the need for a life cycle framework which considers all the principles of sustainable construction at each stage of the sustainable building life cycle.

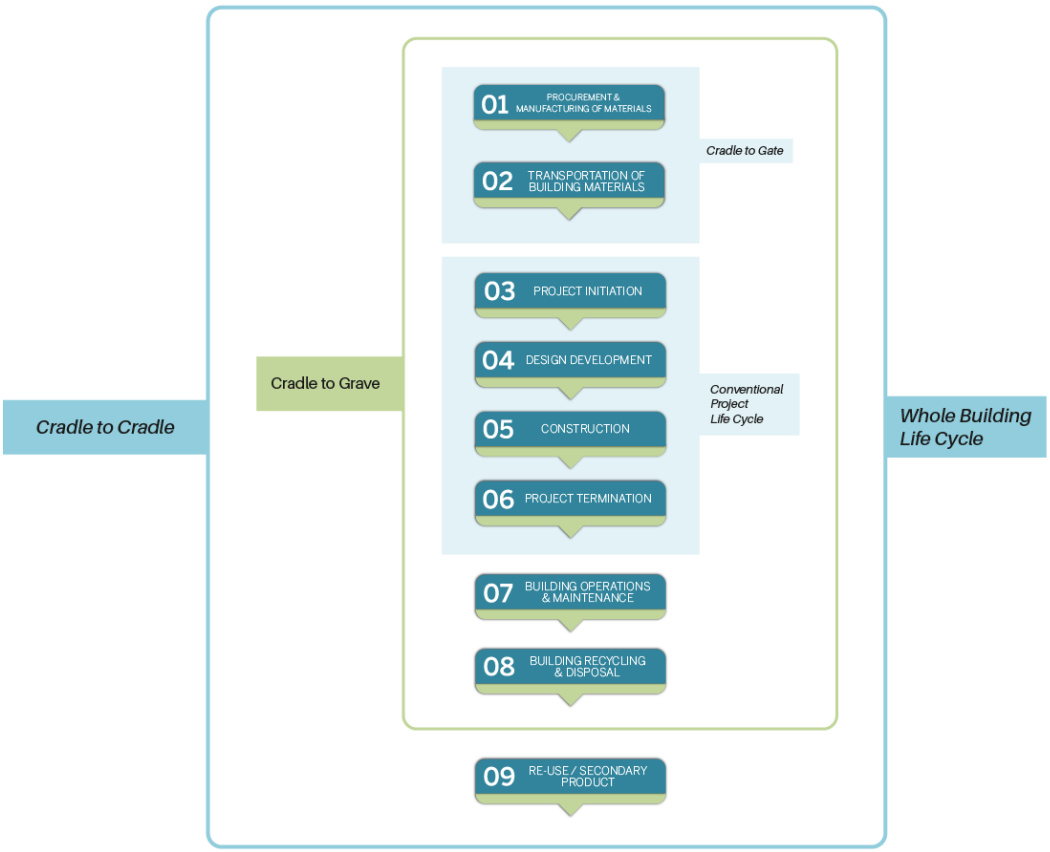

Figure 2-6: Whole Building Life Cycle (Adapted from Bennett (2003), Pearce (2003) and Yim *et al.* (2018))

Sev (2009) highlights that the life cycle approach aims to seek a balance between environmental concerns and conventional building challenges which affect the decisions made during the design phase. By using this approach, (Sev, 2009) argues that it can provide greater understanding of how the design, construction, operation, disposal or recycling of a building affects the natural environment. In addition, Singh *et al.* (2011) indicate that there is an increased interest in adopting life cycle approach methods into the building construction decision making, which facilitates the selection of green building products as well as evaluating and optimising construction processes. By including the whole building life cycle, the building project stakeholders involved in the various stages of the building life cycle have a greater opportunity to engage with one another and exchange varying perspectives. This enables the various stakeholders to resolve challenges early on in the project which they would not normally be able to do (Al-Yami & Price, 2006). Sustainable measures required to ensure that buildings and construction are more sustainable, increasingly rely on life cycle approaches. By adopting a life cycle framework and managing building project activities by setting targets are key factors that are necessary to attain sustainable construction (Nwokoro & Onukwube, 2015).

2.3.2. Principles of Sustainable Construction

The application of sustainable development principles as discussed in Section 2.1 within the construction industry is embodied in the concept of sustainable construction. As such, the environmental, economic, and social dimensions of sustainable development is also applicable to sustainable construction. Further, it is evident throughout the literature that authors have also referred to additional dimensions within varying contexts. Authors who have published work specifically related to the principles of sustainable construction are Kibert (1994), Hill & Bowen (1997), Pawłowski (2008), Zainul Abidin (2010), and Ochieng *et al.* (2014). There is a consensus amongst authors that sustainable construction reflects the principles of sustainable development and six key principles are prevalent in the literature (Figure 2-7). The proposed principles of sustainable construction are described in Table 2-3.

Figure 2-7: Principles of Sustainable Construction (Adapted from Kibert (1994), Hill & Bowen (1997), Pawłowski (2008), Zainul Abidin (2010) and Ochieng *et al.* (2014))

Table 2-3: Principles of Sustainable Construction (Adapted from Kibert (1994), Hill & Bowen (1997), Pawłowski (2008), Zainul Abidin (2010) and Ochieng *et al.* (2014))

Principle	Key constructs of Principle
Social	i. Improved quality of human life ii. Provide the opportunity for social self-determination and cultural diversity in development planning iii. Provide a healthy and safe working environment to protect and promote human health iv. Enhance the capacity of disadvantaged people by implementing skills training v. Consider and allow for fair distribution of the social costs of construction and the social benefits of construction vi. Pursue equity which is intergenerational so that the significant costs related to the current construction are not passed on to future generations
Economic	i. Promote employment creation and labour-intensive construction ii. Ensure financial affordability for intended beneficiaries iii. Evaluate the benefits and costs of building projects to the society and environment iv. Utilise the whole life cycle cost to set pricing and tariffs v. Ensure sustainable policies and practices are adopted which improve competitiveness and profitability in the market vi. Choose environmentally responsible suppliers and contractors who can demonstrate environmental performance vii. Invest some of the proceeds from the use of non- renewable resources in social and human-made capital, to maintain the capacity to meet the needs of future generations
Environmental	i. Minimise the use of water, energy, materials, and land during construction project life cycles ii. Maximise the reuse and recycling of resources to reduce waste iii. Use renewable or recyclable resources for building materials and energy generation iv. Minimise pollution v. Create a healthy and non-toxic environment vi. Protect the natural environment vii. Ensure proper creation and maintenance of areas inhabited by human beings
Technical	i. Ensure buildings are durable, reliable, and functional ii. Improve quality in creating the built environment iii. Use serviceability as a tool to promote sustainable construction iv. Deliver greater well-being and value to clients and end-users of buildings v. Utilise technological advances and expertise to improve knowledge and project efficiency
Moral	i. Sense of responsibility towards preservation of a future for all human beings
Political	i. Strategies which are influenced by politicians should be aligned with sustainable goals ii. Ensure compliance and responsibility through legislature and policies

2.4. Barriers to Sustainable Construction

In order to develop appropriate strategies for a specific country to overcome the barriers of sustainable construction, it is necessary to understand which barriers affect the adoption of sustainable construction (Darko & Chan, 2016). The analysis of the literature highlighted five key themes with 22 significant barriers which were cited by more than one author as listed in Table 2-4.

Table 2-4: Key Barriers to Sustainable Construction

Theme	Barriers	Authors
Socio-cultural	Lack of knowledge of sustainable construction	(AlSanad, 2015; Ametepey *et al.*, 2015; Gan *et al.*, 2015; Ismail *et al.*, 2012; Khalfan *et al.*, 2015; Pitt, Tucker, Riley, *et al.*, 2009; Saleh & Alalouch, 2015; Serpell, Kort & Vera, 2013; Shi *et al.*, 2013; Wilson & Rezgui, 2013)
	Lack of understanding of sustainable construction practices	(Ahn *et al.*, 2013; AlSanad, 2015; Ametepey *et al.*, 2015; Ismail *et al.*, 2012; Opoku & Ahmed, 2014; Pitt *et al.*, 2009)
	Lack of awareness of sustainable construction	(Abidin & Powmya, 2014; Ahn *et al.*, 2013; AlSanad, 2015; Ametepey *et al.*, 2015; Djokoto *et al.*, 2014; Ismail *et al.*, 2012; Khalfan *et al.*, 2015; Mousa, 2015; Pitt *et al.*, 2009; Saleh & Alalouch, 2015)
	Lack of training and education in sustainable construction	(Ahn *et al.*, 2013; Ametepey *et al.*, 2015; Djokoto *et al.*, 2014; Gan *et al.*, 2015; Ismail *et al.*, 2012; Marker, Mason & Morrow, 2014; Wilson & Rezgui, 2013)
	Uncertainty and scepticism about the necessity for sustainable construction practices	(Wilson & Rezgui, 2013)
	Distrust in information sources including consistency, validity, authority, and timeliness	(Mousa, 2015; Wilson & Rezgui, 2013)
	Perceived increased cost of sustainable construction	(Ahn *et al.*, 2013; Ametepey *et al.*, 2015; Marker *et al.*, 2014; Opoku & Ahmed, 2014; Pitt *et al.*, 2009)
	Lack of interest in green initiatives and sustainable construction	(Abidin & Powmya, 2014; AlSanad, 2015; Ametepey *et al.*, 2015)
Economic	Long pay-back periods of adopting green technologies	(Ahn *et al.*, 2013; AlSanad, 2015; Ametepey *et al.*, 2015; Brennan & Cotgrave, 2014; Gan *et al.*, 2015; Häkkinen & Belloni, 2011; Khalfan *et al.*, 2015; Marchman & Clarke, 2011; Marker *et al.*, 2014; Mousa, 2015; Saleh & Alalouch, 2015; Samari, Godrati, Esmaeilifar, *et al.*, 2013)

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Economic	Increased cost of sustainable materials and products increases the capital cost	(AlSanad, 2015; Ametepey *et al.*, 2015; Brennan & Cotgrave, 2014; Djokoto *et al.*, 2014; Opoku & Ahmed, 2014; Samari *et al.*, 2013; Shi *et al.*, 2013)
	Implementing sustainable construction practices is time consuming which causes project delays	(Ahn *et al.*, 2013; Brennan & Cotgrave, 2014; Gan *et al.*, 2015; Saleh & Alalouch, 2015; Shi *et al.*, 2013; Wilson & Rezgui, 2013)
	Risk of investment with implementation of new sustainable materials and methods	(AlSanad, 2015; Ametepey *et al.*, 2015; Brennan & Cotgrave, 2014; Djokoto *et al.*, 2014; Gan *et al.*, 2015; Mousa, 2015; Samari *et al.*, 2013)
	Lack of demand for sustainable construction projects from Clients	(Ahn *et al.*, 2013; Brennan & Cotgrave, 2014; Mousa, 2015; Saleh & Alalouch, 2015)
Stakeholders	Lack of professional knowledge and expertise	(AlSanad, 2015; Ametepey *et al.*, 2015; Djokoto *et al.*, 2014; Gan *et al.*, 2015; Ismail *et al.*, 2012; Mousa, 2015; Saleh & Alalouch, 2015; Samari *et al.*, 2013)
	Resistance to change traditional construction processes	(Abidin & Powmya, 2014; Ahn *et al.*, 2013; AlSanad, 2015; Ametepey *et al.*, 2015; Brennan & Cotgrave, 2014; Djokoto *et al.*, 2014; Gan *et al.*, 2015; Marker *et al.*, 2014; Mousa, 2015; Saleh & Alalouch, 2015; Wilson & Rezgui, 2013)
	Lack of an integrated work environment and communication among all stakeholders	(Ahn *et al.*, 2013; Brennan & Cotgrave, 2014; Djokoto *et al.*, 2014; Gan *et al.*, 2015; Ismail *et al.*, 2012; Serpell *et al.*, 2013)
Political	Lack of building codes and regulation	(Abidin & Powmya, 2014; Ametepey *et al.*, 2015; Gan *et al.*, 2015; Häkkinen & Belloni, 2011; Ismail *et al.*, 2012; Marker *et al.*, 2014; Mousa, 2015; Pitt *et al.*, 2009; Saleh & Alalouch, 2015; Samari *et al.*, 2013)
	Lack of monitoring and enforcement through building codes and regulation	(AlSanad, 2015; Ametepey *et al.*, 2015; Djokoto *et al.*, 2014; Gan *et al.*, 2015; Häkkinen & Belloni, 2011; Ismail *et al.*, 2012; Marker *et al.*, 2014; Mousa, 2015; Saleh & Alalouch, 2015; Wilson & Rezgui, 2013)
	Lack of government support and incentives	(AlSanad, 2015; Ametepey *et al.*, 2015; Djokoto *et al.*, 2014; Gan *et al.*, 2015; Häkkinen & Belloni, 2011; Ismail *et al.*, 2012; Khalfan *et al.*, 2015; Mousa, 2015; Saleh & Alalouch, 2015; Samari *et al.*, 2013; Serpell *et al.*, 2013; Shi *et al.*, 2013)

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Technological	Lack of adequate green technological specifications	(Ametepey *et al.*, 2015; Gan *et al.*, 2015; Mousa, 2015; Saleh & Alalouch, 2015; Samari *et al.*, 2013; Shi *et al.*, 2013)
	Limited availability of green product suppliers, materials, and technologies	(Ahn *et al.*, 2013; Ametepey *et al.*, 2015; Brennan & Cotgrave, 2014; Gan *et al.*, 2015; Ismail *et al.*, 2012; Khalfan *et al.*, 2015; Marker *et al.*, 2014; Mousa, 2015; Saleh & Alalouch, 2015; Shi *et al.*, 2013)
	Lack of databases and information for green technologies	(Djokoto *et al.*, 2014; Gan *et al.*, 2015; Häkkinen & Belloni, 2011; Mousa, 2015; Samari *et al.*, 2013; Shi *et al.*, 2013; Wilson & Rezgui, 2013)

From the literature, several studies indicated that economic and socio-cultural barriers, as well as stakeholders, are the most prevalent barriers linked to the lack of adoption and implementation in developed as well as developing countries. The awareness of sustainable construction in the construction industry of developing countries is generally low (Tabassi, Roufechaei, Ramli, *et al.*, 2016). According to Darko & Chan (2016), this can be attributed to the construction industry not seeing sustainable construction as a priority. Furthermore, in developing countries with a needs-driven environment, there is a concern that development focuses on quantitative delivery without considering issues of sustainability (du Plessis, 2005). These socio-cultural barriers are also prevalent in developed countries. Economic barriers related to cost is a key barrier to both developing and developed countries. The high initial costs of construction projects and additional costs incurred by sustainable technologies and materials hinder the adoption of sustainable construction. However, the perception that sustainable construction is more expensive is due to a lack of understanding of the whole life cycle cost of a building project (Marker *et al.*, 2014; Opoku & Ahmed, 2014). Furthermore, the initial costs of sustainable construction is balanced by the reduction in operational costs (Ametepey *et al.*, 2015) which is not considered during the procurement of construction services and products as the focus is on the capital cost which excludes the operational costs (Häkkinen & Belloni, 2011; Opoku & Ahmed, 2014). Stakeholders also present a key barrier to the adoption of sustainable construction. This is attributed to the lack of knowledge and capability of stakeholders in the industry which leads to a low level of implementation. Häkkinen & Belloni (2011), Darko *et al.* (2017) and Djokoto, Dadzie & Ohemeng-ababio (2014) argue that with a lack of government support and incentives, industry stakeholders are unlikely to adopt sustainable construction practices. Furthermore, a lack of building codes and regulation (Ametepey *et al.*, 2015; Samari *et al.*, 2013), the bureaucracy of governments (Serpell *et al.*, 2013) and a lack of sustainable performance tools (Shi *et al.*, 2013) further hinders the adoption and successful implementation of sustainable construction.

2.5. Drivers of Sustainable Construction

Despite the abovementioned barriers, there are factors which would enable the successful adoption and implementation of sustainable construction practices in the construction industry. An understanding of what drivers would promote the adoption and implementation is essential to facilitate the transition towards adopting sustainable construction practices. Several studies in the literature suggest multiple driving forces do exist but that they need to be addressed to counter the challenges the construction industry is facing to become more sustainable.

2.5.1. Government Regulation

A number of authors suggest that government regulation is one of the main drivers which should be used to enforce the implementation of sustainable construction practices (Aigbavboa *et al.*, 2017; AlSanad, 2015; Häkkinen & Belloni, 2011; Khalfan *et al.*, 2015; Ruparathna & Hewage, 2015; Serpell *et al.*, 2013; Shen *et al.*, 2009; Yin, Laing, Leon, *et al.*, 2018). Shen *et al.* (2009) outlines actions required by each stakeholder in the construction industry at different phases of the construction project and emphasise that government plays a key role in the project feasibility stage. By developing policies and regulations to guide stakeholders on how to balance the economic, social and environmental aspects of sustainable construction, government can provide financial incentives (Aigbavboa *et al.*, 2017; AlSanad, 2015; Ruparathna & Hewage, 2015). This could be in the form of tax-breaks and penalties to ensure adoption and implementation. These findings support previous research by du Plessis (2005, 2007a) who has grouped various levels of government, non-governmental organisations, development agencies, academic and research institutions and professional associations as "*institutional enablers*". According to du Plessis (2005, 2007a), these institutional enablers need to adopt the principles of sustainable development as a core aspect of the way they conduct their business and operations to ensure that they are capable of supporting sustainable construction and the use of associated technologies.

2.5.2. Economy: Market demands, Competitive Advantage, and Corporate Image

In the last few years, much more information on economic drivers which promote the adoption and implementation of green building technologies has emerged which forms part of sustainable construction. An example of this in the literature is that client demand for sustainable construction has a strong influence on whether construction projects are committed to implementing sustainable practices (Aigbavboa *et al.*, 2017; Häkkinen & Belloni, 2011; Ruparathna & Hewage, 2015; Serpell *et al.*, 2013; Shen *et al.*, 2009; Windapo, 2014). Serpell, Kort & Vera (2013) highlight the contradiction between clients playing a critical role in demanding sustainable construction on projects and on the other hand, clients generally having lower requirements of sustainability for projects. By increasing client and stakeholder awareness of the economic, social and environmental benefits of sustainable construction, it will increase the promotion and adoption of sustainable practices (Abidin & Powmya, 2014; Häkkinen & Belloni, 2011; Khalfan *et al.*, 2015; Serpell *et al.*, 2013).

Moreover, company size dictates the level of influence of regulations, corporate image and client demand which is much greater for larger companies and decreases as the company size decreases (Serpell *et al.*, 2013). Bond & Perrett (2012) revealed that in their study in New Zealand, market-related incentives such as competitive advantage, tenant satisfaction and productivity were ranked as more significant drivers than government regulation and regulatory controls.

In South Africa, Windapo (2014) echoes the same sentiment suggesting that developers use green accreditation such as the Green Star rating system to distinguish their buildings as being green and therefore gain a competitive advantage and use this as a marketing tool. Rising energy costs and the need to reduce the overall building operating costs have been the key drivers in South Africa and have remained constant over the past decade (Windapo, 2014). Windapo (2014) therefore concludes that the adoption of green building is driven more by financial and economic benefits as opposed to environmental and social sustainable development. du Plessis (2005) argues that to successfully move towards adopting sustainable development in the construction industry, an attitudinal and behavioural change is required which will only exist through personal commitment to the greater good of mankind. This suggests "*value system enablers*" which besides stemming from a personal value system, is also an outcome of broader social interactions (du Plessis, 2005). The construction industry can pursue sustainable development by redefining its current value system by: developing new innovative ways to measure value and rewards; utilising shared codes of conduct; defining best practice methods, and adopting corporate social responsibility reporting to ensure the transition towards sustainable construction is monitored and evaluated (Ahn *et al.*, 2013; du Plessis, 2005).

2.5.3. Technology

To achieve the goals of sustainable development in the construction industry, science and technology is required to help support the principles of sustainability. du Plessis (2005) defines this as "*technology enablers*" which fall into three categories:

i. Hard technology which can be defined as equipment, materials, industrial processes, and physical infrastructure;
ii. Soft technology which relates to systems, models and tools that support decision-making; and
iii. Knowledge and information platforms such as databases, manuals, and indigenous knowledge systems.

The investigation into drivers of sustainable building by Häkkinen & Belloni (2011) in Finland, identified four key technology enablers to address the current issues surrounding sustainable construction. Firstly, the client's sustainable building requirement which governs the sustainable building process, needs to be managed with stringent methods to ensure that it is measured, monitored and maintained throughout the whole building process. Secondly, stakeholders still lack effective methods and tools to consider sustainable building aspects in all stages of the project as well as guidelines to compare alternative building solutions.

Häkkinen & Belloni (2011) recommends that Building Information Modelling (BIM) and BIM-based tools should play an important role in managing the sustainability of buildings. Thirdly, the development of designer's competence and collaboration of the whole professional team should be promoted through education in the field of sustainable construction, as well as the implementation of effective integrated sustainable building design tools. Lastly, Häkkinen & Belloni (2011) state that there are three critical concepts and services which require development namely: "*new, reliable and functional sustainable building concepts for building refurbishment; new maintenance services that support sustainable operation of buildings; and new concepts for energy services of buildings, considering decentralised solutions and the use of renewable energy*."

Thomson & El-Haram (2011) further explores and summarises the key potential benefits of a sustainability action plan (SAP) which can be used in the construction industry to deliver projects which have a more holistic and integrated approach to sustainable development. SAP's provide a structure around which attitudinal, behavioural, and cultural changes can be established by establishing sustainability as a projects' aspiration. Furthermore, it provides a clear framework and assessment methodology for the project team to consider sustainability and what the implications are for each project activity. A SAP not only encourages a holistic approach to sustainability but also recognises and encourages the use of experts to guide project sustainability. By adopting a SAP in the design process, it facilitates the flow and sharing of knowledge and provides the team with the ability to recognise the opportunities to evolve the design to improve performance. Ultimately, the SAP provides focused leadership which creates a project culture where sustainability is seen as critical as the traditional construction management performance indicators of quality, time, and cost.

2.6. Advisory Documents in South Africa

Sustainable development has been driven by the South African Government since the first development policy, the Reconstruction and Development Programme (RDP) in 1994, which was based on six key principles and included: an integrated and sustainable programme which is driven by the people, providing peace and security for all and aids building the nation, links reconstruction and development and deepens democracy (ANC, 1994). Since then the National Environmental Management Act (NEMA) was passed in 1998 which has been the foundation of sectoral legislation, policies and strategies which provides a basis for cooperate governance to promote the right to a clean and healthy environment. Furthermore, regulatory frameworks such as Environmental Impact Assessments (EIA), Environmental Management Plans (EMP) and Environmental Implementation Plans (EIP) has enabled environmental sustainability as a priority across government and society (Department of Planning Monitoring & Evaluation, 2014). After two decades since the inception of the EIA, there are mixed reviews regarding the effectiveness of the EIA as a tool for managing environmental impacts of developments. This is evident in the Department of Environmental Affairs' findings in a study which identified the various shortcomings of the current EIA namely (Department of Environmental Affairs, 2018):

i. The EIA application is not the best suited instrument for implementation on certain development scenarios and the rigorous process required to obtain Environmental Authorisation (EA) is usually lengthy.

ii. EIAs rarely influences spatial development planning.
iii. On its own, EIA cannot achieve sustainable development.
iv. EIAs are generally site specific for individual developments and cannot potentially consider the cumulative impacts at provincial or national level.
v. The environmental assessment practitioner sector is not regulated.
vi. The quality of EIA reports is not always sufficient.
vii. Interpretation and implementation by all stakeholders of EIA Regulations and Listing Notices are inconsistent.

Following the adoption of the National Framework for Sustainable Development in 2008, the National Strategy for Sustainable Development and Action Plan (NSSD1) was adopted in 2011. The NSSD1 highlights five priorities to integrate sustainable development considerations and transition to a green economy (Department of Environmental Affairs, 2011c): "*Enhancing systems for integrated planning and implementation; Sustaining our ecosystems and using natural resources efficiently; Towards a green economy; Building sustainable communities; and Responding effectively to climate change*". Taking this commitment forward the New Growth Path Green Economy Accord and National Development Plan 2030 (NDP) also emphasises the green economy as a key area of growth. The common theme amongst these reports indicate that there is a need for industry reform, a shift from conventional fragmented approaches to address sustainable development and emphasising the role of innovation and technology in finding sustainable solutions. More recently, the 2030 Agenda on Sustainable Development was adopted by UN member states in September 2015 which consists of 17 priority goals as shown in Figure 2-8.

Figure 2-8: Sustainable Development Goals (SDG) as set by Agenda 2030 (United Nations, 2018)

According to Dlamini, (n.d.) the adoption of Agenda 2030 "presents significant opportunities and challenges to Africa specifically by ensuring that "no one is left behind" in the development process. (Dlamini, n.d.) states that there are three fundamental transitions from the Millennium Development Goals (MDGs) to the SDGs which affect cooperation within development.

The first transition emphasises that the SDGs are more ambitious and broader than the MDGs as they focus on all three dimensions of sustainable development. Secondly, the SDGs highlight the need for an integrated approach which manages trade-offs and maximises synergies across targets. Lastly, the SDGs adopt a universal approach which was not applicable to the MDGs. This implies that goals and objectives of the SDGs are applicable to all countries and stakeholders within countries (Dlamini, n.d.). The international agenda focusing on sustainable development therefore makes it a central issue when it comes to the development of strategies and policies in many countries including South Africa. As shown by the paper published by Casazza & Chulu (2016) named “Aligning the Sustainable Development Goals (SDGs) to the National Development Plan (NDP): Towards domestication of the SDGs in South Africa”, South Africa’s current NDP objectives and those of the SDGs do show a broad convergence between the national and global development framework. These include but are not limited to areas of high convergence such as access to basic social services (SDG 1: no poverty); access to and quality of healthcare services (SDG 3: good health and well-being); access to and quality of education services (SDG 4: quality education); access to water (SDG 6: Clean water and sanitation); access to energy and increase of renewable energy (SDG 7: affordable and clean energy); growth and employment (SDG 8: decent work and economic growth) (Casazza & Chulu, 2016). On the other hand, Casazza & Chulu (2016) highlight areas where the convergence is lower and includes but is not limited to food security and sustainable agriculture (SDG 2: zero hunger) and commitment to issues related to sustainable development and human rights in school curricula (SDG 4).

Specifically related to the sustainable development of the construction industry, Casazza & Chulu (2016) highlight that the NDP does not address issues related to improved quality of water, integrated water resource management and water related ecosystem (SDG 6), green industrialization (SDG 8), objectives that align with SDG targets on resilient infrastructure and sustainable industrialization (SDG 9: industry, innovation and infrastructure), resilience of urban dwellers and urban centres (SDG 11: sustainable cities and communities), as well as sustainable consumption and production (SDG 12: responsible consumption and production). An overview of current regulatory frameworks applicable to the building industry in South Africa which include legislation, national policies and industry standards are summarised in Table 2-5. Although all these regulations are available, Simpeh & Smallwood (2015) suggest that the adoption of sustainable practices in the South African construction industry has been slow. This has been mainly as a result of the inconsistent regulations, and professionals in the construction industry not having confidence in the performance of sustainable alternatives which may increase the risk on projects. Furthermore, since the amendments to SANS 10400 and 10400-XA which are mandatory standards, the interpretation thereof is not standardised and still poses a challenge (Coetzee & Brent, 2015).

Table 2-5: Regulatory Frameworks in the South African Built Environment (GreenCape, 2014)

Year	Legislation/Policy/Standard	Objective
Legislation		
1998	National Environmental Management Act (NEMA), 107	Promote co-operative governance and ensure that the human rights are upheld, but also recognising the necessity of economic development. It assigns clear responsibilities for environmental consequences of development.
2008	National Building Regulations (NBR) and Building Standards Act, Act 103 of 1977	Provide functional guidelines for anybody building any type of structure in South Africa
Policies and Government Strategies		
2004	Breaking New Ground (BNG) – a comprehensive plan for the development of human settlements	Promote an integrated society by developing sustainable human settlements and quality housing within a subsidy system for different income groups.
2005	Social Housing Policy for South Africa	Provides an overview of the national housing programmes for South Africa for the development of social housing in South Africa.
2009	National Housing Code	Prescribes the national norms and standards for the construction of standalone residential dwellings, which apply to all units built through one of the National Housing Programmes.
Western Cape Policies		
2005-2014	Rental Housing Strategy (Building Sustainable Communities)	Presents a 10-year strategic plan for the roll-out of rental stocks in the province.
2012	Information and Guideline documents on the implementation of green procurement in the City of Cape Town (CoCT)	Provides information and describes the preferred ways to implement green public procurement and environmental legal compliance in the CoCT.
Green Building Frameworks		
2011	National Framework for Green Building South Africa	Promotes the objectives of green building in the public sector.
2011	Green Economy Accord	Outlines the South African Government pact between Government, private business, trade unions and civil society to foster green industrial development, and create 300 000 jobs by 2020 in the green economy.
2011	National Greening Framework	Promotes the application of sustainable development principles and practices to the built environment and events management.
2012	Green Building Manual (Drakenstein Municipality)	Outlines a set of guidelines covering green construction principles for built environment professionals.

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2013	Income Tax allowance on energy efficiency savings	Income tax allowance on energy Regulations in terms of Section 12L of the Income Tax Act efficiency savings administered by the DTI aimed at large manufacturing investments. That is: upgrades, expansions or new facilities that exceed R30 million and R200 million respectively.
South African National Standards (SANS)		
2011	SANS 10400	Provides guidelines for the application of the technical aspects of the NBR.
2011	SANS 10400-XA	Provides technical guidelines for the implementation of the new NBR. These are the first set of minimum standards for energy efficiency and environmental sustainability for buildings in the NBR. These regulations are applicable to new and refurbished buildings.

This is echoed in a study conducted by Wilson & Rezgui (2013) in Wales, which emphasised that there are unclear links between the current construction regulations and standards and sustainability principles. They argue that there is no explicit statutory requirement that the regulations governing the built environment should cover sustainability which they describe as a substantial barrier. Other authors such as Shi *et al.* (2013), Ametepey, Aigbavboa & Ansah (2015) & Darko & Chan (2016) suggest that government along with stakeholders in the construction industry should develop specific legislations, codes and standards relating to sustainable construction practices to ensure that it can be implemented and regulated. To address these gaps in policy, du Plessis *et al.* (2002) emphasise that the capacity within government needs to improve to play an active role in the adoption and implementation of sustainable construction, by developing policies which encourage sustainable construction. Furthermore, a lack of appropriate legislation/incentives and capacity for implementation has led to a construction industry with very little regard for environmental considerations (du Plessis *et al.*, 2002). Chief among these reasons are a lack of integration with mainstream decision-making systems, few links between policy and on-the-ground realities, a very narrow base of participation, and the fact that many strategies are little more than wish lists, lacking clear priorities or achievable targets (du Plessis, 2007a). Kibert (2007) argues that policies governing sustainable construction should shift from voluntary to mandatory which will accelerate the transformation of the construction industry. Additionally, the understanding of sustainable construction needs to be improved by creating awareness amongst policymakers and stakeholders to effectively implement sustainable principles.

2.7. Conclusion: Chapter 2

The current literature covers the broad concept of sustainable development and green building and how these two concepts are adopted within the construction industry. The activities outlined within the construction industry which clearly has an impact on the sustainability of the industry is a key indicator that the industry has a significant role to play. The review of existing literature highlights that sustainable construction is an evolving concept which is required to mitigate the negative impacts of the construction industry.

The varying perceptions within the literature regarding a definition which encompasses the full narrative of sustainable construction and, the complex nature of the interacting components and stakeholders within the construction industry, is critical to understanding how the concept of sustainable construction is interpreted, for it to successfully be adopted and implemented. For the purpose of this research, the term sustainable construction is used as it provides a more holistic approach to sustainable development within the construction industry. Sustainable construction can be characterised by the adoption of the three-pillar approach considering all economic, social and environmental aspects, a whole building life cycle approach and the inclusion of technologies to address the needs and provide solutions to the industry, stakeholders and end users.

From the literature, it is also evident that much of the progress regarding sustainable construction development has been promoted and implemented in more developed countries. Furthermore, the concept of sustainable construction within a South African context has been studied by very few authors such as du Plessis *et al.* (2002,2005,2007a,2007b), Sebake (2008) Windapo (2014) and Aigbavboa, Ohiomah & Zwane (2017). Additionally, to effectively implement sustainable construction within the South African context, a critical review of the literature identified key barriers and drivers to adopting sustainable construction. In a developing country which has a needs-driven environment, there is a concern that development focuses on quantitative delivery without considering issues of sustainability (du Plessis, 2005). It is therefore important to raise awareness about sustainable construction and educate stakeholders in the construction industry about the urgency to change their approach to sustainable development.

In lieu of the varying perceptions and opinions about sustainable development in the construction industry and the limited research available surrounding the practice of sustainable construction in the South African construction industry, two key themes need to be explored. Firstly, due to the lack of awareness and uniform understanding, there is a need to assess how sustainable construction is interpreted by stakeholders within the South African construction industry. Secondly, there is a need to explore how these interpretations transition stakeholders into adopting and implementing sustainable construction at project level. The following chapter presents the behaviour change theoretical approach adopted within this study to address these themes.

Chapter 3
Behavioural Change Theoretical Approach

The literature in Chapter 2 has made it evident that the construction industry has a significant role to play in achieving the goals of sustainable development. This is evident by the ability of the construction industry to provide a delivery mechanism for many aspects of local and national government policy and legislation, which is aimed at providing a sustainable built environment (Bosher, Carrillo, Dainty, *et al.*, 2007; Department of Environmental Affairs and Development Planning, 2015). Establishing a fully integrated sustainable built environment is one of the critical aspects which will contribute to harnessing the development potential of South Africa and address the distortions of the past and future needs of the growing population. This goal cannot be achieved without the active participation and collaboration of the public and private sector as well as communities (CSIR, 2000). Furthermore, the goal to achieve a sustainable built environment is a conceptually complex process composed of interrelated systems. To develop a sustainable building various inputs are required from policymakers, stakeholders who manage the development process and operational stakeholders to develop a solution suited to a specific context with respect to the environment, economy and society. In order to improve the adoption and implementation of sustainable practices within the construction industry, the behaviour change processes of stakeholders need to be considered. Stakeholders need to change their behaviour towards adopting sustainable alternatives in the planning, conceptual design, further design and development, construction, operations, and maintenance phases of building projects.

3.1. The Need for Behavioural Change

Environmental challenges such as climate change, ecosystem degradation, loss of biodiversity and ocean acidification are caused by the unsustainable behaviour of human activity. While throughout history humans have modified the natural environment to meet their needs, the current demands on the Earth's resources are exponentially higher than what can be produced, absorbed and neutralised which is leading to environmental depletion and degradation (Hargreaves, 2011). Due to an increased awareness of the magnitude of the impact human activity has on the environment almost three decades ago, international agendas such as the Brundtland report were developed and established to reduce environmental degradation by promoting sustainable development. Although policies and regulations, international agreements and information tools have been applied to encourage sustainable behaviour (Klaniecki, Wuropulos & Hager, 2018), there is still an increase in the consumption of materials and resources and therefore the effectiveness of such implementation strategies can be questioned (Hargreaves, 2011). At the core of how the construction industry interacts with the environment, economy and society is human behaviour.

The construction industry is one of the largest consumers of natural resources involving the extraction of raw materials, consumption of raw materials to produce building materials and construction activities on building project sites. Decisions about various types of construction materials, reusing and recycling of construction materials as well as choosing alternative sustainable materials is directly influenced by stakeholders at project level. Due to the high level of energy, water and land consumption in the construction sector, there is a need for built environment stakeholders to assess the current design and development of buildings and provide innovative solutions to ensure the sustainability of the environment. Given the extent of the environmental challenges faced by many countries, the transition towards the adoption of sustainable alternatives in the construction industry must include dimensions of changing human behaviour (Klaniecki *et al.*, 2018).

On a regular basis, individuals, organisations, key stakeholders and policymakers make decisions that have an impact on the earth's natural resources. Policies and intervention strategies that focus on transitioning these everyday behaviours towards more sustainable outcomes are imperative to achieving development and consumption that is more sustainable (UNEP, 2017). However, changing human behaviour can be challenging (Cane, Connor & Michie, 2012) as we do not always make rational decisions or behave in predictable ways. Cane, Connor & Michie (2012) suggest that although changing behaviour is not easy, it can be more effective if interventions are based on evidence-based principles of behaviour change. These principles are based on the many theories of behaviour change but are seldom utilised to inform the design and evaluation of implementation interventions. To ensure efficacy of interventions it is critical to have a theoretical understanding of behaviour change which represents the accumulated body of knowledge of the factors which influence action and drivers of change (Cane *et al.*, 2012; Davis, Campbell, Hildon, *et al.*, 2015). Behaviour science theories and behaviour change tools can therefore be used as a platform to understand the behaviour of stakeholders in the construction industry and provide insight into what influences the adoption and implementation of sustainable construction practices (Klaniecki *et al.*, 2018; UNEP, 2017). Human behaviour is inherently complex and behaviour change theories allows for a better understanding of what could work in an intervention across multiple contexts, populations and behaviours (Michie, Johnston, Francis, *et al.*, 2008).

3.2. Theoretical Underpinning for a Behaviour Change Framework

Behavioural science encompasses understanding behaviour and developing effective interventions to influence it. Behaviour change interventions involve active components such as activities, products, services and policies which are designed to change the way people act (West, Michie, Atkins, *et al.*, 2019). Michie, van Stralen & West (2011) define behaviour change interventions as sets of activities which have been coordinated and designed to change specific behaviour patterns which can be used to promote a specific behaviour change. Such behaviour patterns can be measured in terms of prevalence or incidence of specific behaviours in specific populations.

To achieve behaviour change on a large scale often involves a cultural shift amongst groups of people within various organisations and communities (Atkins & Michie, 2013). This can require targeting multiple behaviours simultaneously or targeting multiple groups simultaneously such as policymakers, service providers and end-users. Interventions can therefore vary according to the need for behaviour change (West *et al.*, 2019). Michie, van Stralen & West (2011) argue that improving the implementation of intervention strategies is dependent on behaviour change and adopting behavioural change theory. Although it is important to understand which theory to select and how to apply it, in practice, interventions are often only minimally guided by theory, are not comprehensive or well used (Michie *et al.*, 2011). A wide range of theoretical models of behaviour have been developed including the Theory of Planned Behaviour (Ajzen, 1991) and Diffusion of Innovation Theory (Rogers, 1983). A common limitation of these theories is that they only help to understand or predict behaviour and do not aid with understanding behaviour change or developing behaviour change interventions (Atkins, Francis, Islam, *et al.*, 2017; Ojo, Bailey, Brierley, *et al.*, 2019). To this end, Michie, van Stralen & West (2011) developed a systematic behaviour change framework called the Behaviour Change Wheel (BCW) after conducting a review of 19 frameworks with theoretical constructs that help explain and predict behaviour. As discussed in Chapter 2 and Section 3.1, there is a need to change the current behaviour of stakeholders in the construction industry to ensure the sustainability of the industry by adopting sustainable alternatives throughout the life cycle of construction projects. Moreover, the impact of the construction industry on the environment needs to be mitigated. Therefore, the need for behaviour change relative to this research is the adoption and implementation of sustainable construction principles by stakeholders in the construction industry. To effectively change behaviour amongst construction industry stakeholders, a behaviour change intervention is required to alter the current trajectory of the construction industry to one that is more sustainable.

3.3. Background to the Behaviour Change Wheel

The BCW was developed from the need to find an appropriate method for characterising interventions and linking them to an analysis of the targeted behaviour. Although multiple frameworks for behaviour change interventions exist, Morris *et al.* (2012)argue that there are various limitations within the frameworks such as Mindspace (Dolan *et al.*, 2010) and DEFRA's 4E Model (Jackson, 2005) which do not consider the political, social or economic influences on behaviour. In addition, Brug *et al*. (2005) state that many of the frameworks do not provide guidance on how to change the behaviour (Morris *et al.*, 2012), only what needs to change. In some of the frameworks it has been assumed that behaviour was primarily driven by perceptions and beliefs (*Framework on public policy in physical activity* [6]), some focused on the social environment (*Culture Capital Framework*[7]), while others emphasised unconscious biases (*MINDSPACE*).

[6] Framework published by Dunton, Cousineau & Reynolds (2010)
[7] Framework published by Knott, Muers & Aldridge (2008)

Due to the importance of all these aspects of behaviour, it was necessary to bring it all together in a comprehensive and inclusive manner by developing the BCW to address the limitations of the 19 frameworks (Michie *et al.*, 2011). The BCW addressed the limitations by synthesising the common elements of the frameworks and linking them to a model of behaviour that was "*sufficiently broad that it could be applied to any behaviour in any setting*" (Michie, Atkins & West, 2014, p. 17). The 19 frameworks reviewed by Michie, van Stralen & West (2011) are summarised in Table 3-1.

Table 3-1: Behaviour Change Intervention Frameworks (Michie *et al.*, 2014)

Framework	Description
1. Epicure Taxonomy	Taxonomy of approaches designed to influence behaviour patterns
2. Culture Capital Framework	Framework of knowledge about culture change, offering practical tools for policymaking
3. EPOC taxonomy of interventions Cochrane	Checklist to guide systematic literature reviewers about the types of information to extract from primary studies
4. RURU: Intervention implementation taxonomy	Taxonomy covering a wide range of policy, practice and organisational targets aimed at increasing impact of research
5. MINDSPACE	Checklist for policymakers aimed at changing or shaping behaviour
6. Taxonomy of behaviour change techniques	Taxonomy of behaviour change techniques grouped by change targets
7. Intervention mapping	Protocol for a systematic development of theory- and evidence-based interventions
8. People and places framework	Framework that explains how communication and marketing can be used to advance public health
9. Public health: ethical issues	Ladder of interventions by government, industry, organisations, and individuals to promote public health
10. Injury control framework	Heuristic framework for categorising and evaluating behaviour change strategies aimed at controlling injuries
11. Implementation taxonomy	Theory-based taxonomy of methods for implementing change in practice
12. Legal framework	Conceptual framework for identifying possible legal strategies used for preventing cardiovascular diseases
13. PETeR White	Comprehensive and universally applicable model or taxonomy of health
14. DEFRA's 4E model	Process model for policy makers aimed at promoting pro-environmental behaviours in accordance with social marketing principles

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15. STD/ HIV framework	Taxonomy to expand the scope of interventions that can be used to prevent STD and HIV transmission
16. Framework on public policy in physical activity	Taxonomy aimed at understanding how and why policies successfully impact on behaviour change
17. Intervention framework for retail pharmacies	A framework that presents factors that may affect retail pharmacy describing and strategies for behaviour change to improve appropriateness of prescribing
18. Environmental policy framework	A taxonomy of major environmental problems, their different levels and global spheres of impact, and conceptual modelling of environmental problem-solving
19. Population Services International (PSI) framework	A conceptual framework to guide and help conduct research on social marketing interventions

In order to evaluate the applicability of the frameworks, three criteria of usefulness were used: comprehensiveness, coherence, and links to an overarching model of behaviour. The review found that each model focused on various behavioural determinants (e.g. beliefs and perceptions, unconscious biases and social environments) and although these determinants are important to understand behaviour and designing behaviour change interventions, none of the frameworks provided a coherent and comprehensive model. This provides various challenges for researchers who need to choose an appropriate theory to address their research objective (Cane *et al.*, 2012; Michie, Johnston, Abraham, *et al.*, 2005). As a result, Michie, van Stralen & West (2011) proposed a new framework which is centred on a "*behaviour system*" involving three essential conditions: **C**apability (the psychological and physical capacity to engage in the behaviour), **O**pportunity (the physical and social environment that enables the behaviour) and **M**otivation (reflective and automatic mechanisms that activate or inhibit behaviour) (termed as the COM-B model). Figure 3-1 illustrates the three layers of the Behaviour Change Wheel (BCW) which incorporates the COM-B system. Nine intervention functions around the central COM-B system is aimed at addressing the shortfalls in one or more of the conditions and around this are seven policy categories. The policy categories are provided to facilitate the intervention functions to occur. The three-stage process to intervention design which the BCW follows is discussed below as: Stage 1: Understanding the behaviour, Stage 2: Identifying intervention options and Stage 3: Identify intervention content and implementation options.

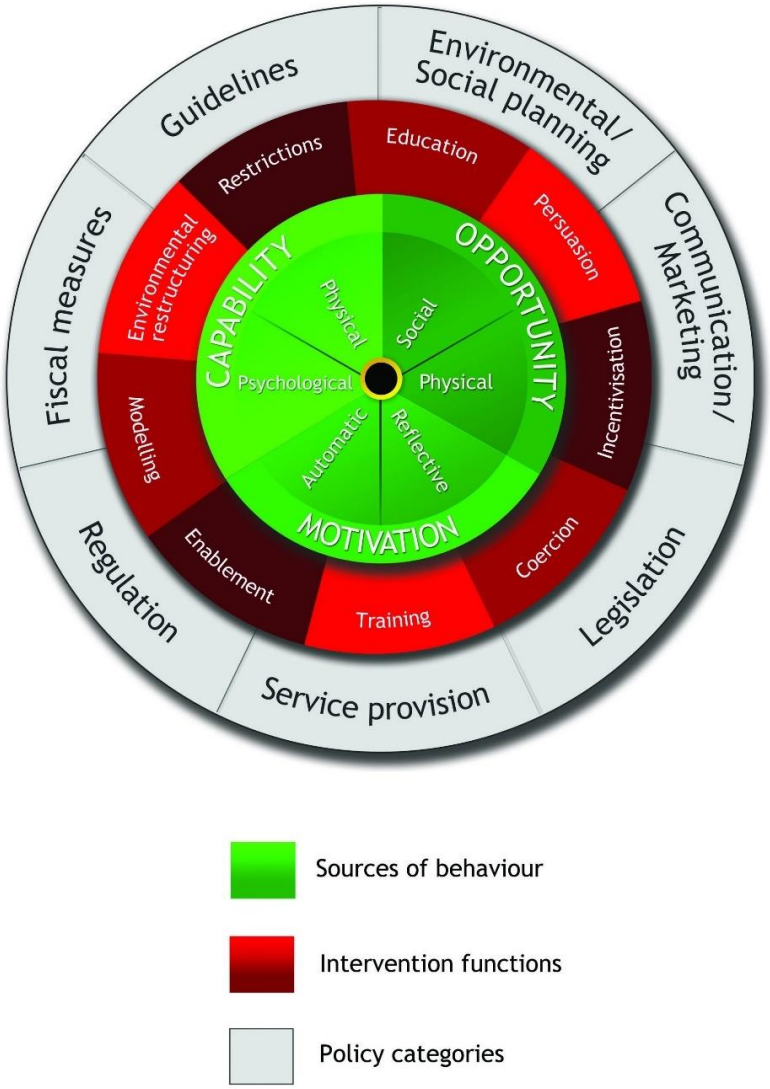

Figure 3-1: Behaviour Change Wheel (Michie *et al.*, 2011)

3.1.1. Stage 1: Understanding the Behaviour

The first stage of the BCW includes a behavioural analysis to understand the target behaviour in as much detail as possible. It involves specifying the target behaviour and what needs to change. The COM-B model is the starting point used by the BCW to aid the understanding of the behaviour in the context in which it occurs (Michie *et al.*, 2014). To change the incidence of any behaviour of an individual, group or organisation involves changing one or more of the conditions of the COM-B model, in other words: changing the capability, opportunity and motivation relating to the behaviour itself or behaviours that compete with or support it. To further understand what needs to change, the Theoretical Domains Framework (TDF) can be used as a detailed analysis framework to inform the COM-B model. The development of the TDF is discussed in the section below.

Theoretical Domains Framework

To change professional practice, it has been agreed that there is no "magic bullet" (Oxman, Ann Thomson, Davis, *et al.*, 1995) and that the effectiveness of intervention strategies is sensitive to context (Wensing, Van Der Weijden & Grol, 1998). Michie *et al.* (2005) however suggest that the mixed results and limited practical value of implementation research was due to a limited theoretical underpinning for the development of interventions. The authors argue that a consensus of psychological theories is necessary to provide clarity and simplify the accessibility and usefulness of theories in behavioural change research. A team of behavioural scientists in collaboration with implementation researchers therefore developed the TDF to provide access to a theoretical basis for implementation research. The TDF is an integrated framework grounded in psychological theory which synthesises 128 theoretical constructs from 33 theories relevant to implementation. The process used to reach consensus by this multi-disciplinary group to develop the framework included six stages:

i. identifying theories and theoretical constructs relevant to behaviour change;
ii. simplifying these theories and constructs into principal theoretical domains;
iii. evaluating the importance of the theoretical domains;
iv. conducting an inter-disciplinary evaluation and synthesis of the constructs and domains; and
v. validating the domain list through pilot interview questions to establish perceptions about the domains and constructs.

The result of the consensus identified 12 theoretical domains[8] that should be considered when seeking to understand how to design interventions to achieve improved implementation or to understand why certain implementation interventions fail (Michie *et al.*, 2005). The domains combine motivation theories, action theories and organisation theories into one integrated framework[9]. In 2012, Cane, Connor & Michie (2012) conducted a validation of the TDF to examine the content of the framework relating to i) the number of domains, ii) each component in the overarching domain structure and iii) the naming of the domains and whether it represented the description that best reflected the content of the domains. The resultant version of the TDF which was developed after the validation showed similar structure to the original version with slight variations and therefore ultimately consisting of 14 domains covering 84 theoretical constructs. For the purpose of this research, the 14-domain version of the TDF will be used and is presented in Table 3-2.

[8] For the original version of the TDF please refer to article published by Michie *et al.* (2005).
[9] For a list of the theories please refer to Appendix A adopted from Michie *et al.* (2005).

Table 3-2: Theoretical Domains Framework (Cane *et al.*, 2012)

Domain (definition[10])	Theoretical Construct
Knowledge (An awareness of the existence of something)	Knowledge (including knowledge of condition /scientific rationale) Procedural knowledge Knowledge of task environment
Skills (An ability or proficiency acquired through practice)	Skills Skills development Competence Ability Interpersonal skills Practice Skill assessment
Social/Professional Role and Identity (A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting)	Professional identity Professional role Social identity Identity Professional boundaries Professional confidence Group identity Leadership Organisational commitment
Beliefs about Capabilities (Acceptance of the truth, reality, or validity about an ability, talent, or facility that a person can put to constructive use)	Self-confidence Perceived competence Self-efficacy Perceived behavioural control Beliefs Self-Esteem Empowerment Professional Confidence
Optimism (The confidence that things will happen for the best or that desired goals will be attained)	Optimism Pessimism Unrealistic Optimism Identity
Beliefs about Consequences (Acceptance of the truth, reality, or validity about outcomes of a behaviour in a given situation)	Outcome expectancies Characteristics of outcome expectancies Beliefs Anticipated regret Consequents

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[10] All definitions are based on definitions from the American Psychological Associations' Dictionary of Psychology (VandenBos, 2007).

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Reinforcement (Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus)	Rewards (proximal/distal, valued/not valued, probable/improbable) Incentives Punishment Consequents Reinforcement Contingencies & Sanctions
Intentions (A conscious decision to perform a behaviour or a resolve to act in a certain way)	Stability of intentions Stages of change model Transition model/stages of change
Goals (Mental representations of outcomes or end states that an individual wants to achieve)	Goals (distal / proximal) Goal priority Goal/target setting Goals (autonomous / controlled) Action Planning Implementation intention
Memory, Attention and Decision Processes (The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives)	Memory Attention Attention control Decision making Cognitive overload/tiredness
Environmental Context and Resources (Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence, and adaptive behaviour)	Environmental stressors Resources/material resources Organisational culture/climate Salient events/critical incidents Person x environment interaction Barriers and facilitators
Social Influences (Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours)	Social pressure Social norms Group conformity Social comparisons Group norms Social support Power Intergroup conflict Alienation Group identity Modelling
Emotion (A complex reaction pattern, involving experiential, behavioural, and physiological elements, by which the individual attempts to deal with a personally significant matter or event)	Fear Anxiety Affect Stress Depression Positive/Negative Effect Burn-out

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Behavioural Regulation (Anything aimed at managing or changing objectively observed or measured actions)	Self-monitoring Breaking habit Action planning

Each domain of the TDF can be related back to a COM-B component (Figure 3-2) which is useful as it provides insight from the detailed analysis of the TDF to inform the COM-B model and therefore to improve an intervention design.

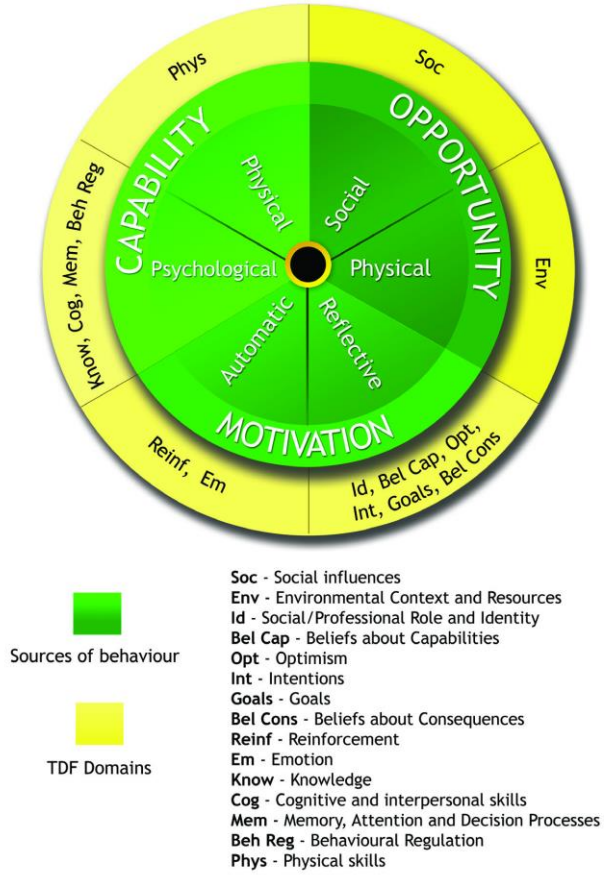

Figure 3-2: TDF Domains linked to COM-B Components within the Behaviour Change Wheel (Michie *et al.*, 2014)

3.1.2. Stage 2: Identify Intervention Options

The COM-B and TDF identifies what needs to shift for a desired behaviour to be achieved and therefore what to target in an intervention strategy. The second stage of the BCW outlines which intervention functions are likely to be appropriate and an effective measure of change. A matrix is used to map the COM-B model to the nine intervention functions that would support the delivery of the intervention (Michie *et al.*, 2014). Table 3-3 provides the definitions of each of the intervention functions. Michie, Atkins & West (2014) emphasise the effectiveness of interventions and further introduces the APEASE criteria to design and evaluate interventions or intervention ideas.

The APEASE criteria specifies that intervention functions and policy categories should be: **A**ffordable, **P**ractical, **E**ffective/Cost-Effective, **A**cceptable, **S**afe and **E**quitable.

Table 3-3: BCW Intervention Function Definitions (Michie *et al.*, 2014)

Intervention Function	Definition
Education	Increasing knowledge or understanding.
Persuasion	Using communication to induce positive or negative feelings or stimulate action.
Incentivisation	Creating an expectation of reward.
Coercion	Creating an expectation of punishment or cost.
Training	Imparting skills.
Restriction	Using rules to reduce the opportunity to engage in the target behaviour (or to increase the target behaviour by reducing the opportunity to engage in competing behaviours).
Environmental Restructuring	Changing the physical or social context.
Modelling	Providing an example for people to aspire to or imitate.
Enablement	Increasing means/ reducing barriers to increase capability (beyond education and training) or opportunity (beyond environmental restructuring).

3.1.3. Stage 3: Identify Components and Implementation Options

The last stage of the BCW identifies intervention content which prescribes behaviour change techniques (BCTs) that would be most appropriate to the intervention functions and modes of delivering the interventions. A BCT is defined by Michie, Atkins & West (2014, p. 234) as "*an active component of an intervention designed to change behaviour*". A BCT can be characterised by the fact that it is observable, replicable, the smallest component of an intervention designed to change behaviour, and an active ingredient (i.e. proposed mechanism of change) within the intervention. During this stage, the intervention functions identified in Stage 2 is linked to the appropriate BCTs using the BCW. Furthermore, the appropriate BCTs can be narrowed down by using the APEASE criteria to identify the most feasible modes of delivery mechanisms for the intervention components such as workshops, pamphlets and websites (Michie *et al.*, 2014).

3.2. Adopting the BCW for a Sustainable Construction Intervention Design

The BCW along with the TDF and COM-B model offers several advantages for developing a behaviour change intervention to improve the adoption and implementation of sustainable construction practices by construction industry stakeholders. Firstly, the BCW is a synthesis of 19 existing behaviour change models and includes a range of important behavioural determinants including beliefs and perceptions, unconscious biases, motivation and the environment (Michie *et al.*, 2011). It allows the intervention designer to consider a range of intervention options linked to specific behavioural change mechanisms and choose intervention functions which are most promising through a systematic evaluation of theory and evidence (Michie *et al.*, 2014).

Secondly, the TDF adopted in this research study to understand the behaviour of adopting and implementing sustainable construction, allows the research to be explored through a theoretical lens of behaviour change. It provides a robust method for the analysis and identification of the barriers and enablers to sustainable construction to understand behaviours theoretically so that current practices in the construction industry can be effectively targeted for change. The TDF allows the research study to progress from investigation of these barriers and enablers towards an intervention. Thirdly, the BCW goes beyond most behaviour change models which only identifies and explains the behaviour without providing interventions to change the behaviour. It provides a systematic way in which to analyse the behaviour and therefore gain insight into which intervention functions could be most appropriate to adopt, given a specific context (Michie *et al.*, 2014).

The application of utilising the TDF, COM-B Model and BCW in research studies have mostly been adopted in literature to support research in the medical and implementation science field (Atkins *et al.*, 2017). However, it has also been adopted in studies about behaviour change relating to sustainable consumption and sustainable development. An example of this is a case study conducted by Gainforth *et al.* (2016) which adopts the TDF and BCW to develop interventions to change recycling behaviours. The following section discusses behaviour change interventions which have been successful in their application to promote sustainable development which can be used as a guide to similarly foster the adoption and implementation of sustainable construction through behaviour change interventions.

3.2.1. Successful Behaviour Change Interventions

According to a publication “Consuming Differently, Consuming Sustainably: Behavioural Insights for Policymaking” by UNEP (2017), understanding the decision-making approach offered by behavioural science is necessary to improve the effectiveness of strategies and policies for sustainable consumption in both developed and developing countries. The publication recommends three key elements required to achieve change in consumption patterns and achieve the Sustainable Development Goals (SDGs): “*incorporate behavioural science into policy processes and tools*; *build internal behavioural policy capacity within policymaking entities*; and *expand behavioural science research efforts and dissemination*.” Globally, government authorities, intergovernmental organisations, educational institutions, businesses and organisations have begun to adopt behavioural science theory and methodologies to design and implement effective behaviour change policies and programmes (Klaniecki *et al.*, 2018). Most behaviour change interventions have primarily been applied in developed countries with high per-capita consumption rates. However, developing countries present many opportunities to adopt behavioural science to inform policy to align with sustainable development goals due to rapid growth of consumption (UNEP, 2017). Table 3-4 presents examples of successful applications of behavioural design to priority consumption areas: energy, water, transportation and mobility, food and diet, and waste and disposal.

Table 3-4: Examples of Successful Behaviour Change Interventions (UNEP, 2017)

Country	Behaviours Targeted	Intervention Tools Used	Results
Uganda	Uptake of efficient Cookstoves	Communication/Marketing: Unique sales offers such as free trial periods or extended time periods to pay for products.	5-25% increase in the adoption of using efficient cookstoves
Norway, Switzerland, Denmark	Smart Grid Technology Uptake	Communication/Marketing: Making the more sustainable choice the default	2.5 times more likely to choose the default option of accepting the Smart Grid installation in the opt-out condition
Costa Rica	Household water consumption	Communication/Marketing: Utilising a sticker-based intervention on water utility bills that highlighted neighbourhood comparisons.	3.7-5.6% decrease in water consumption
Australia	Household water consumption	Communication/Marketing: Specific tips or guidance on how to change behaviour results in sustained behaviours	10.29L decrease in water consumption per person per day
Kenya	Water purification	Environmental/Social Planning: Providing water purification services at the water source to make the provision of the service more convenient	Uptake rates increased from 10% to 60%
India	Traffic Congestion	Fiscal measures: Incentives for arriving during less congested times	Morning peak commute times dropped from 71 to 54 minutes (17 minute decrease), 13% increase in the number of people travelling before peak commute times
Japan	Sustainable transportation	Communication/Marketing: Provide information about negative impacts of conventional modes of transport, goal-setting techniques to aid commuters to follow through on their intentions to change their travel behaviour	7.5% reduction in car use; 68.6% increase in public transportation use
Norway	Decrease Food Waste	Communication/Marketing: Physical and social cues such as reducing plate sizes promote sustainable habits	19.5% decrease in food waste
United States of America	Encourage Sustainable Food Choices	Communication/Marketing: Relevant knowledge helps promote sustainable behaviour such as providing information about transport distances of food products on LED devices on shopping carts	72% of products purchased with LED shopping carts had lower mileage
Peru	Promoting Recycling	Service Provision: Distribution of recycling bins to households to make it easier for residents to cleanly store recyclables	6% increase in recycling of household items

3.3. Conclusion: Chapter 3

This chapter outlines the multi-level factors which influence behaviour and how behaviour change theory and intervention tools can be used to facilitate the design of effective interventions. Although there has been an increase in the utilisation of behaviour change theory in sustainable consumption literature, there is very limited theory-based intervention tools that could improve the adoption of sustainable construction amongst construction industry stakeholders. This highlights a significant gap in current research efforts to encourage sustainable alternatives to design and construction of the built environment. It provides a limitation on the opportunity which could exist for decision-makers and key stakeholders to design effective interventions and programmes to improve the adoption and implementation of sustainable construction.

Using a behaviour change theory approach to develop intervention strategies will advance the evidence in this field of research and increase the awareness of the need to adopt and implement sustainable construction. Sustainable construction requires active engagement and collaboration of all disciplines to effectively adopt and implement sustainable designs and therefore sustainable buildings and projects. The TDF, COM-B Model and BCW allows the research study to be explored through a theoretical lens of behaviour change. It allows for the analysis and identification of the barriers and enablers to sustainable construction from a quantitative perspective as well as qualitative perspective and can include all stakeholders. This would provide a basis to utilise the BCW to map where key areas of barriers and enablers have been identified within the domains of the TDF and therefore progress towards a theoretical basis for intervention. This research study aims to utilise the BCW to develop a comprehensive understanding of the barriers and drivers of sustainable construction, and to improve the adoption and implementation strategies of sustainable construction through a behaviour change intervention.

Chapter 4
Research Design and Methodology

This chapter of the research study discusses the choice of a suitable research design and methodology to achieve the aims and objectives of this study. This study addresses the three remaining research objectives through three phases and is outlined in Section 4.1, Section 4.3 and Section 4.4. Phase One adopts a qualitative research approach to provide descriptive results of the current barriers and drivers identified in the literature through an integrative review. Phase Two identifies the key barriers and drivers of SC as perceived by stakeholders in the construction industry through an online self-administered survey questionnaire. Phase Three identifies the intervention components and strategies that can be used by stakeholders in the construction industry to facilitate the adoption of SC. This provided a basis for developing a behaviour change intervention.

4.1. Research Design Framework

Before data can be collected and analysed, it is important to identify the research design and method(s) to be adopted in the research study. The purpose of the research design in a study is to provide a framework that guides how the data will be collected and analysed. The research framework adopted in this research is outlined in Figure 4-1. This research employs a mix of strategies of inquiry to achieve its aim and objectives. The rationales for selecting each of these strategies, as well as the methods used for data collection and analysis are discussed in the following sections.

The phases of the research design will follow the systematic stages as outlined in the BCW. Data gathered from the integrative review of the literature in Phase One and survey questionnaire in Phase Two was used in Phase Three to identify the components of an intervention that could be used to overcome the barriers of successful adoption and implementation of sustainable construction. Phase Three culminated in the design of a theory-based intervention which was validated by construction industry stakeholders through semi-structured interviews.

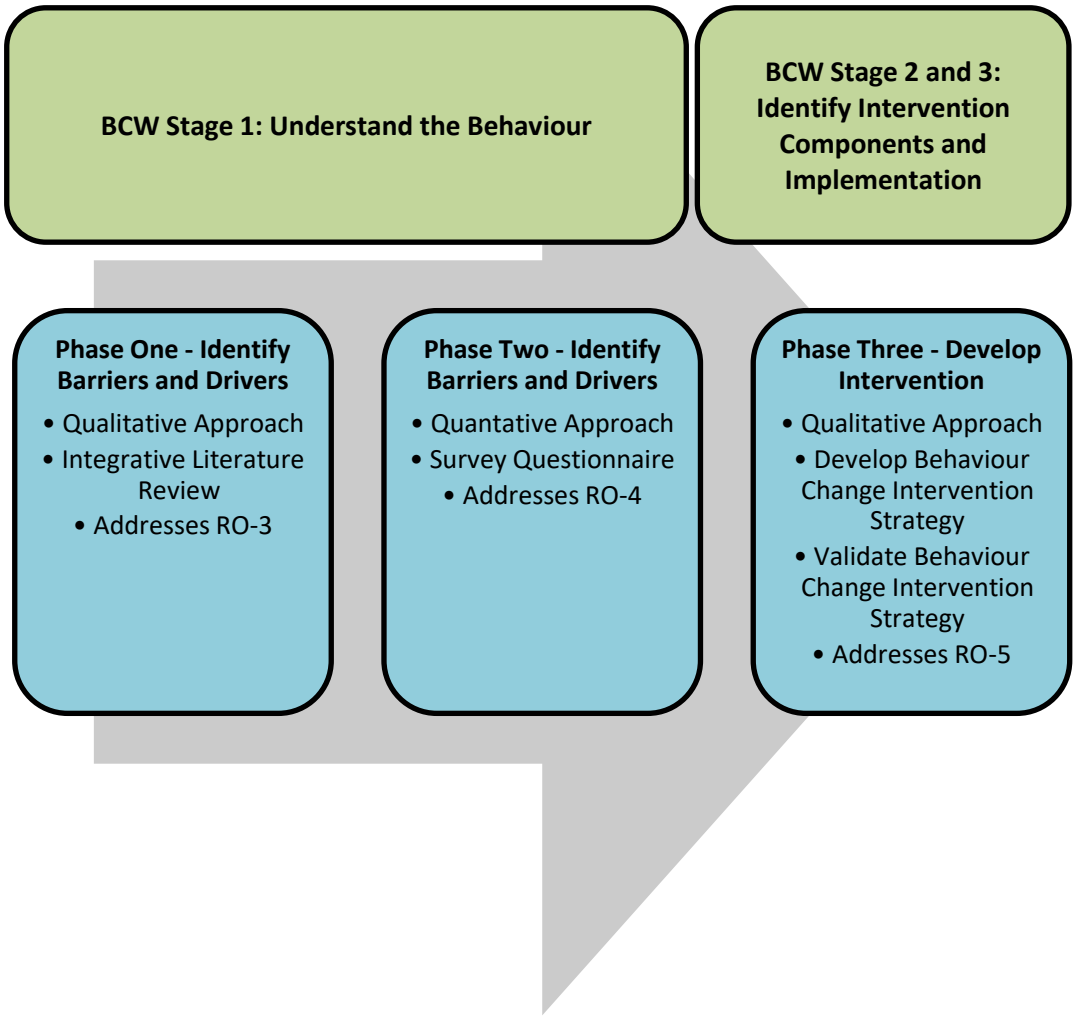

Figure 4-1: Research Design Framework

4.1.1. Mixed Methods Research

This research study comprises of various stakeholders from multiple disciplinary backgrounds. The concept of sustainable development within the construction industry highlights the multi-disciplinary nature of the research. Therefore, the chosen research approach needs to achieve an in-depth understanding of the social realities which exist and how they interact within both areas of interest. Furthermore, sustainable development and construction are both complex entities which are defined and interpreted differently by various participants. To understand and analyse these differences and how they affect the implementation of sustainable construction, the research has to be conducted in the real-world context of the participants. This is to ensure that the perceptions and views of the participants are true to their social realities. The research objectives of this study emphasise the need to assess the perception of- and obtain multiple perspectives on -SC. This in turn requires a strategy to understand the variation in the interpretations of SC.

To facilitate this, a mixed method approach was adopted to integrate and enhance the findings from both a quantitative research approach and a qualitative research approach. A three-phased, explanatory sequential mixed methods design (qual → quan → QUAL) as classified by Creswell (2012) was utilised. This design captures the best of both quantitative and qualitative data: an integrative review of the literature in Phase One informed the quantitative survey design in Phase Two which was developed into a behaviour change intervention in Phase Three. Phase Three, which is a qualitative phase, takes priority as it encompasses the main aim and objective of this research study. This approach is generically depicted by the quan → QUAL classification of mixed methods research (Figure 4-2).

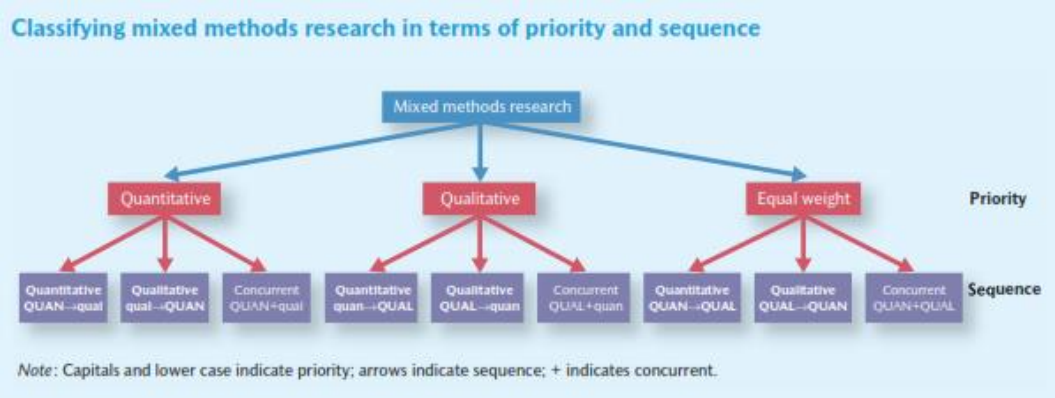

Figure 4-2: Classification of Mixed Methods Research (Bryman, 2012)

The rationale for this approach is that the quantitative data and results provide a general picture of the research problem; more analysis, and in the case of this research study, the qualitative data collection phase is needed to refine, extend, and validate the general picture. This design has the advantage of clearly identified quantitative and qualitative parts, an advantage for readers as well as for those designing and conducting the study. Unlike the convergent design, the researcher does not have to converge or integrate two different forms of data. The difficulty in using this design, however, is that the design is labour intensive, and it requires both expertise and time to collect both quantitative and qualitative data. Based on the literature by Bryman (2006), the quantitative and qualitative aspect of this research was combined with the aim to provide context to Phase Three based on the results from Phase Two. Furthermore, validating the findings in Phase Three provided credibility of both Phase Two and Phase Three. The research project was therefore broken into three distinct phases which guides the decisions made in relation to the strategies of inquiry and data collection and analysis methods discussed within the remaining sections of this chapter.

4.2. Phase One: Understanding the Target Behaviour (Qualitative Strand)

Phase One of the three-phased mixed methods design focuses on understanding the target behaviour, which links to stage 1 of the BCW. To understand the behaviour of stakeholders in the construction industry, we had to identify the key potential barriers and drivers of adopting and implementing sustainable construction practices. A five-step integrative review approach was adopted to identify the barriers and drivers of sustainable construction which was mapped to the Theoretical Domains Framework (TDF) and Capability, Opportunity and Motivation-Behaviour (COM-B) model. The following section discusses the research design for conducting the integrative review and the anticipated outputs of this phase. This phase of the research addresses research objective three (RO-3: *Identify the drivers and barriers of SC adoption and implementation*).

4.2.1. Integrative Review Research Design

Integrative reviews provide a more comprehensive understanding of a particular phenomenon as it allows the inclusion of both experimental and non-experimental research in order to understand a phenomenon of concern more holistically (Whittemore & Knafl, 2005). The concept of sustainable construction has not been explored extensively in the literature and therefore the integrative review aids the understanding of this concept and what the potential barriers and drivers are to the adoption of sustainable construction. Integrative reviews further allow deductions to be made on a transparent basis as all relevant, sound research with diverse methodologies is included (Whittemore & Knafl, 2005). This aids the purpose of this review by generating an overall view of the evidence available in the literature for sustainable construction. The five-step integrative review process used in this review is detailed below.

Step 1: Problem Identification

The construction industry in South Africa is a large contributor to the development and growth of the economy. The industry also has a significant impact on the sustainability of the built environment considering that it is a vehicle used to address challenges such as lack of infrastructure, insufficient housing and rapid urbanization. These challenges are specifically dominant in developing countries such as South Africa. The preliminary investigation suggests that without the adoption of sustainable construction practices within the industry, it will continue to significantly impact the sustainability of resources, the environment and compromise the needs of present generations as well as future generations. However limited research exists in South Africa which examines the barriers and challenges facing the construction industry which hinders the successful adoption and implementation of sustainable construction. Furthermore, in order to overcome these barriers, we have to identify which factors and drivers would promote the successful adoption of sustainable construction. Therefore, the purpose of this integrative review was to identify the key barriers and drivers faced by other countries and use this to map the barriers and drivers to the TDF and COM-B model, and identify key domains to focus on to develop intervention strategies to overcome these barriers.

Step 2: Literature Search

The integrative review specifically focuses on the barriers and drivers to the successful adoption and implementation of sustainable construction which facilitated the literature search. An online search was conducted using Scopus as the main database with additional searches conducted in Google Scholar and Science Direct. As highlighted in literature, various terms are used interchangeably when it comes to sustainable construction. This review therefore adopted keywords and synonyms as shown in Table 4-1 and specific inclusion criteria to identify and select articles.

Table 4-1: Selection Criteria for Articles

No	Inclusion Criteria	
1	Type	Journal Articles
		Conference Proceedings
2	Year	2009 - Present
3	Keywords	"sustainable construction" OR "sustainable building" OR "construction sustainability" OR "green building" OR "sustainable development"
		"construction industry" OR "building construction" OR "construction management" OR "engineering management" OR "construction and engineering management"
		"barriers" OR "obstacles" OR "challenges" OR "impediments"
		“drivers” OR “promoting” OR “motivating factors”
4	Subject Area	Engineering
		Environment
		Society
		Business
		Decision Making
		Earth

The search strategy process for both the barriers and drivers is shown in Figure 4-3. The initial literature search for the barriers and drivers rendered 650 and 249 articles, respectively. From the literature search, which initially rendered 899 articles in total, only 37 articles met the inclusion criteria and was relevant to the current study. The relevance to the study was based on the applicability and quality of the articles. The applicability was guided by the inclusion criteria and the quality appraisal was guided by whether the abstract, introduction and conclusion indicated that the article was relevant to the study, and whether or not the research design approach and methodologies adopted in the articles lend itself to being applicable to South Africa. The initial search rendered a large number of articles as a result of at least one of the keywords being contained in the title, abstract or keywords of the articles which met the initial search requirements. However, further analysis using a content review was done to ensure that articles discussed, assessed and potentially examined the barriers and (or) drivers to the adoption and implementation of SC. It is important to note that this study provides insights based on the selected articles and does not review all the articles potentially published in other literature databases, books, dissertations, and other media.

This literature review therefore only analysed articles obtained using the above-mentioned selection criteria.

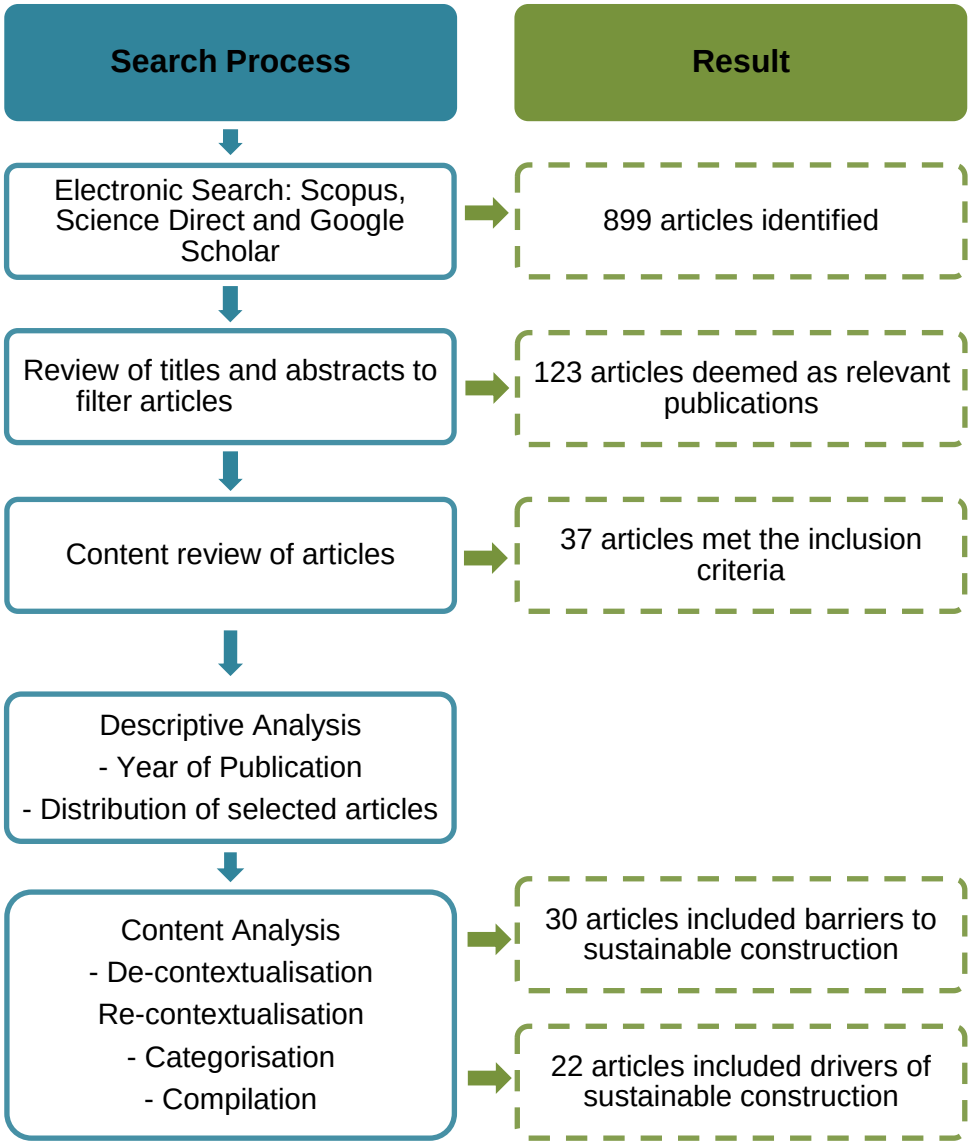

Figure 4-3: Search strategy process to identify barriers and drivers

Step 3: Data evaluation

According to Whittemore & Knafl (2005), extracting the methodological features of primary sources or selected literature in meta-analysis, systematic and integrative reviews is recommended to assess the overall quality. Integrative reviews can potentially include empirical sources with similar research methods, empirical sources with various research methods or sources which are empirical and theoretical (Whittemore & Knafl, 2005). For each of these scenarios, a different method of assessing the quality can be adopted. Sources with similar research methods can make use of exclusion and inclusion criteria to calculate quality scores and then incorporate these scores into the design.

On the other hand, sources with diverse research methods may only reasonably be evaluated for quality if there are certain outliers which might infer that the methodological quality of the source is a feasible reason for the discrepancy in the findings. Furthermore, for studies which include empirical and theoretical sources, evaluating quality similar to that of historical research may be appropriate (Whittemore & Knafl, 2005). Whittemore & Knafl (2005) argues that each research method has different criteria which exemplifies quality and therefore the process of evaluating quality would be more conducive to reviews which have similar or identical research methods. The sample of the literature selected for this review included empirical research with a variety of research methods. No article that was reviewed had a significant outlier which could be linked to the methodological approach and therefore all articles were deemed acceptable.

Step 4: Data analysis

In order to analyse the data in a research review, the data needs to be categorised, ordered, coded and summarised. According to Whittemore & Knafl (2005), an unbiased and thorough interpretation of the data, as well as synthesising the evidence is the aim of the data analysis stage in an integrative review. A method of constant comparison is used in this review to convert the data which has been extracted into categories which enables the identification of trends, themes, distinctions and relationships. Initially, the extracted data is compared item by item so that similar data is categorised and coded. Subsequently, the coded categories are then compared which further the analysis and synthesis of the data. Whittemore & Knafl (2005) state that this approach to data analysis in an integrative review is appropriate with the use of data from sources with various research methods. After identifying the relevant articles, a descriptive analysis was conducted to characterise the selected articles using frequency and percentage methods. The factors used in the descriptive analysis provide an overview of the year of publication, the publication type, the country or region of publication and the research approach and methods in the published article. A content analysis was conducted following the descriptive analysis to inductively assess, identify and contextualise the categories of barriers and drivers which hinder or promote the adoption and implementation of sustainable construction. Content analysis is a technique using a structured and systematic coding and categorisation approach to examine and identify trends and patterns amongst a string of words and compressing it into fewer content categories (Hsieh & Shannon, 2005; Stemler, 2001). A content analysis approach is recommended by Atkins *et al.* (2017) when the TDF is used in a qualitative research approach. Although preparation, organisation and reporting are the three major components of the content analysis process, there are no systematic rules for data analysis and the goal of all content analysis is to condense many words in the text into much smaller content categories (Elo & Kyngäs, 2008). To conduct the content analysis, a four-stage approach proposed by Bengtsson (2016) was used as follows:

Stage 1: De-contextualization

This stage involved making sense of the data and selecting a unit of analysis. The unit of analysis adopted are themes, as opposed to physical linguistic units (e.g. words, sentences or paragraphs). Themes represent an expression or idea using a single word, phrase, sentence or even an entire document (Bengtsson, 2016).

A code can therefore be assigned to a theme which represents any size of text as long as it is representative of a single theme (Chang, Zuo, Soebarto, *et al.*, 2016). The coding process in this study utilised the themes of barriers and drivers of sustainable construction as the units of analysis. An initial standardised list of coding groups was established to de-contextualise the text in the articles as shown in Table 4-2 as well as identify the articles based on the descriptive analysis. All the information in the selected articles was manually extracted and recorded in a Microsoft Excel Spreadsheet which refers to the code list.

Stage 2: Re-contextualization

Stage 2 refers to the process of open coding by condensing the various descriptions of the unit of analysis under the two major themes which is the barriers and drivers of sustainable construction. The first step of re-contextualization involves labelling the extracted meanings with explicit codes or sub-themes under the major themes based on their similarity. As an example, statements that indicate that increased cost, time and risk is associated with the adoption of sustainable construction were coded as “economic barriers” in the open coding process. The codes of sub-themes can easily be collected throughout this stage and therefore freely generates categories (Elo & Kyngäs, 2008).

Table 4-2: Initial Article Code List

Code	Code Definition
Year	Year of publication of article
Author(s)	List of authors
Article Title	Title of article
Journal or Conference	Journals or conferences where article has been published
Country	Country or region where data was collected
Research Approach	Research approach used in the study
Research Method	Research methods used to collect data
Barriers	Barriers identified that hinder sustainable construction adoption and implementation
Drivers	Drivers identified that promote sustainable construction adoption and implementation

Stage 3 and 4: Categorisation and Compilation

Categorising during Stage 3 requires sorting the sub-themes into categories followed by a compilation process. During the categorising process, similar or dissimilar sub-themes are collapsed into broader sub-themes which provides the grouping lists of sub-themes in Stage 2. Each sub-theme was then named according to the content-specific words within that category. The data was then recorded in a new Excel spreadsheet to track the number of studies for each sub-theme.

The final stage of the data analysis requires the mapping of the sub-themes and meanings to the TDF and the COM-B model. This was done by mapping the content of each of the sub-themes of the drivers and barriers to each of the domains in the TDF in a separate spreadsheet. This spreadsheet would form the basis for the questionnaire survey required for Phase Two of this research study.

Step 5: Interpretation of Results

The interpretation and findings from the data analysis of Phase One is presented in Chapter 5.

4.2.2. Phase One Anticipated Outputs

The barriers and drivers of sustainable construction identified through the integrative review mapped to the TDF and COM-B model forms the basis for the questionnaire survey required for Phase Two of this research study.

4.3. Phase Two: Understanding the Target Behaviour (Quantitative Strand)

The quantitative phase of this research will provide data from a structured questionnaire survey conducted through recruiting various stakeholders who are currently working in the construction industry in South Africa. The purpose of the survey was to identify the drivers and barriers identified by stakeholders in the construction industry and use this as a guide to inform which components should be prioritised in the intervention design. This stage of the research addresses the fourth objective of the study: *Understand the perception of barriers and drivers of SC by construction industry stakeholders in South Africa* (RO-4).

4.3.1. Survey Questionnaire Research Design

For the purpose of this study, a cross-sectional design was employed. Cross-sectional design is generally associated with surveys although it can include other research methods such as “structured observation, content analysis, official statistics and diaries” (Bryman *et al.*, 2017). Cross-sectional design is characterised by collecting data on more than one case at a single point in time. Variation is important and can be established through more than one case in respect of people, organisations, countries and so forth. More than one case increases the likelihood of variation amongst interested variables in the study. Quantitative data is collected to establish variation between cases and connections between two or more variables (Blaxter, Hughes & Tight, 2006). Qualitative data can also be collected using cross-sectional design through interviews. The limitation of cross-sectional design is that variables cannot be manipulated and therefore only relationships can be examined, not causality (Bryman *et al.*, 2017). Bryman *et al.* (2017) further suggest that the research study can therefore only draw inferences about causality without the credibility and validity of an experimental design. The research is better poised to be described as employing a cross-sectional design rather than a case study because the case itself is not the apparent object of interest: it provides context that forms a backdrop to the findings.

4.3.2. Study Population and Sampling

The population of this study were all construction industry professionals working in the built environment in South Africa on building projects. Due to the large number of professionals in the construction industry, no available list of all construction industry professionals, and potential challenges with access and communication, the sampling frame adopted was a nonprobability sample. Nonprobability sampling is a sampling technique in which the researcher chooses participants based on their willingness to participate in the research study.

A purposive snowball sampling technique was therefore used in this research to obtain a valid and effective overall sample size. This method has been used in previous construction, engineering and management studies and allows for data to be gathered from participants who share the research study or make referrals of prospective participants (Gan *et al.*, 2015; Jiang & Wong, 2016; Darko *et al.*, 2017; Chan *et al.*, 2018). The online survey questionnaire was distributed via LinkedIn (a professional social media platform) to professionals who met the inclusion criteria (i.e. working in the built environment in South Africa on building projects). Using search criteria to filter each of the discipline services provided within the design and development phase of building projects (e.g. quantity surveyors, architects, landscape architects, structural engineers, civil engineers, building services engineers which includes mechanical, electrical and fire) as well as location (South Africa), individuals were sent messages inviting them to participate in the research study. Initial participants were asked to share the survey with other professionals in the built environment whom they knew of that also worked on building projects.

4.3.3. Instrumentation

The purpose of the survey questionnaire in this study was to understand which barriers and drivers of sustainable construction need to be prioritised for an intervention strategy. A self-administered online questionnaire is the preferred type of data collection procedure for this phase of the research for the following reasons:

i. Cost-effective to administer.
ii. Ease of gathering data as surveys can be distributed rapidly and completed.
iii. Data inputs are readily available from an online survey database.
iv. Due to automated data capturing, there is a reduced possibility of errors whilst handling the data.
v. Online surveys are convenient to potential participants as they can complete the survey at a time and place that is convenient to them.

One of the disadvantages of an online survey is that an interviewer is absent, and participants have no one to ask for help should they require help to answer a certain question or do not understand the question. Secondly, online surveys also require participants to have access to the internet which may exclude certain individuals. And lastly, participants might only complete the online survey for the sake of getting an incentive for their participation as opposed to wanting to contribute to the advancement of the research.

Survey Questionnaire Design

The survey questionnaire was adapted from Huijg *et al.* (2014) and informed by the TDF and COM- B model to guide the behavioural analysis and understand the perceived barriers and drivers of sustainable construction identified by participants (Refer to Appendix F). The barriers and drivers identified in Phase One was included in the survey questionnaire as belief statements along with belief statement items from the TDF domains presented by Huijg *et al.* (2014) which had not been identified in literature. The results of the survey questionnaire allowed the researcher to identify key perceptions from the various domains of the TDF that can be targeted in an intervention strategy to facilitate the adoption and implementation of SC.

The survey questionnaire consisted of seven sections covering: i) Background to the research study and informed consent; ii) Key definitions pertaining to the study; iii) Demographics of participants; iv) TDF Domains Knowledge, Skills and Social and Professional Role and Identity; v) TDF Domains Beliefs about Capabilities, Optimism, Beliefs about Consequences; vi) TDF Domains Reinforcement, Intentions, Goals, Social Influences and Behavioural Regulation and vii) Environmental Context and Resources. The scales used to measure the items include categorical nominal (e.g. type of profession, type of service disciplines at organisations, yes/no questions) and ordinal scales (e.g. years of experience, number of employees at an organisation, Likert scale). The Likert scale which makes up the majority of the questionnaire items was a five-point scale measuring: 1 - strongly disagree, 2 – disagree, 3 – neither disagree or agree, 4 – agree and 5 – strongly agree. The Likert scale provides an overview of the intensity of an attitude towards a statement and was therefore deemed the appropriate scale used to measure the TDF domain items (Bryman, 2010).

4.3.4. Data Collection

The online survey questionnaire was distributed using an online survey platform called CheckBox[11] which was administered through the University of Stellenbosch during September 2019. Initial participants all received messages through LinkedIn inviting them to participate in the research study. A follow-up message was sent after a week to remind participants to complete the survey. During the second week, another group of participants were messaged to participate with a follow up message sent at the start of the third week. Follow up messages were sent to ensure a higher response rate as participants might not have been able to complete the survey when they received the first message.

4.3.5. Data Analysis

Descriptive statistics were reported and discussed in Chapter 6 to describe the characteristics of the participants and their perceptions of SC through means and proportions with a 95% confidence interval. The data collected was manipulated and analysed using the statistical software package SPSS. The data analysis was conducted by performing various statistical analysis approaches. Firstly, the Cronbach's Alpha test was used to measure the reliability of the data, frequency tables were used to report the results from the Likert scale items, followed by determining if there was a significant difference between two or more groups of participants using the Mann-Whitney U test and Kruskal Wallis test. The Mann-Whitney test is a nonparametric test to compare two categorical unpaired groups of data. In this study, the two groups studied were structural and civil engineers as these groups represented a significant sample of at least 30 data sets each. The Kruskal Wallis test is another nonparametric test used when more than two categorical groups are compared, which in the case of this research study was identified as the *years of experience,* which had four groups (0 to 4 years, 5 to 9 years, 10 to 19 years, greater than or equal to 20 years).

[11] CheckBox is an online survey tool used to create surveys and provides features to extract the raw data from completed surveys for analysis.

4.3.6. Phase Two Anticipated Outputs

The results from Phase Two was used in two ways. Firstly, it provided a detailed description of the key barriers that need to be addressed and the key drivers that need to be enhanced to promote the adoption and implementation of sustainable construction in the South African construction industry. Secondly, the key barriers and drivers will be the focus of the development of a behaviour change intervention to address the target behaviour in Phase Three. The key barriers and drivers were mapped to the TDF and COM-B model to provide a link to the intervention functions which are most likely to bring about change.

4.4. Phase Three: Developing a Behaviour Change Intervention (Qualitative Strand)

Phase Three presents the design and development of the behaviour change intervention toolbox using the three stages of the BCW. This phase includes the evaluation of the toolbox by subject matter experts which is discussed in detail in Chapter 7. This phase of the research addresses the fifth research objective: *Develop a behaviour change intervention by identifying the components and/or strategies that can be used by construction industry stakeholders to facilitate the adoption and implementation of sustainable construction through a sustainable project management process (RO-5).*

4.4.1. Behaviour Change Intervention Design

The data obtained from Phase One and Phase Two was used to develop a behaviour change intervention that includes behaviour change techniques (BCTs) designed to overcome the barriers and enhance the drivers of adopting sustainable construction in the construction industry. The TDF and COM-B provides information on what needs to shift for the desired behaviour change to be achieved and therefore what needs to be targeted in an intervention (Michie *et al.*, 2014). The intervention will be developed as follows: Intervention functions and content will be identified based on the key barriers and drivers from the findings in Phase Two and based on the target behaviour. The BCW identifies which intervention functions are most likely to be effective in bringing about behaviour change in each TDF domain and COM-B component (Michie *et al.*, 2014). The APEASE criteria will be applied to each intervention function to determine its affordability, practicability, effectiveness and cost-effectiveness, acceptability, safety and equity and explore its appropriateness for the context of construction industry stakeholders. The APEASE criteria is used to guide the strategic decision-making process during intervention design (Michie *et al.*, 2014). After the intervention functions have been identified, the BCT Taxonomy (BCTTv1) (Michie, Richardson, Johnston, *et al.*, 2013) will be used to identify the BCTs that would best suit the intervention functions and would be feasible and most useful for addressing the barriers and enablers of sustainable construction. Using the target behaviour, the intervention components were identified. Four semi-structured interviews were conducted with subject matter experts to review the findings from Phase One and Two, assess the intervention content and components identified, evaluate the BCTs and discuss the quality and applicability of the behaviour change intervention. The interview protocol is provided in Appendix G and Appendix H.

4.4.2. Phase Three Anticipated Outputs

Phase Three culminated in a behaviour change intervention which aims to facilitate and improve the adoption and implementation of sustainable construction targeting a specific behaviour. The intervention will be also be evaluated for its quality and applicability in the construction industry.

4.5. Conclusion: Chapter 4

In order to facilitate the adoption and implementation of SC amongst construction industry stakeholders, it is important to understand what currently hinders the adoption and what solutions might enhance what currently drives the adoption of SC. This research study followed a systematic mixed methods research approach with a theoretical basis to develop a behaviour change intervention aimed at promoting the adoption and implementation of SC in the construction industry in South Africa. The mixed methods approach allows for the integration of both qualitative and quantitative results based on similar studies in literature in other countries and from the perspective of stakeholders in the construction industry in South Africa. This will enhance our understanding of the barriers and drivers of SC and therefore provide a foundation for the development of an intervention to promote SC. The BCW guides this research study which adopts both the TDF and COM-B model as theoretical frameworks to understand the behaviour in context and design a theory-based intervention.

Although the BCW has been extensively used in health services research, accordingly to the researcher's knowledge, this is the first research study adopting the BCW in the context of sustainable construction. Behavioural science and theory has however been adopted in other environmental studies such as pro-environmental studies (Darnton, Elster-jones, Lucas, *et al.*, 2006; Kollmuss & Aygeman, 2002; Lopes, Gill & Fam, 2015; Morioka, Bolis, Evans, *et al.*, 2017; Steg & Vlek, 2009), sustainable consumption studies (Darnton *et al.*, 2011; Wilson & Marselle, 2016; UNEP, 2017) and behaviour change for sustainable development studies (Klaniecki *et al.*, 2018; Kuijer & Bakker, 2015; Wilson & Marselle, 2016). The adoption of behavioural science and theory within the context of the construction industry is relevant as human behaviour is at the core of all processes, methods and decision-making throughout the lifecycle of a building or construction project. In order to reduce the impact of the construction industry on the environment, whilst growing the economy and considering societal needs, there is a need to shift the behaviour of stakeholders in the construction industry. Stakeholders in the construction industry are key decision-makers who can impact the future of how the construction industry will respond to environmental challenges, economic challenges and ensure the provision of a built environment that is sustainable.

Chapter 5
Phase One: Understanding Sustainable Construction Behaviour (Qualitative Strand)

This chapter discusses the research findings of Phase One, which includes the descriptive and content analysis of the barriers and drivers of sustainable construction through an integrative review. The results from the integrative review were then mapped to the COM-B model and TDF to provide a theoretical basis for the development of the questionnaire in Phase Two. This phase of the research addresses research objective three (RO-3: *Identify the drivers and barriers of SC adoption and implementation*).

5.1. Descriptive Analysis

After evaluating the articles within the literature, 37 articles met the inclusion criteria and were selected to be classified and coded as shown in Appendix B. Figure 5-1 indicates the annual number of selected articles which have been published with a trend of fluctuating growth since 2009 and varies between 1 and 6 articles published per annum.

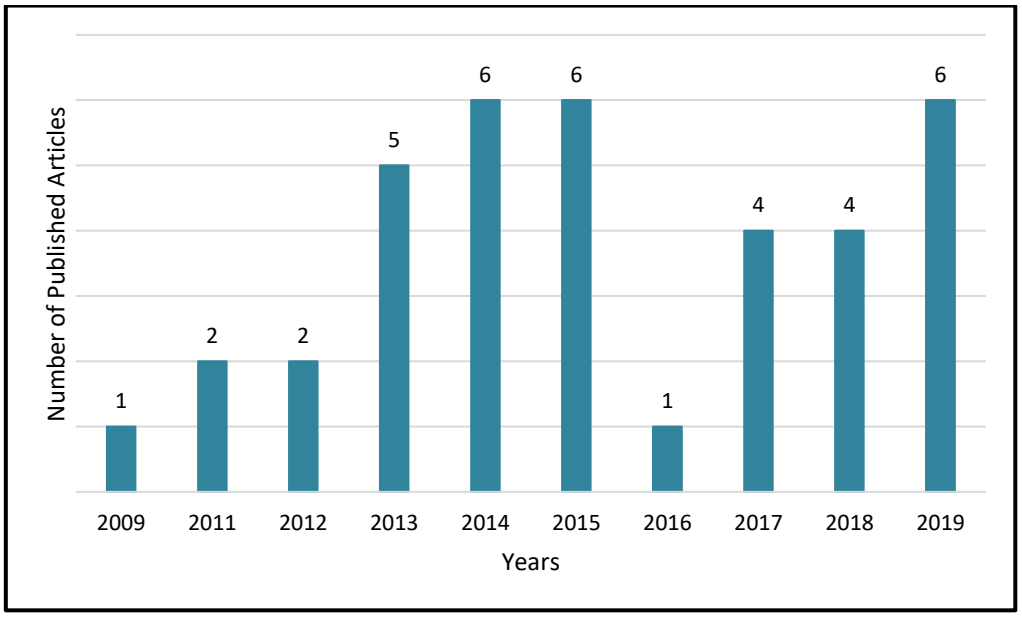

Figure 5-1: Number of relevant articles published annually between 2009 and 2019

The distribution of the selected articles published in journals and conferences are presented in Table 5-1. Journal articles accounted for 89% (33 articles) of the publications and conference papers accounted for 11% (4 articles) of the publications.

Table 5-1: Distribution of selected journal and conference articles

Journal or Conference	Number of Selected Articles
Journal of Cleaner Production	5
Energy Procedia	2
Habitat International	2
Journal of Sustainable Development	2
Procedia Engineering	2
Sustainability	2
Sustainable Cities and Society	2
Technological and Economic Development of Economy	2
Construction Innovation	1
47th ASC Annual International Conference Proceedings	1
AIP Conference Proceedings	1
Building Research & Information	1
Built Environment Project and Asset Management	1
Colloquium on Humanities, Science & Engineering Research	1
Energy & Buildings	1
Environment, Development and Sustainability	1
International Journal of Sustainable Building Technology and Urban Development	1
International Journal of Sustainable Tropical Design Research and Practice	1
IOP Conference Series: Earth and Environmental Science	1
Journal of Economics, Business and Management	1
Journal of Management in Engineering	1
Modern Applied Science	1
Performance Improvement Quarterly	1
Procedia Manufacturing	1
Resources, Conservation and Recycling	1
Structural Survey	1
Total	**37**

Considering the possible variation in the social, economic, political and cultural contexts, the countries or regions of origin of the articles were identified and presented in Table 5-2. The 37 articles covered a total of 19 countries or regions including both developed and developing countries with the most articles published in Australia (5 articles), Ghana (4 articles), Malaysia (4 articles), China (3 articles), United States (3 articles) and the United Kingdom (3 articles). In the context of this review, the majority of the articles were studied in developing countries.

Table 5-2: Distribution of selected articles by country or region

Country of Origin	Developed/Developing[12]	Number of Selected Articles
Australia	Developed	5
Ghana	Developing	4
Malaysia	Developing	4
China	Developing	3
United States	Developed	3
United Kingdom	Developed	3
Oman	Developing	2
Singapore	Developing	2
South Africa	Developing	2
Chile	Developing	1
Egypt	Developing	1
Finland	Developed	1
Kuwait	Developing	1
Multi-National	Developing	1
Pacific Northwest	Developed	1
Vietnam	Developing	1
Wales	Developed	1
Zambia	Developing	1
Total		**37**

5.1.1. Research Approach and Methods for Selected Journal Articles

The analysis of the articles indicated that all studies were empirical and included qualitative, quantitative and mixed method approaches as shown in Figure 5-2. Many articles adopted a quantitative approach to the research study whilst mixed methods and qualitative studies only accounted for 9 and 6 articles respectively out of the selected 37 articles. There is therefore an opportunity for more conceptual studies to be adopted using a theoretical approach as well as a qualitative research approach. Similarly, there is the potential to increase the adoption of mixed method approaches as it leads to greater data validation and triangulation in research studies. Figure 5-3 indicates that questionnaires as a research method accounted for most of the articles. Quantitative studies adopted questionnaires as a primary research method whilst qualitative studies used focus groups, workshops, case studies and interviews. Mixed method studies predominantly used a combination of survey questionnaires with interviews.

[12] Data extracted from *World Economic Situation and Prospects 2019* report published by the United Nations.

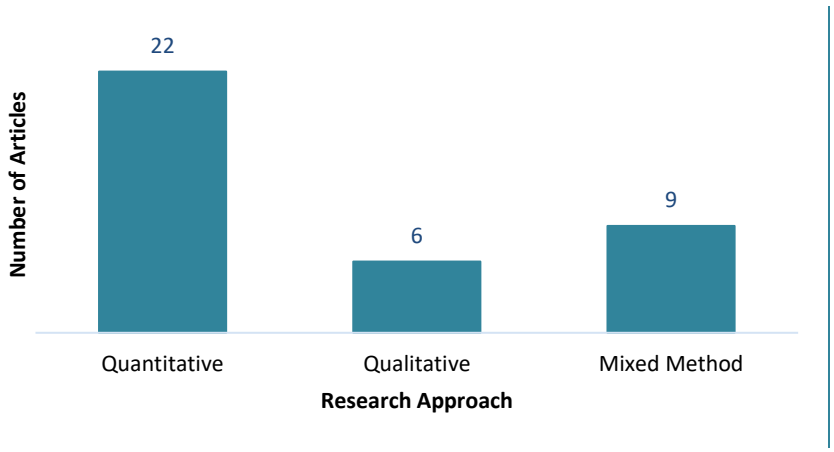

Figure 5-2: Research Approach of Selected Journal Articles

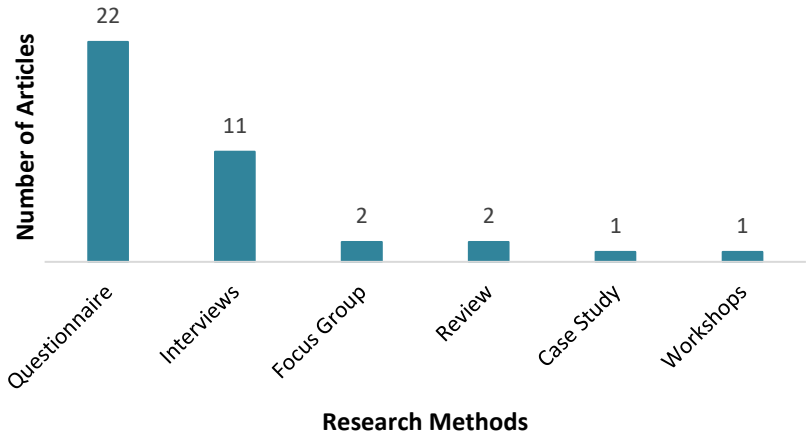

Figure 5-3: Research Methods Adopted in Selected Articles

5.2. Content Analysis

A content analysis was conducted to inductively identify and contextualise the categorisation of barriers and drivers of sustainable construction amongst construction industry stakeholders. The following section presents the results of the analysis grouped by the barriers to SC adoption and associated themes, as well as the drivers of SC and its associated themes.

5.2.1. Barriers to Sustainable Construction

To develop a more meaningful interpretation of the data, the emerging themes of the barriers in the literature were grouped based on existing literature and can be summarised with five key themes as follows:

i. Socio-cultural barriers: includes barriers related to knowledge, information, awareness, understanding, training, and education.
ii. Economic barriers: includes barriers which have financial implications and are related to the economy, market, the construction industry, cost, time, and risk.

iii. Stakeholder barriers: includes barriers which are related to leadership and management in the construction industry, mentoring, methods of application and demonstration of sustainable construction, strategies relating to the promotion of sustainable construction.
iv. Political barriers: includes barriers which are related to government, regulation, laws, policies, incentives, initiatives, and performance measurement tools to identify and incentivize the application of sustainable construction.
v. Technological barriers: includes barriers which are related to products, materials and technological specifications and methods required to successfully implement sustainable construction.

Table 5-3 provides a summary of all the barriers cited by various authors in the literature and the frequency of citations. The barriers in the table have been coded to provide ease of reference for the total number of citations per barrier (See Appendix C for barrier code descriptions). The most frequently cited barriers across all articles include the lack of knowledge of sustainable construction practices and its benefits (57%)[13], the resistance to change traditional construction processes (57%), a lack of building codes and regulation (57%), a lack of government support and incentives (57%) and limited availability of green product suppliers, materials and technologies (57%).

[13] Typically indicates the percentage of authors who cited the listed barrier.

Table 5-3: Barriers to Sustainable Construction

Barriers		Socio-Cultural Barriers								Economic Barriers					Stakeholder Barriers			Political Barriers			Technological Barriers		
Year	Authors	KN	UN	AW	TE	UC	DI	IC	IN	PR	CSM	PD	RI	DE	PE	RE	IT	CR	MR	GS	TS	PS	DA
2009	Pitt	✓	✓	✓				✓						✓				✓					
2011	Marchman and Clarke									✓													
2011	Häkkinen and Belloni									✓								✓	✓	✓			✓
2012	Ismail *et al.*	✓	✓	✓	✓										✓		✓	✓	✓	✓		✓	
2012	Shari and Soebarto																						
2013	Ahn *et al.*		✓	✓	✓			✓		✓		✓				✓	✓					✓	
2013	Samari *et al.*									✓	✓		✓	✓	✓			✓		✓	✓		✓
2013	Serpell, Kort and Sergio	✓															✓			✓			
2013	Shi *et al.*	✓									✓	✓								✓	✓	✓	✓
2013	Wilson and Rezgui	✓			✓	✓	✓					✓				✓			✓				✓
2014	Abidin and Powmya			✓					✓					✓		✓		✓					
2014	Brennan and Cotgrave									✓	✓	✓	✓	✓		✓	✓					✓	
2014	Djokoto *et al.*			✓	✓						✓		✓	✓	✓	✓	✓		✓	✓			✓
2014	Marker *et al.*				✓			✓		✓				✓		✓		✓	✓			✓	
2014	Opoku and Ahmed		✓					✓			✓												
2015	AlSanad	✓	✓	✓					✓	✓	✓		✓	✓	✓	✓			✓	✓			
2015	Ametepey *et al.*	✓	✓	✓	✓			✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	
2015	Gan *et al.*	✓			✓					✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓

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2015	Khalfan *et al.*	✓		✓						✓				✓						✓		✓	
2015	Mousa			✓			✓			✓			✓		✓	✓		✓	✓	✓	✓	✓	✓
2015	Saleh and Alalouch	✓		✓						✓		✓			✓	✓		✓	✓	✓	✓	✓	
2017	Aigbavboa *et al.*		✓	✓				✓			✓			✓									
2017	Chan *et al.*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
2017	Darko *et al.*	✓	✓	✓	✓				✓	✓		✓	✓	✓	✓	✓			✓	✓	✓	✓	✓
2018	Darko *et al.*	✓		✓	✓			✓	✓				✓		✓	✓		✓		✓		✓	✓
2018	Chan *et al.*	✓		✓			✓	✓	✓	✓		✓	✓	✓	✓	✓		✓		✓		✓	✓
2018	Munyasya *et al.*	✓						✓									✓	✓				✓	
2019	Klufallah *et al.*	✓						✓	✓		✓		✓		✓			✓		✓	✓		
2019	Lim *et al.*			✓	✓			✓		✓					✓	✓		✓				✓	
2019	Pham *et al.*	✓	✓					✓	✓			✓				✓	✓	✓				✓	
Total		**17**	**10**	**16**	**11**	**2**	**4**	**13**	**9**	**16**	**10**	**10**	**12**	**13**	**14**	**17**	**8**	**17**	**12**	**17**	**9**	**17**	**11**

20 articles out of the 30 which focussed on the barriers to sustainable construction adoption ranked the barriers in order of the most important perceived barriers. Figure 5-4 indicates the variation of themes which was ranked 1st to 5th by the various authors. Economic barriers were found to be ranked 1st by most authors. These barriers include mainly cost related restraints such as the initial cost of sustainable construction (Ahn *et al.*, 2013; Gan *et al.*, 2015; Pitt *et al.*, 2009), lack of credit resources to cover initial costs (Samari *et al.*, 2013), additional costs caused by sustainable construction (Aigbavboa *et al.*, 2017; Khalfan *et al.*, 2015; Opoku & Ahmed, 2014; Shi *et al.*, 2013) and the real up front cost in comparison to the return on investment (Marker *et al.*, 2014). Authors ranked socio-cultural barriers as the 2nd most important barrier. The socio-cultural barriers identified highlighted the lack of information about how sustainable construction affects the operational cost of a project (Häkkinen & Belloni, 2011), the perceived increased costs for sustainable construction practices (Marker *et al.*, 2014; Opoku & Ahmed, 2014), lack of awareness, knowledge and understanding of sustainable construction and its benefits (Aigbavboa *et al.*, 2017; Darko, Chan, Ameyaw, *et al.*, 2017) and a lack of client demand (Pitt *et al.*, 2009).

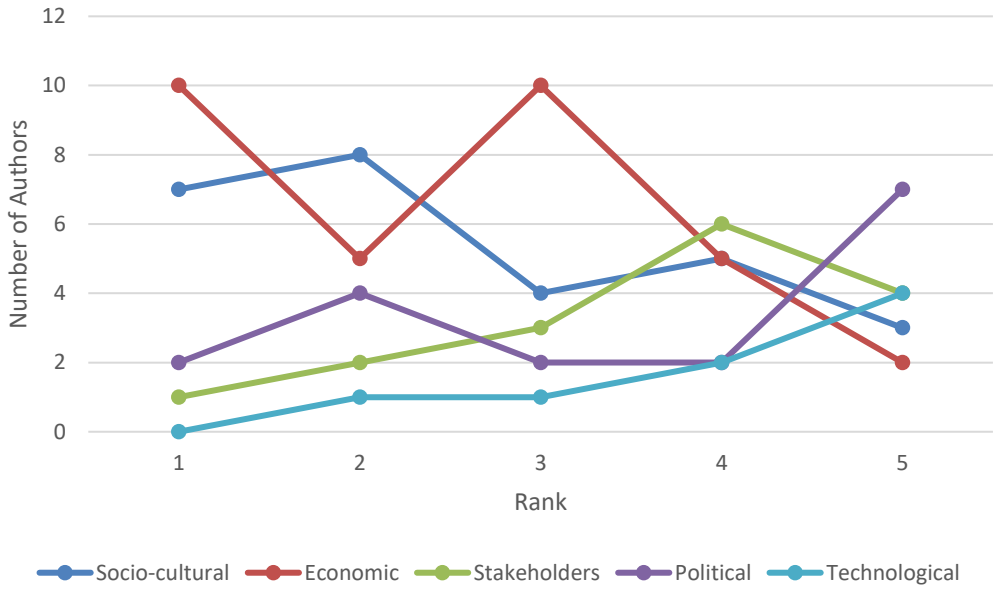

Figure 5-4: Barrier Themes Ranked 1st to 5th

Economic barriers ranked 3rd, emphasises the construction industry maintaining its current practices (Ahn *et al.*, 2013) which relates to the industry prioritising economic needs above social and environmental needs (Serpell *et al.*, 2013). Furthermore, cost related barriers related to the poor performance of the economy (Marker *et al.*, 2014; Opoku & Ahmed, 2014) means that there is an increased risk associated with adopting and investing in sustainable alternatives in the construction industry (Ametepey *et al.*, 2015; Munyasya & Chileshe, 2018). Barriers related to stakeholders and their perspectives ranked 4th, highlights the general lack of professional skills and expertise (AlSanad, 2015; Ametepey *et al.*, 2015) in the construction industry to adequately provide a strong business case for sustainable construction (Pitt *et al.*, 2009).

Furthermore, stakeholders are more likely to pursue traditional procurement methods (Munyasya & Chileshe, 2018) to avoid the additional responsibilities required to implement sustainable construction practises and to manage conflicting and competing targets of their organisations' business aims (Opoku & Ahmed, 2014). The barriers ranked as being the 5th most important factor to consider when adopting and implementing sustainable construction illustrates the important role that government has to play. Häkkinen & Belloni (2011), Darko *et al.* (2018) and Djokoto *et al.* (2014) argue that with a lack of government support and incentives, industry stakeholders are unlikely to adopt sustainable construction practices. Furthermore, a lack of building codes and regulation (Samari *et al.*, 2013), the bureaucracy of governments (Serpell *et al.*, 2013) and a lack of sustainable performance tools (Shi *et al.*, 2013) further hinders the adoption and successful implementation of sustainable construction.

5.2.2. Drivers of Sustainable Construction

Table 5-4, Table 5-5 and Table 5-6 presents the six main types of drivers, their attributes, and the frequency of citations from various authors in the literature (See Appendix D for driver code descriptions). The most frequently cited drivers include: governments' support and encouragement to adopt SC through financial and market-based incentives (73%)[14], increasing the awareness of SC amongst stakeholders (50%), developing mandatory SC building and planning policies and regulations (50%), developing rating systems and standards with sustainable design guidelines and construction standards (41%), improving product and material innovation and providing certification (36%), and increasing the education of SC amongst stakeholders (36%).

[14] Typically indicates the percentage of authors who cited the listed driver.

Table 5-4: Socio-Cultural, Economic and Environmental Drivers of Sustainable Construction

Drivers		Socio-Cultural Drivers							Economic Drivers						Environmental Drivers					
Year	Author	KN	AW	ED	TR	EUB	QU	DI	JO	RWLC	HRI	IPV	IE	AF	EP	EC	WC	RC	WR	RMU
2009	Pitt		✓					✓			✓									
2011	Häkkinen and Belloni		✓								✓									
2012	Shari and Soebarto		✓	✓				✓						✓	✓					
2013	Ahn *et al.*	✓	✓	✓	✓	✓	✓			✓						✓	✓	✓	✓	
2013	Serpell, Kort and Sergio		✓					✓												
2014	Abidin and Powmya	✓	✓					✓	✓	✓					✓					
2014	Brennan and Cotgrave			✓																
2014	Windapo							✓			✓				✓					
2015	AlSanad			✓																
2015	Gan *et al.*	✓		✓	✓						✓			✓						
2015	Khalfan *et al.*		✓			✓	✓								✓					
2015	Mousa		✓																	
2016	Jiang and Wong							✓		✓									✓	✓
2017	Chan *et al.*		✓	✓																
2017	Darko *et al.*					✓	✓		✓	✓		✓	✓		✓	✓	✓	✓	✓	✓
2017	Hwang *et al.*													✓						
2018	Darko and Chan					✓	✓		✓	✓	✓	✓			✓	✓	✓	✓	✓	✓
2018	Darko *et al.*		✓	✓	✓									✓						
2018	Munyasya *et al.*	✓																		
2018	Yin *et al.*			✓			✓												✓	✓
2019	Oke *et al.*		✓					✓					✓					✓		
2019	Zhang *et al.*								✓		✓									
Total		**4**	**11**	**8**	**3**	**4**	**5**	**7**	**4**	**5**	**6**	**2**	**2**	**4**	**6**	**3**	**3**	**4**	**5**	**4**

Table 5-5: Stakeholder and Political Drivers of Sustainable Construction

Drivers		Stakeholder Drivers												Political Drivers									
Year	Author	CI	CA	CSR	ID	EMS	DSC	SSS	BPS	CO	BI	CB	CCP	IS	LUP	RSS	MBP	ESP	DRN	SIM	IF	TR	SURD
2009	Pitt	✓	✓											✓	✓		✓		✓			✓	
2011	Häkkinen and Belloni													✓	✓		✓					✓	
2012	Shari and Soebarto				✓	✓	✓	✓			✓							✓					
2013	Ahn *et al.*				✓									✓	✓	✓							
2013	Samari *et al.*																						
2013	Serpell, Kort and Sergio																✓					✓	✓
2014	Abidin and Powmya	✓		✓	✓									✓									
2014	Brennan and Cotgrave				✓									✓	✓	✓			✓	✓			
2014	Windapo			✓												✓							
2015	AlSanad													✓	✓	✓							
2015	Gan *et al.*									✓	✓	✓		✓		✓	✓		✓	✓	✓		
2015	Khalfan *et al.*											✓	✓	✓			✓						
2015	Mousa													✓	✓	✓	✓					✓	✓
2016	Jiang and Wong			✓		✓	✓			✓	✓		✓			✓	✓	✓					
2017	Chan *et al.*										✓			✓		✓	✓	✓			✓		✓
2017	Darko *et al.*	✓		✓				✓	✓														
2017	Hwang *et al.*										✓			✓								✓	✓
2018	Darko and Chan	✓						✓	✓														
2018	Darko *et al.*					✓								✓		✓	✓	✓			✓		
2018	Munyasya *et al.*				✓									✓									
2018	Yin *et al.*	✓	✓							✓			✓	✓									
2019	Oke *et al.*	✓			✓				✓	✓		✓	✓	✓	✓		✓	✓	✓	✓			
2019	Zhang *et al.*	✓	✓				✓		✓		✓			✓			✓						
Total		**7**	**3**	**4**	**6**	**3**	**3**	**3**	**4**	**4**	**6**	**3**	**4**	**16**	**7**	**9**	**11**	**5**	**4**	**3**	**3**	**5**	**4**

Table 5-6: Technological Drivers of Sustainable Construction

Drivers		Technological Drivers			
Year	**Author**	**PCI**	**DSM**	**SRD**	**AI**
2009	Pitt				
2011	Häkkinen and Belloni				
2012	Shari and Soebarto	✓			
2013	Ahn *et al.*	✓	✓		
2013	Samari *et al.*				
2013	Serpell, Kort and Sergio		✓		
2014	Abidin and Powmya				
2014	Brennan and Cotgrave				
2014	Windapo				
2015	AlSanad				
2015	Gan *et al.*	✓			✓
2015	Khalfan *et al.*	✓			
2015	Mousa				
2016	Jiang and Wong	✓	✓	✓	✓
2017	Chan *et al.*			✓	✓
2017	Darko *et al.*				
2017	Hwang *et al.*				
2018	Darko and Chan				
2018	Darko *et al.*			✓	✓
2018	Munyasya *et al.*	✓			
2018	Yin *et al.*			✓	
2019	Oke *et al.*	✓	✓		
2019	Zhang *et al.*	✓			
Total		**8**	**4**	**4**	**4**

12 articles out of the 22 which focussed on drivers of SC, ranked the drivers in order of most critical to increase the adoption and implementation of SC. Figure 5-5 indicates the variation of themes which was ranked 1st to 5th by the various authors. Drivers related to stakeholders and their perceptions was ranked 1st by most authors. These drivers highlight the importance of construction industry stakeholders setting a standard for future design and construction (Darko, Zhang, *et al.*, 2017) through innovation (Munyasya & Chileshe, 2018) and adopting sustainable alternatives to traditional construction processes. Furthermore, the success of SC is dependent on the participation and collaboration of all industry stakeholders (Yin *et al.*, 2018) which can be enhanced through linking research about SC to those who need to implement it (i.e. construction industry stakeholders) (Oke, Aghimien, Aigbavboa, *et al.*, 2019).

Political drivers were ranked 2nd to 5th by the majority of authors which emphasises the importance of governments to drive the agenda of SC adoption and implementation through: mandatory regulations and policies (Chan, Darko & Ameyaw, 2017; Oke *et al.*, 2019; Serpell *et al.*, 2013), green design guidelines and construction standards (AlSanad, 2015; Munyasya & Chileshe, 2018; Yin *et al.*, 2018), financial and market-based incentives for SC adopters (Chan, Darko & Ameyaw, 2017; Hwang, Shan & Supa'at, 2017), tax relief for developers and contractors for the use of sustainable building products, systems, and technologies, and providing subsidies for research and development of sustainable building products, systems, and technologies (Hwang *et al.*, 2017).

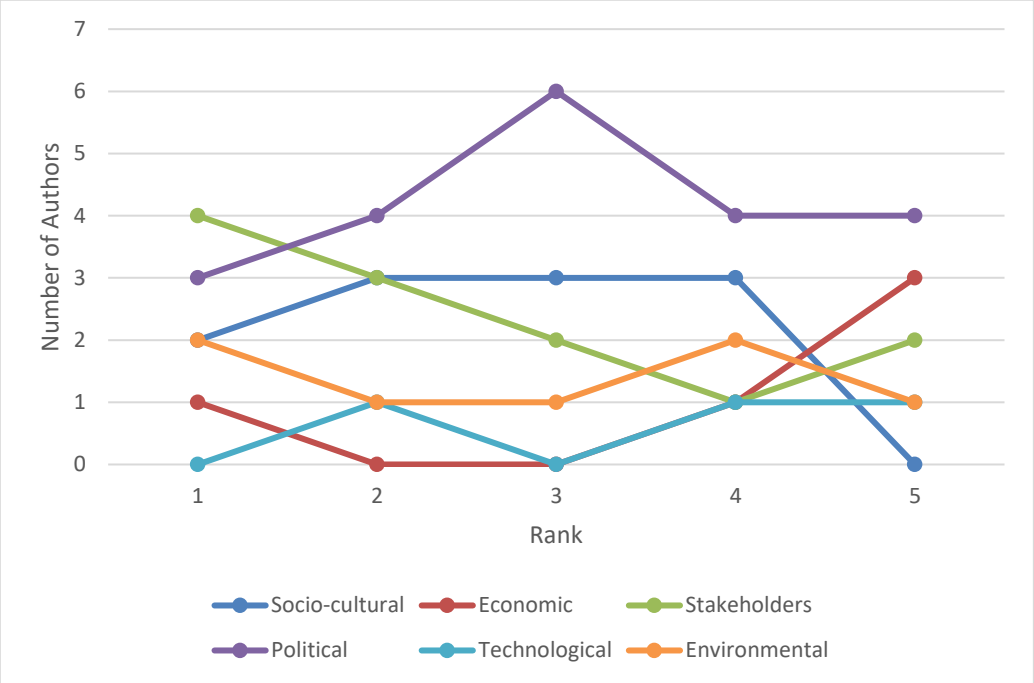

Figure 5-5: Driver Themes Ranked 1st to 5th

5.3. TDF and COM-B Model Mapping

A total of 56 barriers and drivers were identified from the integrative review and coded against the COM-B components and the TDF domains. The frequencies of the barriers and drivers were as follows: Capability: knowledge (3); cognitive and interpersonal skills (4); behavioural regulation (2); Opportunity: environmental context and resources (22); Motivation: reinforcement (6); social/ professional role and identity (5); beliefs about consequences (14). Appendix E provides a summary of the barriers and drivers mapped to COM-B and TDF. The COM-B components and TDF domains identified from the literature indicate the domains of the specific barriers and drivers at a theoretical level which need to be targeted in the behaviour change intervention.

5.4. Conclusion: Chapter 5

Based on the integrative review of 37 articles, this chapter aimed to identify the key barriers and drivers of sustainable construction in the literature and to establish which COM-B components and TDF domains were most prevalent. The descriptive analysis shows that there has been an increasing interest in sustainable construction amongst researchers with studies focused on both developing and developed countries. A quantitative research approach was the most common strategy of inquiry using survey questionnaires with limited studies adopting qualitative and mixed method approaches.

This reveals that there is an opportunity to enhance the research in this field by adopting qualitative methods as well as mixed methods to improve the validation and triangulation of data. The content analysis provides insight into the key themes of the barriers and drivers of sustainable construction. Six key themes were identified in the literature which groups the potential barriers and drivers to the implementation of sustainable construction: i) socio-cultural barriers and drivers comprising of how to improve the lack of knowledge, understanding and awareness of SC; ii) economic barriers and drivers comprising of measures to reduce high initial costs, increased capital costs and the increased time as a result of the adoption of SC practices and technologies; iii) stakeholder barriers and drivers comprising of how to improve the knowledge and capacity of stakeholders to provide their expertise on how to adopt and implement SC; iv) political barriers and drivers comprising of a lack of assessment tools to measure sustainable construction, lack of policy and legislation which governs sustainable construction, and a lack of support and incentives from government and how government can support and encourage SC through tax reliefs, financial incentives and funding; v) technological barriers and drivers comprising of a lack of adequate green technological specifications and limited availability of green suppliers and information and how to improve the access to sustainable products and the research and development of sustainable products and vi) environmental drivers which comprises of the various environmental benefits of adopting SC which aims to protect the environment and reduce the environmental impact of the construction industry.

Chapter 6
Phase Two: Understanding Sustainable Construction Behaviour (Quantitative Strand)

This chapter sets out the results of Phase Two of this research, which provides a quantitative overview of the perception and understanding of SC by construction industry stakeholders in South Africa. Initially, this chapter will discuss the reliability of the five-point Likert scale used in the questionnaire and the descriptive statistics which provides context to the characteristics of the sample population. The chapter then goes on to discuss the findings of the analysis of the Theoretical Domains Framework (TDF) variables within the domains and COM-B model under the headings *Capability*, *Opportunity* and *Motivation*. This will be followed by a critical discussion and synthesis of the results of the questionnaire. In addition, the TDF domains will be analysed as subscales to provide insight into which domains needs to be targeted to develop an intervention for behaviour change. Overall, this chapter addresses research objective four: (RO-4: *Understand the perception of barriers and drivers of SC by construction industry stakeholders in South Africa*).

6.1. Data Reliability

To measure the internal consistency amongst the various factors to assess the reliability of the data gathered from the five-point scale used in the survey questionnaire, Cronbach's alpha coefficient was used. The value of Cronbach's alpha for all 75 items in the questionnaire was 0.941, suggesting that the items have relatively high internal consistency and values between 0.70 and 0.95 is reported as acceptable (Tavakol & Dennick, 2011). Items should be reassessed if the value is low which suggests too few questions or poor inter-correlation and on the other hand, if the value is too high, it may suggest redundant items which need to be discarded (Tavakol & Dennick, 2011).

6.2. Descriptive Analysis

This section describes the results from the survey questionnaire based on the demographics and background information of the participants. The findings include the professional experience of the participants and their participation in green building projects based on the size of their organisation.

6.2.1. Demographics and Background Information

Out of the 290 survey questionnaires that were sent out, 108 responses were received which represents a 37% response rate. It has been argued that studies within the construction industry generally have a lower response rate between 20% and 30% (Abidin & Powmya, 2014; Gan *et al.*, 2015).

However, the sample size can be considered representative of the population as the central limit theorem holds true with a sample size greater than 30, which means statistical analysis can be conducted. The descriptive statistics of the sample population is presented in Table 6-1 and Table 6-2. The highest representation of professionals in the sample were structural engineers (37, 34.3%), civil engineers (36, 33.3%) and mechanical engineers (14, 13%). The total years of experience varied amongst the professionals in the construction industry. Participants with less than 5 years of experience represented the majority of the sample size (47, 43.5%) followed by those with between 5 (inclusive) and 9 years, representing the second largest portion of participants (35.2%). The majority of the sample indicated that they have never been involved in a sustainable or green building project (69, 63.9%) as opposed to 39 participants (36.1%) who said they have.

Table 6-1: Profile of Respondents

Professions	Frequency	Percentage (%)
Contractor	1	0.9
Quantity Surveyor	7	6.5
Architect	7	6.5
Structural Engineer	37	34.3
Civil Engineer	36	33.3
Mechanical Engineer	14	13.0
Electrical Engineer	2	1.9
Environmental Engineer	3	2.8
Façade Engineer	1	0.9
Total	**108**	**100.0**

Table 6-2: Experience of Respondents

	Years of Experience (Construction Industry)				Sustainable/Green Building Experience	
Professions	0 - 4	5 - 9	10- 19	>=20	Yes	No
Contractor	0	1	0	0	1	0
Quantity Surveyor	4	3	0	0	0	7
Architect	0	4	3	0	3	4
Structural Engineer	17	12	6	2	12	25
Civil Engineer	22	10	3	1	8	28
Mechanical Engineer	4	4	4	2	12	2
Electrical Engineer	0	2	0	0	1	1
Environmental Engineer	0	2	1	0	1	2
Façade Engineer	0	0	1	0	1	0
Subtotal	**47**	**38**	**18**	**5**	**39**	**69**
Percentage (%)	**43.5**	**35.2**	**16.7**	**4.6**	**36.1**	**63.9**

As shown in Table 6-3, 39 participants (36.1%) are employed in organisations with over 250 employees, which according to section 20(2) of the National Small Enterprise Act 1996 (2019) (Department of Small Business Development, 2019), constitutes a large organisation within the South African context. 33.3% of participants (36) are employed at medium-sized organisations, 19.5% (21) are employed at small organisations and 11.1% (12) at micro organisations. Furthermore, the majority of the sample (77, 71.3%) indicated that their organisation has undertaken sustainable or green building projects, 19.4% (21) said they were unsure and 9.3% (10) indicated that their organisation has not undertaken sustainable or green building projects.

Table 6-3: Profile of Organisations

	Undertaken Sustainable or Green Building Projects				
Organisation Size	**Yes**	**No**	**Unsure**	**Total**	**Percentage (%)**
Up to 10	7	2	3	**12**	**11.1**
11 to 50	13	4	4	**21**	**19.5**
51-250	26	2	8	**36**	**33.3**
Above 250	31	2	6	**39**	**36.1**
Total	**77**	**10**	**21**	**108**	**100**
Percentage (%)	**71.3**	**9.3**	**19.4**	**100**	

6.3. TDF and COM-B Variable Analysis

The questionnaire (refer to Appendix F) provided five response categories ranging from strongly disagree to strongly agree. During the frequency analysis, the responses “agree” and “strongly agree” were combined into one category *agree*, which represents a participant who agrees with a statement, and the responses “disagree” and “strongly disagree” were combined into one category *disagree* which represents a participant who disagrees with a statement. This is referred to as *Categorisation* in the tables provided. Questionnaire statements have been simplified for ease of reference (see Appendix F for full statement description). This section also provides insight into the mode (most frequent response) for each statement. The following section describes the data within the TDF and COM-B model domains and categories.

6.3.1. Capability

Capability represents an individual’s ability to engage in a target behaviour and having the necessary knowledge and skills to do so (Michie *et al.*, 2011). Construction industry stakeholders’ psychological capabilities influence their adoption and implementation of SC. The results from the *Knowledge*, *Skills* and *Behavioural Regulation* domains linked to psychological capability are presented below.

Knowledge

Construction industry stakeholders' assessment of their capabilities regarding their knowledge of SC was generally positive as the most frequent responses to all five questions was *agree* (Table 6-4). Most participants agree that they have an awareness of SC (78.7%), are familiar with the content and objectives of SC (71.3%) and have knowledge of SC (51.9%). Participants agree that there is an interest in adopting SC in the construction industry (62.9%) and 50% agree that there is a demand for SC implementation. However, 15.7% of participants disagree that there is an interest and demand in the construction industry to adopt SC and 13% do not know what the content and objectives of SC are.

Table 6-4: Questionnaire Statement Responses (Knowledge Domain)

Knowledge Domain		Questionnaire Response (%)					
Questionnaire Statement	**Mode**	**1**	**2**	**3**	**4**	**5**	**Categorisation**
CF1 - Awareness of SC	4 (Agree)	1.9	4.6	14.8	65.7	13.0	Agree
CF2 - Knowledge of SC	4 (Agree)	1.9	11.1	35.2	42.6	9.3	Agree
CF3 - Familiarity with SC	4 (Agree)	2.8	3.7	22.2	61.1	10.2	Agree
CF4 - Interest in SC	4 (Agree)	3.7	12.0	21.3	50.9	12.0	Agree
CF5 - Demand for SC	4 (Agree)	0.9	14.8	34.3	36.1	13.9	Agree

Skills

As shown in Table 6-5, responses in the Skills domain indicated that the majority of stakeholders understand SC (88.9%) and agree that the skills required to adopt SC are within the scope of construction industry professionals (75.9%). Participants agree that education on SC is available (61.1%) through external service providers (56.5%) and internally through their organisations (32%). However, 15.8% believe that there is no external training available on SC and the majority of participants do not have access to training within their organisations (38.9%).

Table 6-5: Questionnaire Statement Responses (Skills Domain)

Skills Domain		Questionnaire Response (%)					
Questionnaire Statement	**Mode**	**1**	**2**	**3**	**4**	**5**	**Categorisation**
CF6 - Understanding of SC	4 (Agree)	1.9	1.9	7.4	59.3	29.6	Agree
CF7 - SC skills are within the scope of CI professionals	4 (Agree)	2.8	2.8	18.5	56.5	19.4	Agree
CF8 - SC education is available	4 (Agree)	1.9	7.4	29.6	45.4	15.7	Agree
CF9 - External training on SC is available	4 (Agree)	1.9	13.9	27.8	43.5	13.0	Agree
CF10 - Internal training on SC is available	4 (Agree)	8.3	30.6	28.7	31.5	0.9	Disagree

Behavioural Regulation

Participants perceived that there is a requirement for behaviour change in the construction industry (92.6%) as current construction practices are not sustainable and 71.3% agree that there is a resistance to adopt sustainable alternatives to construction industry processes and methods (Table 6-6).

Table 6-6: Questionnaire Statement Responses (Behavioural Regulation Domain)

Behavioural Regulation Domain		Questionnaire Response (%)					
Questionnaire Statement	**Mode**	**1**	**2**	**3**	**4**	**5**	**Categorisation**
CF51 - Resistance to change behaviour	4 (Agree)	0.9	4.6	23.1	54.6	16.7	Agree
CF52 - Commitment to change behaviour	4 (Agree)	0	0.9	6.5	58.3	34.3	Agree

6.3.2. Opportunity

Opportunity represents the social and physical environment which shapes the opportunity to engage in a target behaviour (Michie *et al.*, 2011). Social opportunity refers to the social factors that influence the way we think about things (i.e. cultural norms and social cues). Physical opportunity is represented by the environment which includes time, resources, and location. The results from the *Social Influences* and *Environmental Context and Resources domains* linked to social and physical opportunity are presented below.

Social Influences

Social structures within organisations, as well as the construction industry, influence stakeholders' behaviour towards adopting and implementing SC. 75% of participants agree that their peers in the construction industry support and encourage SC and more than half of participants (52.8%) agree that their peers in the construction industry demonstrate an interest in SC (Table 6-7). Participants agreed that their superiors would encourage them to further develop their skills within the scope of SC (44.4%) whereas 17.6% of participants felt that their construction industry peers are not interested in SC. 14.8% of participants indicated that their superiors do not encourage and support SC skills development.

Table 6-7: Questionnaire Statement Responses (Social Influences Domain)

Social Influences Domain		Questionnaire Response (%)					
Questionnaire Statement	**Mode**	**1**	**2**	**3**	**4**	**5**	**Categorisation**
CF48 - Industry peers support and encourage SC	4 (Agree)	0.9	5.6	18.5	59.3	15.7	Agree
CF49 - Industry superiors encourage and support SC skills development	3 (Neither Agree or Disagree)	0.9	13.9	40.7	36.1	8.3	Agree
CF50 - Industry peers demonstrate an interest in SC	4 (Agree)	2.8	14.8	29.6	45.4	7.4	Agree

Environmental Context and Resources

Questions CF53 to CF57 measured the participants' perception about the interest in SC in the construction industry and the availability of sustainable technologies and information (Table 6-8). The majority of participants agree that there is a lack of interest in SC (48.2%) and a lack of an integrated work environment amongst construction industry stakeholders (60.2%).

Participants indicated that there is a lack of sustainable technology specifications (61.1%), a lack of databases and information about sustainable technologies (58.4%) and a limited availability of sustainable technology suppliers (50%). On the other hand, 20.3% of participants stated that there is an interest in SC and 15.8% disagreed with the statement that there are limited sustainable suppliers available. Five questions (CF58 to CF62) as shown in Table 6-8 probed how much participants agreed with statements about what SC promoted and responses were highly positive. In order of the highest response rates, participants agree that SC promotes resource conservation (93.5%), water conservation (91.7%), energy conservation (90.7%), environmental protection (88.9%) and waste reduction (83.3%). Question CF63 to CF75 of the questionnaire probed participants to rate the internal and external drivers of SC. For drivers linked to organisations and professionals (CF63 to CF66), participants indicated that organisations are responsible for facilitating a culture of best practice sharing in relation to SC (93.5%) and should promote a culture and awareness about SC (91.6%). The results further indicated that for the successful implementation of SC, a mutual understanding and commitment amongst construction industry professionals is required (88.9%) and executive management should support and encourage SC adoption (87.1%). Participants agree that an institutional framework which guides the adoption of SC is necessary (89.8%), performance-based measurements (85.2%) and mandatory policies which govern the adoption and implementation of SC will promote SC (85.2%). In addition, developing and strengthening regulatory mechanisms (85.2%) and better enforcement of SC policies after it has been developed (83.4%) will further facilitate the adoption and implementation of SC.

Table 6-8: Questionnaire Statement Responses (Environmental Context and Resources Domain)

Environmental Context and Resources Domain		Questionnaire Response (%)					
Questionnaire Statement	**Mode**	**1**	**2**	**3**	**4**	**5**	**Categorisation**
CF53 - Lack of Interest in SC	4 (Agree)	0.9	19.4	31.5	45.4	2.8	Agree
CF54 - Lack of communication and integrated work environment	4 (Agree)	0.0	12.0	27.8	50.0	10.2	Agree
CF55 - Lack of sustainable technology specifications	4 (Agree)	0.9	11.1	26.9	53.7	7.4	Agree
CF56 - Limited availability of sustainable product suppliers	4 (Agree)	1.9	13.9	34.3	41.7	8.3	Agree
CF57 - Lack of databases and information for SC technologies	4 (Agree)	0.0	10.2	31.5	51.9	6.5	Agree
CF58 - SC promotes environmental protection	4 (Agree)	0.0	0.9	10.2	45.4	43.5	Agree
CF59 - SC promotes energy conservation	4 (Agree)	0.0	0.9	8.3	46.3	44.4	Agree

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CF60 - SC promotes water conservation	5 (Strongly Agree)	0.0	0.9	7.4	45.4	46.3	Agree
CF61 - SC promotes resource conservation	4 (Agree)	0.0	0.9	5.6	48.1	45.4	Agree
CF62 - SC promotes waste reduction	4 (Agree)	0.0	3.7	13.0	44.4	38.9	Agree
CF63 - SC requires support from executive management	4 (Agree)	0.0	0.0	13.0	56.5	30.6	Agree
CF64 - Organisations should promote a culture and awareness about SC	4 (Agree)	0.0	0.0	8.3	58.3	33.3	Agree
CF65 - Organisations should facilitate best practice sharing of SC	4 (Agree)	0.0	0.9	5.6	58.3	35.2	Agree
CF66 - Mutual understanding and commitment amongst SC professionals is required	4 (Agree)	0.0	0.9	10.2	56.5	32.4	Agree
CF67 - Performance-based measurements will promote SC	4 (Agree)	0.0	1.9	13.0	49.1	36.1	Agree
CF68 - Mandatory SC building policies and regulations will promote SC	4 (Agree)	0.0	2.8	12.0	50.9	34.3	Agree
CF69 - Better enforcement of SC building policies after development will promote SC	4 (Agree)	0.0	2.8	13.9	52.8	30.6	Agree
CF70 - Developing and strengthening regulatory mechanisms	4 (Agree)	0.0	3.7	11.1	52.8	32.4	Agree
CF71 - Institutional framework to guide SC is required	4 (Agree)	0.0	0.9	9.3	54.6	35.2	Agree
CF72 - Product and material innovation and/or certification is required	4 (Agree)	0.0	0.9	7.4	60.2	31.5	Agree
CF73 - Materials manufacturers should be proactive in development of SC technologies	4 (Agree)	0.0	1.9	4.6	53.7	39.8	Agree
CF74 - Collaborative and strengthened R&D within the construction industry	4 (Agree)	0.0	1.9	6.5	57.4	34.3	Agree
CF75 - Availability of better information on cost and benefits of SC technologies from a reliable database	4 (Agree)	0.0	1.9	6.5	49.1	42.6	Agree

6.3.3. Motivation

Motivation to engage in a target behaviour can either be reflective or automatic. Reflective motivation processes involve plans (self-conscious intentions) and evaluations (beliefs about what is good and bad) (Michie *et al.*, 2014). On the other hand, automatic motivation processes involve the wants and needs, desires, impulses and reflex responses of individuals. The results from the *Social/Professional Role and Identity*, *Beliefs about Capabilities, Optimism, Beliefs about Consequences, Intentions and Goals,* and *Reinforcement* domains linked to reflective and automatic motivation are presented below.

Social/Professional Role and Identity

All the questions related to participants' social and professional role and identity had highly positive responses with small variance. Participants agree that construction industry professionals play a role in the implementation of SC (90.7%), that SC forms part of their work (87.9%) and that they have a responsibility towards adopting SC (83.3%) (Table 6-9). The results also indicate that the highest agreement amongst participants related to an organisation's identity, is that SC shows an organisation's commitment towards its social and environmental responsibility (89.8%). Furthermore, adopting and implementing SC is beneficial to an organisation through improving their corporate image (84.2%) and providing the organisation with a competitive advantage in the construction industry (82.4%). Participants agree that SC allows collaboration amongst construction industry professionals (83.4%) and provides an integrated and whole building design approach (80.6%). Participants further indicated that SC sets a standard for the future of development within the built environment (87%).

Table 6-9: Questionnaire Statement Responses (Social/Professional Role and Identity Domain)

Social/Professional Role and Identity		Questionnaire Response (%)					
Questionnaire Statement	**Mode**	**1**	**2**	**3**	**4**	**5**	**Categorisation**
CF11 -CI professionals have a responsibility towards SC	4 (Agree)	0.0	5.6	11.1	50.9	32.4	Agree
CF12 - SC forms part of CI professionals work	4 (Agree)	0.9	1.9	9.3	44.4	43.5	Agree
CF13 - CI professionals play a role in the implementation of SC	4 (Agree)	0.9	2.8	5.6	47.2	43.5	Agree
CF14 - SC provides a good corporate image	5 (Strongly Agree)	0.9	0.9	13.9	37.0	47.2	Agree
CF15 - SC provides a competitive advantage	4 (Agree)	0.9	7.4	9.3	43.5	38.9	Agree
CF16 - SC shows an organisation's commitment to social responsibility	4 (Agree)	0.9	3.7	5.6	46.3	43.5	Agree
CF17 - SC provides collaboration amongst CI professionals	4 (Agree)	0.0	2.8	13.9	49.1	34.3	Agree

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CF18 - SC provides an integrated and whole building design approach	4 (Agree)	0.0	0.9	18.5	50.0	30.6	Agree
CF19 - SC sets a standard for future development in the built environment	4 (Agree)	0.9	1.9	10.2	50.0	37.0	Agree

Beliefs about Capabilities

Construction industry professionals are confident that they would adopt SC if they had the skills (87.9%) even if there are time constraints on a project (71.3%) and no incentive to do so (79.6%) (Table 6-10).

Table 6-10: Questionnaire Statement Responses (Beliefs about Capabilities Domain)

Beliefs about Capabilities		Questionnaire Response (%)					
Questionnaire Statement	**Mode**	**1**	**2**	**3**	**4**	**5**	**Categorisation**
CF20 - CI professionals would adopt SC if they had the skills	4 (Agree)	0.0	2.8	9.3	54.6	33.3	Agree
CF21 - CI professionals would adopt SC even if there are time constraints on building projects	4 (Agree)	0.0	9.3	19.4	56.5	14.8	Agree
CF22 - CI professionals would adopt SC even if there is no incentive to do so on building projects	4 (Agree)	0.0	3.7	16.7	61.1	18.5	Agree

Optimism

Participants are highly optimistic about SC as it represents a positive change for the construction industry (91.6%) and the adoption and implementation thereof will have a positive impact on the economy, society and environment (88.9%) (Table 6-11).

Table 6-11: Questionnaire Statement Responses (Optimism Domain)

Optimism		Questionnaire Response (%)					
Questionnaire Statement	**Mode**	**1**	**2**	**3**	**4**	**5**	**Categorisation**
CF23 - Adopting and implementing SC will mean positive outcomes for the economy, society and the environment	4 (Agree)	0.0	0.9	10.2	50.0	38.9	Agree
CF24 - SC represents a positive change for the construction industry in South Africa	5 (Strongly Agree)	0.0	1.9	6.5	44.4	47.2	Agree

Beliefs about Consequences

When prompted about their beliefs about the consequences of adopting and implementing SC, participants agree that SC benefits the end-user through sustainable buildings, which improve indoor air quality and comfort (79.6%) and end-user's productivity (60.2%) (Table 6-12). Participants were probed about the economic benefits and barriers of SC and the results in order of the highest frequency response rates indicated that: SC will ensure green market growth and provide job opportunities (71.3%), SC improves the performance of the economy (60.2%), the implementation of SC will increase the capital cost of construction (59.3%), sustainable products and materials will increase the capital cost of construction (57.4%) and SC adoption would enhance the value of properties (51%). The results further indicated that participants agree that there is a risk of investment when adopting sustainable materials and construction methods (38.9%) even though 26% of participants indicate that there is no risk. 44.4% of participants agree that adopting SC will reduce the whole-life cycle cost of a building whilst on the other hand 21.3% indicate that SC will not reduce the cost. Majority of participants (50%) neither agree nor disagree that adopting SC will only derive profits after long periods of time (CF35), whereas 35.2% agree that there will be delayed profits on projects which adopt SC and 14.8% indicate that there will be no delay. Additionally, 45.3% of participants indicated that SC would provide a high return on investment whilst the majority (47.2%) neither agree nor disagree. Most participants indicate that there is a need to adopt SC (80.5%) and that they are not sceptical about the necessity to adopt SC (70.4%).

Table 6-12: Questionnaire Statement Responses (Beliefs about Consequences Domain)

Beliefs about Consequences		Questionnaire Response (%)					
Questionnaire Statement	**Mode**	**1**	**2**	**3**	**4**	**5**	**Categorisation**
CF25 - Sustainable buildings improve end-users productivity	4 (Agree)	0.9	4.6	34.3	41.7	18.5	Agree
CF26 - Sustainable buildings improve indoor environmental quality, enhanced occupants' health, comfort and well-being	4 (Agree)	0.0	0.9	19.4	50.9	28.7	Agree
CF27 - SC ensures green market growth and provides job opportunities	4 (Agree)	0.0	1.9	26.9	45.4	25.9	Agree
CF28 - Necessity to adopt and implement SC	4 (Agree)	0.0	4.6	14.8	48.1	32.4	Agree
CF29 - SC is time consuming which could cause project delays	3 (Neither Agree nor Disagree)	4.6	15.7	38.9	32.4	8.3	Agree
CF30 - SC implementation will increase the capital cost of construction of building projects	4 (Agree)	0.9	9.3	30.6	46.3	13.0	Agree

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CF31 - Sustainable products and materials will increase the capital cost of building projects	4 (Agree)	0.9	13.0	28.7	46.3	11.1	Agree
CF32 - Risk of investment with implementing new sustainable materials and construction methods	4 (Agree)	1.9	24.1	35.2	37.0	1.9	Agree
CF33 - Scepticism about the necessity to implement SC principles on building projects	2 (Disagree)	18.5	51.9	20.4	8.3	0.9	Disagree
CF34 - SC reduces the whole life-cycle cost of a building	3 (Neither Agree nor Disagree)	6.5	14.8	34.3	32.4	12.0	Agree
CF35 - SC has long pay-back periods	3 (Neither Agree nor Disagree)	2.8	12.0	50.0	27.8	7.4	Neutral
CF36 - SC provides high return on investment of buildings	3 (Neither Agree nor Disagree)	0.0	7.4	47.2	37.0	8.3	Neutral
CF37 - SC enhances property value	4 (Agree)	0.0	8.3	40.7	41.7	9.3	Agree
CF38 - SC improves performance of the economy	4 (Agree)	0.0	4.6	35.2	41.7	18.5	Agree

Intentions and Goals

The highly positive responses to questions about participants' intentions and goals indicated that they do intend to consider adopting SC (93.6%) and develop their knowledge and skills about SC (85.2%) (Table 6-13). 78.7% of participants agree that increasing their awareness and knowledge about SC is an important goal in their career and 69.5% intend to promote SC education internally and promote internal training of SC within their organisation (65.7%).

Table 6-13: Questionnaire Statement Responses (Intentions and Goals Domain)

Intentions and Goals		Questionnaire Response (%)					
Questionnaire Statement	**Mode**	**1**	**2**	**3**	**4**	**5**	**Categorisation**
CF43 - Intention to develop SC knowledge and skills	4 (Agree)	0.0	0.0	14.8	61.1	24.1	Agree
CF44 - Intention to consider adopting SC	4 (Agree)	0.0	0.0	6.5	66.7	26.9	Agree
CF45 - Intention to promote the education of SC internally	4 (Agree)	0.0	1.9	28.7	51.9	17.6	Agree
CF46 - Intention to promote internal training of SC	4 (Agree)	0.0	6.5	27.8	50.9	14.8	Agree
CF47 - Increasing SC awareness and knowledge is an important career goal	4 (Agree)	0.0	0.9	20.4	50.9	27.8	Agree

Reinforcement

The results from this section of the questionnaire indicate that government support and encouragement through financial and market-based incentives (95.4%), tax relief on projects which adopt SC (90.7%), subsidies for research and development linked to SC (89.8%), and access to funding through financial institutions (87%), will increase SC adoption and implementation (Table 6-14).

Table 6-14: Questionnaire Statement Responses (Reinforcement Domain)

Reinforcement		Questionnaire Response (%)					
Questionnaire Statement	**Mode**	**1**	**2**	**3**	**4**	**5**	**Categorisation**
CF39 - Access to funding	4 (Agree)	0.0	2.8	10.2	58.3	28.7	Agree
CF40 - Financial and Market-based Incentives	4 (Agree)	0.0	0.0	4.6	57.4	38.0	Agree
CF41 - Tax relief	5 (Strongly Agree)	0.9	1.9	6.5	44.4	46.3	Agree
CF42 - Subsidies for R&D	5 (Strongly Agree)	0.9	1.9	7.4	42.6	47.2	Agree

6.4. Discussion: Quantitative Results

Although there is a high level of awareness and familiarity with SC, there is a variation in the results when it comes to knowledge about SC and the demand for SC in the construction industry. The high level of awareness and familiarity amongst construction industry stakeholders is contrary to previous studies conducted in developing countries by authors such as Ismail *et al.* (2012), Shari & Soebarto (2012), Djokoto, Dadzie & Ohemeng-Ababio (2014). Their studies suggest that there is a lack of awareness amongst construction industry stakeholders and the public. Firstly, the difference in results could be due to the nature of the research designs adopted such as Shari & Soebarto (2012) who conducted a qualitative study using semi-structured interviews to identify the barriers to the adoption of SC whilst the current research study used a survey questionnaire. Secondly, previous research studies focused on specific stakeholder groups such as developers only, architects only or contractors only. An example of this is the research study conducted by Ismail *et al.* (2012) which only included developers. This is a different target population to the current research study which includes architects, engineers, contractors and quantity surveyors. Lastly, the research instrument (i.e. the questionnaire) is structured differently as shown in the study conducted by Djokoto, Dadzie & Ohemeng-Ababio (2014), where the authors prompted participants to rate the extent to which each of the identified barriers affects SC using a five-point Likert scale. In the current study, participants were prompted to rate the extent to which they agreed or disagreed with various belief statements about SC.

In a study conducted by Lim, Liu & Oo (2019), the authors state that although quantity surveyors in Australia had a reasonable level of awareness of SC, there was still a lack of implementation which could be attributed to individual's attitudes towards SC, cultural and institutional challenges.

This provides insight into the variation of results regarding the knowledge and demand for SC, which could be explained by a lack of “actionable” knowledge that presents itself in the form of limited information about best practices, access to existing relevant knowledge and the perception of information overload (Wilson & Rezgui, 2013). In other words, although participants have the knowledge of what the contents and objectives of SC are, there is no knowledge sharing amongst professionals or information guides to inform SC implementation. Furthermore, the variation in the results for the demand for SC suggests that there might be lack of demand from clients for sustainable projects (Serpell, Kort & Vera, 2013), a lack of evidence of the benefits and opportunities of SC and the perception that SC will increase project cost (Shari & Soebarto, 2012). Participants indicated that SC is within the scope of construction industry professionals and that they have access to education and training related to SC. Participants felt that it is critical for construction industry stakeholders to change their current behaviour and adopt sustainable alternatives to design and construction methods and processes.

Participants described the social opportunity to adopt and implement SC as positive in relation to the support and encouragement from peers in the construction industry. However, there could be limitations to career development within the scope of sustainability as superiors in the construction industry might not support the development of skills related to SC. As Opoku & Ahmed (2014) state, there is a shortage of skills and capacity in terms of numbers of construction industry professionals who can support the implementation of SC. Construction industry stakeholders should therefore be encouraged by their industry peers and superiors and be given the opportunity to develop their skills to improve the sustainability of the construction industry. Furthermore, without an integrated work environment where stakeholders are working in collaboration to achieve the objectives of SC, it further deters the successful adoption and implementation of SC (Häkkinen & Belloni, 2011). The physical opportunity to adopt and implement SC highlights various barriers such as the lack of availability of sustainable technologies, lack of sustainable product and material suppliers and databases with information about sustainable products. This is well-documented in the literature as common technological barriers to the adoption and implementation of SC (Aigbavboa *et al.*, 2017; Chan, Darko, Ameyaw, *et al.*, 2017; Häkkinen & Belloni, 2011; Khalfan *et al.*, 2015; Pham, Kim & Luu, 2019; Pitt *et al.*, 2009; Shi *et al.*, 2013). Participants appreciate that the principles of SC encourage environmental protection through the conservation of resources, energy and water and waste reduction. By providing opportunities within organisations to develop a culture of sustainability, best practice sharing and commitment to increasing the awareness of SC, will improve the adoption of SC. Furthermore, regulations and frameworks to guide the adoption and implementation of SC as well as reliable databases with sustainable product information will further aid the adoption and implementation of SC. The findings suggest that there are opportunities to transition towards a more sustainable construction industry.

The survey results indicate that motivation plays a role in determining the likelihood of participants engaging with SC. In terms of reflective motivation[15], all participants indicated that SC was beneficial to the development of their careers as construction industry professionals. Participants agreed that if they had the skills, they would adopt SC and were highly optimistic about the benefits of SC for the construction industry in the long term. Participants had strong intentions to develop their SC knowledge and skills and encourage the education and training thereof. In terms of automatic motivation[16], participants indicated government should support and encourage SC through incentives, tax relief, subsidies and access to funding for projects that incorporate sustainable principles and practices. These findings are supported by previous literature, which suggests that motivation and support from key role players in the construction industry such as government, developers and clients are essential for successful and widespread adoption of SC specifically in the early stages of adoption. The results from the survey suggest that addressing the barriers to the implementation of SC linked to the capabilities, opportunities and motivation of construction industry stakeholders may facilitate the transition towards a more sustainable construction industry.

6.5. TDF Domains Analysis

The Cronbach's alpha values for the subscales of the questionnaire (i.e. the TDF domains) were shown to have very good reliability (above 0.80 for five scales and above 0.70 for four scales) (Table 6-15). The general acceptable values of alpha range between 0.70 and 0.95 and scales with values below 0.70 could be attributed to the low number of items in the scale or heterogeneous constructs (Tavakol & Dennick, 2011). The items in the questionnaire were therefore combined into the TDF domains for further analysis.

Table 6-15: Reliability of TDF Domains

Scale	Number of Items	Scale reliability (α)
Knowledge	5	0.683
Skills	5	0.770
Social/Professional Role and Identity	9	0.905
Beliefs about Capabilities	3	0.761
Optimism	2	0.704
Beliefs about Consequences	14	0.768
Reinforcement	4	0.830
Intentions and Goals	5	0.885
Social Influences	3	0.824
Behavioural Regulation	2	0.521
Environmental Context and Resources	23	0.912

[15] Reflective processes involving plans (self-conscious intentions) and evaluations (beliefs about what is good and bad) (Michie *et al.*, 2014).
[16] Automatic processes involving emotional reactions, desires (wants and needs), impulses, inhibitions, drive states and reflex responses (Michie *et al.*, 2014).

To identify which domains' need to be targeted in the behaviour change intervention, the domains were analysed as scales. Table 6-16 displays the minimum and maximum value for the responses, means and standard deviations averaged across all participants.

Table 6-16: Descriptive Statistics for TDF Domains

Scale	Minimum	Maximum	Mean (*)	SD {*}
Capability				
Knowledge	1	5	3.61	0.59
Skills	1	5	3.61	0.65
Behavioural Regulation	2	5	4.04	0.59
Opportunity				
Social Influences	1	5	3.53	0.74
Environmental Context and Resources	3	5	4.08	0.42
Motivation				
Social/Professional Role Identity	2	5	4.20	0.60
Beliefs about Capabilities	2	5	3.97	0.62
Optimism	3	5	4.32	0.60
Beliefs about Consequences	3	5	3.49	0.43
Intentions and Goals	3	5	3.99	0.57
Reinforcement	3	5	4.28	0.57

The means for all scales indicate that on average, participants were positively inclined towards the adoption and implementation of sustainable construction. The *Optimism* scale had the highest mean (4.32{0.60}) followed by the *Reinforcement* scale (4.28{0.57}) and *Social/Professional Role and Identity* scale (4.20{0.60}). All these scales fall under the category of Motivation within the COM-B model which indicates that there is a strong motivation to adopt and implement SC amongst construction industry professionals. The *Beliefs about Consequences* scale had the lowest mean (3.49{0.43}) followed by the *Social Influences* scale (3.53{0.74}), the *Knowledge* scale (3.61{0.59}) and the *Skills* scale (3.61{0.65}). These scales also indicate the largest variability in responses, which indicates that there could be improvement in all the COM-B categories to improve the adoption and implementation of SC. The data demonstrates overall that the items in each scale are measuring similar and related constructs. The eleven TDF scales were further used to ascertain significant differences in the following three key areas: i) differences between the various stakeholder groups, ii) differences between organisation size, iii) differences between years of experience amongst participants. A normality test indicated that the data for all scales did not follow a normal distribution and therefore non-parametric tests were conducted. The overall test for all key areas indicates that there were no significant differences amongst various stakeholder groups, organisation size and no significant differences in responses as a function of years of experience.

To determine which domains should be targeted for the behaviour change intervention, an analysis of the means and standard deviations for each stakeholder group, as well as the years of experience, were assessed by determining the lowest mean indicators. The analysis of the TDF domains indicate that there are five key behaviours which should be targeted including construction industry stakeholders' *beliefs about consequences, knowledge*, *social influences, skills* and *beliefs about capabilities*. This informs the target behavioural domains to be addressed in the development of the behaviour change intervention in the following chapter.

6.6. Conclusion: Chapter 6

The overall positive response to the study suggests that there is a need to adopt and implement SC and construction industry stakeholders are optimistic about the positive impact SC could have on the economy, environment and society. The findings of this phase of the research study highlights a range of factors related to construction industry stakeholders' capability, opportunity and motivation that require improvement to increase the adoption and implementation of SC. It is evident that informative and practical multi-level interventions are needed to target behaviours at individual, organisational and construction industry (population) level. Using the TDF domains and COM-B model, five key target areas were identified: *beliefs about consequences, knowledge, social influences, skills* and *beliefs about capabilities,* which will be used to develop a behaviour change intervention.

Chapter 7
Phase Three: Designing a Behaviour Change Intervention

This chapter is the final phase of the three-phased mixed methods research design framework, which was guided by the behaviour change wheel and aimed at developing a behaviour change intervention to facilitate the adoption and implementation of SC by construction industry stakeholders. This chapter discusses the overall results of the three stages of the behaviour change intervention design developed by Michie, Atkins & West (2014) to guide the development of the intervention using multiple data sources (Figure 7-1). This chapter discusses the development of the behaviour change intervention toolbox in Section 7.3 using Building Information Modelling (BIM) as a sustainable project management process (Section 7.1.5) to enable the adoption and implementation of SC. The last section of this chapter presents the validation process of the intervention toolbox which is based on qualitative data gathered from semi-structured interviews. The results from the interviews are discussed and used to refine and adapt the toolbox based on feedback from subject matter experts (SMEs) gathered from the interviews. The refined toolbox is presented in this chapter and the preliminary toolbox that was used in the interviews is presented in Appendix H. This phase of the research addresses research objective five (RO-5: *Develop a behaviour change intervention by identifying the components and/or strategies that can be used by construction industry stakeholders to facilitate the adoption and implementation of SC through a sustainable management process*).

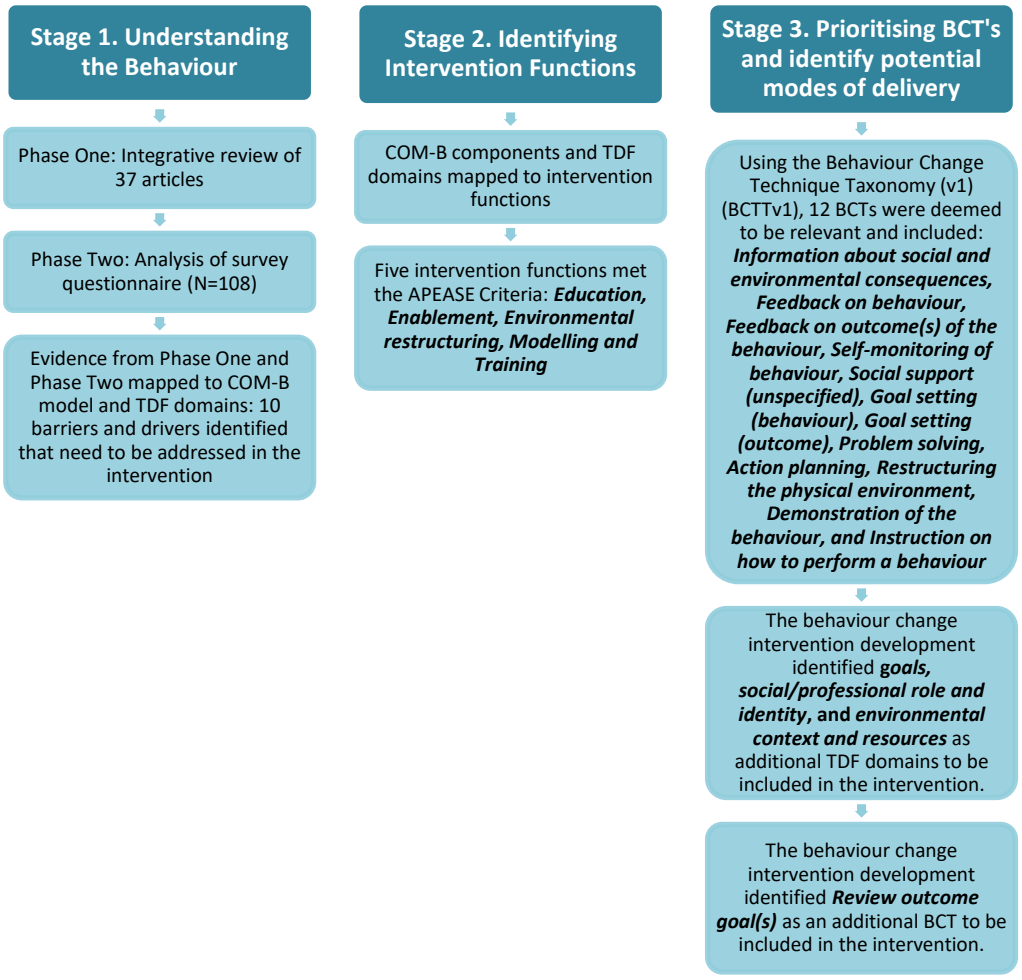

Figure 7-1: Summary of research study stages and intervention content selection

7.1. Stage 1: Understanding the Behaviour

The first phase of this research study involved an integrative review of the published literature to understand the key barriers and drivers to the adoption and implementation of SC. The second phase of the research studied the perception and understanding of SC amongst construction industry stakeholders in South Africa aimed at identifying the key barriers and drivers based on responses to the survey questionnaire. The survey questionnaire design and data analysis in phase two was guided by the TDF and COM-B model. By adopting the COM-B model and TDF to conduct an analysis of the behaviour of construction industry stakeholders, this research study identified the following COM-B components and TDF domains(indicated in brackets) as key targets: *Psychological Capability* (Knowledge, Skills and Behavioural Regulation), *Social Opportunity* (Social Influences), and *Reflective Motivation* (Beliefs about Capabilities and Beliefs about Consequences) (Table 7-1).

Table 7-1: Phase One and Phase Two findings mapped to COM-B model.

COM-B		Capability			Opportunity	Motivation	
		Psychological			Social	Reflective	
TDF		Know	Cog	Beh Reg	Soc	Bel Caps	Bel Cons
Barriers and Drivers	Awareness, Knowledge and Information of SC						
	Interest in SC and Demand for SC						
	Training availability of SC						
	Access to Education on SC						
	Behavioural Change towards SC						
	Industry peer influences						
	Confidence in SC implementation						
	Economic Factors						
	Perception of SC						
	Social Benefits						

Legend of data sources and Acronyms: *Green* – Phase One: Integrative literature review; *Blue* – Phase Two: Quantitative survey questionnaire; Know – Knowledge; Cog - Cognitive Skills; Beh Reg – Behavioural Regulation; Soc – Social Influences; Bel Caps – Beliefs about Capabilities; and Bel Cons – Beliefs about Consequences

7.1.1. Capability

Both the literature review and participants in the questionnaire describes a lack of knowledge and awareness of sustainable construction as an important barrier to adoption. Increasing awareness, knowledge and providing access to information about sustainable construction will improve the interest and demand for sustainable construction. Furthermore, access to education and training was identified as a facilitator to the adoption of sustainable construction.

7.1.2. Opportunity

Construction industry stakeholders described social opportunity as a barrier and driver to the adoption of sustainable construction. The survey questionnaire data illustrated the importance of industry peer influence on stakeholders in the construction industry. Support and encouragement from industry peers would facilitate the transition towards the adoption of sustainable construction.

7.1.3. Motivation

Construction industry stakeholders indicated a strong reflective motivation to adopt sustainable construction even with project constraints such as time and limited resources. The literature and survey questionnaire illustrated that stakeholders are aware of the economic barriers and drivers of sustainable construction; sustainable construction is perceived to contribute to environmental sustainability and that there are social benefits such as job creation through the adoption and implementation of sustainable construction.

7.1.4. Specifying the Target Behaviour

To determine what the specified target behaviour for the intervention will be, three considerations for potential target behaviours have been identified as shown in Table 7-2. Selecting and specifying a target behaviour can be achieved through prioritising and determining i) the likely impact if the behaviour were to be changed, ii) how likely it is that the behaviour can be changed (will be influenced by financial and human resources, acceptability, preference), iii) the positive "spillover" effect if that behaviour were to be changed and lastly, iv) ease of measurement which aims to examine if you were to evaluate the extent to which the intervention has changed the target behaviour, it should be measurable (Michie *et al.*, 2014). Each of these components are measured on a scale according to it being very promising as a target behaviour, being quite promising, unpromising but worth considering, and lastly, it not being acceptable.

Table 7-2: Specifying the Target Behaviour

Potential target behaviours relevant to improving the adoption and implementation of SC practices by construction industry stakeholders	Impact of behaviour change	Likelihood of changing behaviour	Spillover Effect	Ease of Measurement
Adopt a construction waste management plan using lean principles throughout the life cycle of a building project	Very promising	Quite promising	Quite promising	Quite promising
Adopt BIM as a tool to facilitate the adoption of sustainable construction practices	Very promising	Quite promising	Very promising	Quite promising
Adopt a sustainability action plan throughout the life cycle of a building project	Very promising	Quite promising	Very promising	Quite promising

Due to the complex nature and various interacting components of the construction industry and the stakeholders who work in the construction, the specified target behaviour focuses on one phase of the life-cycle of a building project (design and development phase of the whole building life cycle). Furthermore, the term sustainable construction covers a multitude of principles and practices by which construction industry stakeholders can improve the economic, environmental, and social sustainability of the construction industry. For example, managing natural resources used during construction, providing energy efficient buildings and construction waste management etc. From Table 7-2, it is evident that all the target behaviours were mostly promising. For ease of measurement for a construction waste management and sustainability action plan, it will require a level of expertise that might not be immediately available and complex measuring systems such as life cycle assessments might be a barrier to implementing these plans. On the other hand, adopting BIM which most stakeholders are familiar with and have been exposed to, will be easier to measure as organisations are generally familiar with the processes required to adopt and implement BIM (Gu & London, 2010). By incorporating sustainability objectives throughout the life cycle of the project (resource efficiency, waste management, sustainable materials), BIM allows for the consideration of the impact of the building project prior to construction and adjustments can be along the way to optimise the building (Enshassi, Hamra & Alkilani, 2018). Not only are you able to manage a project across the life cycle, but sustainability objectives can also be managed and monitored (Matar, Georgy & Abou-Zeid, 2010). A construction waste management and sustainability action plan could be used in addition to BIM on projects to ensure that the sustainability aspect is a key design and development consideration.

The behaviour change intervention in this research study will therefore focus on adopting a technological solution to implement a sustainable project management process to facilitate the transition towards a sustainable construction industry. Through the analysis of Phase One and Phase Two of the research design, the following specified target behaviour has been identified: *Construction industry stakeholders involved in the design and development phase of the life-cycle of a building project should implement sustainable construction practices on building projects within their organisations through the adoption of a sustainable project management process called Building Information Modelling (BIM)*.

7.1.5. BIM in Sustainable Construction

The integration of BIM in sustainable design and construction has been witnessed in the construction industry along with the rapid growth and continuous improvement of software applications to enrich the construction industry's best practices (Wong & Fan, 2013). Due to the large extent of coordination required on construction projects, the collaboration of various disciplines within the scope of the project is essential to ensuring the success of construction projects. BIM technologies and systems can streamline these project management processes by providing information and data for the whole building life cycle (Rajendran, Ta Wee & Kai Chen, 2012), providing integration and coordination to facilitate the sustainability objectives of construction projects, and allowing early detection of clashes and errors which informs decision-makers.

The following section aims to provide insight into the concept of sustainable project management, discuss the role of BIM in sustainable construction and how BIM can facilitate the transition towards a more sustainable construction industry.

Sustainable Project Management

Sustainable project management (SPM) encompasses the planning, monitoring and controlling of project delivery and support processes which considers the economic, environmental and social aspects of the lifecycle of project resources, processes, deliverables and effects (Chawla, Chanda, Angra, *et al.*, 2018). It aims to realise benefits for all stakeholders and must be performed in a transparent, fair and ethical manner that includes and promotes active stakeholder participation (Silvius & Schipper, 2014). BIM is an example of a sustainable construction project management strategy which has the potential to provide positive impacts on the economic, environmental and social aspects of sustainability.

What is BIM?

Various definitions for Building Information Modelling (BIM) exists in the literature but the common features of BIM can be described as: BIM is a product which consists of a structured dataset which describes a building; BIM is a process which requires collaborative work amongst construction industry stakeholders to produce the building information model (the product); BIM is a system which comprises of an interacting communication structure and management of information and tasks to optimise the design, increase the quality and efficiency of the project and improve the whole lifecycle management of the building (Ghaffarianhoseini, Tookey, Ghaffarianhoseini, *et al.*, 2017; Wong & Fan, 2013). BIM describes all the activities involved in object-oriented computer aided design which supports the parametric digital representation of all building elements in terms of their 3D geometric attributes and non-geometric attributes such as material properties (Ghaffarianhoseini *et al.*, 2017; Gu & London, 2010). Furthermore, the information contained in BIM can be used to illustrate the whole lifecycle of a building, from cradle to cradle which includes inception to design and demolition to materials reuse. The spaces, systems, products and sequences within the building is represented in a relative scale to one another and in turn, relative to the entire project (National Building Specification, 2016).

Role of BIM and its benefits to Sustainable Construction

BIM has become a critical part of sustainability analysis and simulation as it allows multi-disciplinary data to be assessed in one model which can be updated as the model changes over time (Azhar & Brown, 2009). Furthermore, BIM plays an important role in the reduction of construction waste and environmental degradation. The demand for BIM has therefore seen an increase in the field of sustainability as it can contribute to sustainable construction throughout various stages of a building project: BIM facilitates effective decision-making at early stages of a building project and allows for the prediction of the performance during the operation and maintenance phases of the building's lifecycle (Soltani, 2016). The contribution of BIM to the sustainability of the construction industry can be grouped according to the three main dimensions of sustainable development: economic, environmental, and social.

Economic Dimension

The contribution of BIM to sustainable construction has a direct influence on the economic aspect of a building project through the return on investment which BIM provides through primarily preventing schedule delays, and reducing the necessity to do rework as a result of miscommunication (Ghaffarianhoseini *et al.*, 2017).
BIM has the potential to have a positive impact on time, cost and quality of building projects. A conceptual model can be created with the intent to provide cost information to assist developers with determining whether a building of a given size, quality level and desired requirements are achievable within a specified budget and time frame. BIM can improve the quality management, scheduling, project management, design validation, on-time project completion and effective resource management (Burczyk, 2018). This is achieved through the collaboration of technical, construction, operational and manufacturing knowledge to share data and coordinate a building project which is facilitated through BIM. Furthermore, BIM enables the integration of disjointed practices in the construction industry and can act as a key driver for changing business processes (Khosrowshahi & Arayici, 2012). A literature review conducted by Mesároš & Mandičák (2017) highlighted the following key benefits of BIM: "*cost reducing in construction project management*; *time reducing in project documentation*; *time reducing for the entire lifecycle of the construction project, including the design phase*; *faster access to information and relevant documents by all participants of the construction project*; *increasing of employee productivity*; *increasing of financial control*; *support and facilitate of decision-making*; *increasing the quality of the documents, the elimination of error documentation*; *elimination of errors in the construction process – increasing of construction quality*; and *increasing revenues from contracts.*"

Environmental Dimension

The contributions of BIM to digital design and visualisation, design optimisations and integrated project delivery allows project stakeholders to assess environmental impacts easier. Integrated analysis tools within BIM can be utilised to assess the impact of materials and energy on the performance of a building and provide solutions which reduce the consumption of resources such as water (Burczyk, 2018; Wong & Fan, 2013). BIM allows the environmental analysis of a building to be updated as the design evolves and provides stakeholders with an opportunity to assess multiple solutions and make amendments to a virtual building without the need to do a costly redesign. BIM contributes to the environmental sustainability of the construction industry through reducing the waste of a building from its inception to its demolition and possible reuse. Each clash on site due to poor coordination and detection, each component of inefficiency and reworking, and each poorly managed or inefficient maintenance strategy on a building project contributes to a building's carbon consumption. By enabling the coordination of all design and construction information across various disciplines in one central model, BIM mitigates the carbon consumption of a building.

Social Dimension

The sustainability of the construction industry depends on the social awareness of the impact of the construction industry on the environment by stakeholders, the public and government. As BIM provides an opportunity for integrated project delivery, it reduces the risks in a building project by improving the communication and collaboration amongst stakeholders.

The safety on building projects is improved through the early detection of problems and risks on a building project using a federated BIM model. BIM enhances the quality of the built environment and similarly it provides a better quality of living through the construction of sustainable buildings (Wong & Fan, 2013). With an increase in the demand for BIM it creates scope for innovative career opportunities through organisations who promote the implementation of BIM. Now that we have identified the specified target behaviour and the technological solution which will be used to change the behaviour, we will discuss the next stages of the intervention design.

7.2. Stage 2: Identify Intervention Function Options

An intervention function can be described as the broad categories through which an intervention can change behaviour such as education, persuasion and training (Michie *et al.*, 2014). The BCW includes a matrix that links each COM-B component and TDF domain to the intervention functions which are most likely to be effective in bringing about behaviour change. Mapping the COM-B components and TDF domains to the intervention function matrix identified five of the intervention functions that needs to be considered: *education, enablement, environmental restructuring, modelling and training* (Table 7-3). Using this matrix and applying the APEASE criteria (affordability, practicability, effectiveness/cost-effectiveness, acceptability, safety and equity), each intervention function was analysed to determine its suitability within the context of the construction industry.

Table 7-3: COM-B components and TDF domains mapped intervention functions

Barriers and Drivers (COM-B | TDF)	Intervention Functions								
	Coercion	Education	Enablement	Environmental restructuring	Incentivisation	Modelling	Persuasion	Restriction	Training
Awareness, Knowledge and Information of SC (Capability – Psychological | Knowledge)									
Interest in SC and Demand for SC (Capability – Psychological | Knowledge)									
Training availability of SC (Capability – Psychological | Cognitive Skills)									
Access to Education on SC (Capability – Psychological | Cognitive Skills)									

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Behavioural Change towards SC (Capability – Psychological | Behavioural Regulation)									
Industry peer influences (Opportunity – Social | Social Influences)									
Confidence in SC implementation (Motivation – Reflective | Beliefs about Capabilities)									
Economic Factors of SC (Motivation – Reflective | Beliefs about Consequences)									
Perception of SC (Motivation – Reflective | Beliefs about Consequences)									
Social Benefits of SC (Motivation – Reflective | Beliefs about Consequences)									

7.3. Stage 3: Identify Intervention Components and Implementation Options

In Stage 1 we aimed to understand the current behaviour amongst construction industry stakeholders and specified a target behaviour and Stage 2 provided intervention functions which can be used to achieve the target behaviour. In order to develop the components of the behaviour change intervention, the BCT taxonomy (BCTTv1) was used to identify the potential BCTs[17] that would best serve the intervention functions. The matrix with intervention functions mapped to the relevant BCTs was used along with the APEASE criteria to consider which BCTs would be feasible to adopt within the context of the construction industry.

The following 12 BCTs were deemed to be relevant: *information about social and environmental consequences*, *feedback on behaviour, feedback on outcome(s) of the behaviour, self-monitoring of behaviour, social support (unspecified), goal setting (behaviour), goal setting (outcome), problem solving, action planning, restructuring the physical environment, demonstration of the behaviour,* and *instruction on how to perform a behaviour* (Table 7-4).

[17] An active component of an intervention designed to change behaviour (Michie *et al.*, 2014).

Table 7-4: Barriers and Drivers mapped to selected behaviour change techniques in the BCTTv1

Barriers and Drivers (Intervention Functions)	Behaviour Change Techniques											
	Information about social and environmental consequences	Feedback on behaviour	Feedback on outcome(s) of the behaviour	Self-monitoring of behaviour	Social support (unspecified)	Goal setting (behaviour)	Goal setting (outcome)	Problem solving	Action planning	Restructuring the physical environment	Demonstration of the behaviour	Instruction on how to perform a behaviour
Awareness, Knowledge and Information of SC (Education, Enablement, Training)	✓	✓	✓	✓						✓	✓	✓
Interest in SC and Demand for SC (Education, Enablement, Training)	✓	✓	✓	✓						✓	✓	✓
Training availability of SC (Education, Enablement, Training)	✓	✓	✓	✓						✓	✓	✓
Access to Education on SC (Education, Enablement, Training)	✓	✓	✓	✓						✓	✓	✓
Behavioural Change towards SC (Education, Enablement, Training)	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓

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Industry peer influences (Enablement, Environmental Restructuring, Modelling)					✓	✓	✓	✓	✓	✓	✓	
Confidence in SC implementation (Education)	✓	✓	✓	✓						✓		
Economic Factors of SC (Education)	✓	✓	✓									
Perception of SC (Education)	✓	✓	✓									
Social Benefits of SC (Education)	✓	✓	✓									

The Template for Intervention Description and Replication (TIDieR) developed by Hoffmann *et al.* (2014) provides a checklist for reporting and understanding the general content of behaviour change interventions. In this research, it is adapted and used to provide the theoretical basis and summary of the intervention toolbox including what is delivered (intervention components), the rationale of why this component is relevant, what the mode of delivery is, to whom it will delivered, and when or how often it will be delivered. Table 7-5 consists of the following broad intervention components: group education and training, technology provided to aid implementation, educational documents, developing a business case for BIM, developing a BIM implementation roadmap (strategy), executing BIM projects, ongoing audits and feedback.

Table 7-5: Behaviour Change Intervention Toolbox summary based on TIDieR

Phase	Intervention Components	Rationale	Mode of Delivery	Delivered to	When/How often
Pre-BIM Implementation					
Phase 1	Introductory education sessions about Sustainable Construction and BIM	To familiarise stakeholders with SC and BIM and generate enthusiasm and motivation	Face-to-face (groups)	Building Design Team at their respective organisations	Once when BIM is first introduced and when a new employee joins organisation
Phase 2	Training delivered by BIM specialist	To train employees on how to implement BIM	Face-to-face (groups)	Building Design Team at their respective organisations	Once when BIM implementation is first introduced, Multiple training sessions if groups are too large, Ad-hoc additional training sessions for various levels of experience
BIM Strategy Development					
Phase 3	Develop a Business Case for BIM which aligns with the organisations' sustainability vision and goals	To identify the reasons for adopting BIM and justify the investment in education and training	Documents	Organisation	Once when BIM adoption is first introduced
	Develop BIM Implementation roadmap across business functions with targets and ways to realise them	To improve the organisations proficiency to deliver BIM enabled projects	Face-to-face, Documents	Organisation	Once when BIM adoption is first introduced
BIM Mobilisation					
Phase 4	Execute BIM Implementation Plan on all new building projects and provide personalised feedback to teams involved in implementation	To assess transition towards BIM adoption and evaluate the process To target specific incidents of limited and lack of implementation	Face-to-Face (groups)	Building Design Team at their respective organisations	Monthly feedback sessions for 3 months, quarterly and annual feedback sessions

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Phase 5	Software and hardware resources provided to aid implementation	To make implementation more convenient	Environment Changes	Building Design Team at their respective organisations	Ongoing
	Educational documents	Educate stakeholders about BIM and promote self-monitoring	Documents	Building Design Team at their respective organisations	Ongoing
Phase 6	Audit and group feedback - verbal feedback	To focus staff on targets and progress	Feedback delivered face-to-face and through documentation	Building Design Team at their respective organisations	Monthly feedback sessions, quarterly and annual feedback sessions

7.4. Behaviour Change Intervention Toolbox

BIM will be used as a tool to influence the behaviour of construction industry stakeholders at an organisational and individual level towards adopting sustainable construction. This is achieved through multiple modes of delivery and intervention content as highlighted in Table 7-5. A matrix which summarises the links between the TDF, COM-B model, BCW intervention functions and BCTs from Stage 1, 2 and 3 with descriptions is presented in Table 7-6 which provides insight into the Building Information Modelling Implementation Intervention (BIMII) toolbox shown in Table 7-7. The matrix highlights that the intervention content will be linked to all the components of the COM-B model, specifically *psychological capability*, *social opportunity* and *reflective motivation* and 6 of the 14 TDF domains (*knowledge, skills, behavioural regulation, social influences, beliefs about capabilities* and *beliefs about consequences*). Psychological capability will be targeted through the intervention functions of *education* (increasing knowledge or understanding), *enablement* (increasing means/ reducing barriers to increase capability (beyond education and training) or opportunity (beyond environmental restructuring)) and *training* (imparting skills). Social opportunity will be targeted through the intervention functions of *enablement*, *environmental restructuring* (changing the physical or social context) and *modelling* (providing an example for people to aspire to or imitate). Lastly, reflective motivation will be targeted through *education*. The BCTs which best serve the intervention functions based on the barriers and drivers have been provided along with the proposed modes of delivery for the intervention.

The BIMII toolbox content is characterised by the behavioural analysis of the barriers and drivers using the COM-B model and TDF, the intervention components linked to each phase of the intervention toolbox, intervention functions, and BCTs which will target a wide range of theoretical mechanisms of action. It is based on the specified target behaviour to implement sustainable construction practices on building projects by using BIM which is a sustainable project management process to facilitate the adoption and implementation of SC amongst construction industry stakeholders.

The BIMII toolbox is split into three key stages which define the six phases of the implementation toolbox: i) Pre-BIM Implementation; ii) BIM implementation strategy development and iii) BIM implementation mobilisation (Table 7-7).

Pre-BIM Implementation

The first stage (Phase 1 and Phase 2) provides a basis for organisations to equip employees with the necessary knowledge and training required to adopt and implement BIM as a tool to facilitate the transition towards a more sustainable construction industry. The mechanisms of action identified in this stage were *knowledge, skills, beliefs about consequences* and *behavioural regulation* which will be targeted through providing *information about social and environmental consequences, instruction on how to perform the behaviour* and *demonstration of the behaviour.*

BIM implementation strategy development

The second stage (Phase 3) provides an opportunity for construction industry stakeholders at management level to consider BIM as part of their organisations' strategic vision and goals to achieve sustainability and contribute to a sustainable construction industry. The mechanisms of action identified in this stage were *behavioural regulation, beliefs about capabilities, social influences* and *goals.* Although *goals* were not part of the behavioural analysis in Stage 1 of the BCW design, it was identified as a mechanism of action which should be targeted in the intervention. It provides a function to set goals to achieve the target behaviour which can be monitored and evaluated. The BCTs identified in this stage were *problem solving, action planning* and *goal setting (behaviour)*.

BIM implementation mobilisation

The third and last stage of the BIMII toolbox (Phase 4 to Phase 6) illustrates the requirements to mobilise a BIM implementation strategy within an organisation and demonstrates the key factors to achieving successful BIM adoption and implementation through a pilot project, support from management and peers, providing the resources required to aid implementation and to ensure ongoing audits and feedback on projects. The mechanisms of action identified in this stage were *knowledge, skills, behavioural regulation, social influences, beliefs about capabilities, beliefs about consequences, social/professional role and identity*, *environmental context and resources* and *goals.* Similarly to Phase 3, *social/professional role and identity*, *environmental context and resources* and *goals* were identified in addition to the six TDF domains identified in Stage 1 of the BCW design. Providing social processes of encouragement, pressure and support within in an organisation to adopt and implement BIM positively influences the employee's role and identity within the construction industry by allowing them the opportunity to contribute to the sustainability of the industry. Furthermore, by restructuring the physical environment within an organisation through the provision of resources (technology and documentation) provides a physical opportunity to employees to engage in the adoption and implementation of BIM.

During the audit and feedback process, it is important for organisations and employees to set targeted goals of BIM implementation which can be measured and evaluated to provide feedback on how BIM implementation has impacted building projects. The BCTs identified in this stage were *review outcome goal(s), social support (unspecified), restructuring the physical environment, instruction on how to perform a behaviour, self-monitoring of behaviour, feedback on outcome(s) of behaviour, feedback on behaviour* and *problem solving*. *Review outcome goal(s)* was identified as an additional BCT which could be useful to an organisation to identify how implementation goals have progressed and what the impact of adopting BIM was on a project in terms of time, whole lifecycle cost, quality and overall sustainability.

Table 7-6: Matrix of TDF, COM-B Model, BCW and BCTT (v1)

Behavioural analysis using COM-B and TDF – barriers and drivers of SC adoption and implementation (Stage 1)			Intervention Functions (Stage 2)	Behaviour Change Techniques (BCT v1) (Stage 3a)	Modes of Delivery (Stage 3b)
COM-B		TDF domains linking to COM-B components			
CAPABILITY	***Psychological Capability***	***Knowledge***	Education, Enablement, Training	**Education:** *Information about social and environmental consequences; Feedback on behaviour; Feedback on outcome(s) of the behaviour; Self-monitoring of behaviour*	Face-to-face Documents Environment Changes
	Limited awareness, knowledge, and information about SC Lack of interest in SC and demand for SC	Develop scientific knowledge about SC to increase the interest and demand for the adoption and implementation of SC through BIM			
	Psychological Capability	***Skills***	Education, Enablement, Training	**Enablement:** *Social support (unspecified); Goal setting (behaviour); Problem solving; Action planning; Self-monitoring of behaviour*	Feedback delivered face-to-face Feedback delivered through documentation
	Lack of training availability of SC Limited access to education on SC	Develop skills to improve competency to adopt and implement SC through BIM			
	Psychological Capability	***Behavioural regulation***	Education, Enablement, Training	**Training:** *Demonstration of the behaviour; Instruction on how to perform a behaviour*	
	Behavioural Change towards SC	Develop skills of goal setting, problem solving, action planning and self-monitoring to change current unsustainable practices in the construction industry through BIM adoption			

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Behavioural analysis using COM-B and TDF – barriers and drivers of SC adoption and implementation (Stage 1)			Intervention Functions (Stage 2)	Behaviour Change Techniques (BCT v1) (Stage 3a)	Modes of Delivery (Stage 3b)
COM-B		**TDF domains linking to COM-B components**			
OPPORTUNITY	***Social Opportunity***	***Social influences***	Enablement, Environmental restructuring, Modelling	**Environmental Restructuring:** *Restructuring the physical environment* **Modelling:** *Demonstration of the behaviour*	
	Industry peer influences	Provide opportunity and encourage the adoption and implementation of SC through BIM implementation strategy			
MOTIVATION	***Reflective Motivation***	***Beliefs about capabilities***	Education		
	Confidence in SC implementation	Believing that improving knowledge and skills of BIM adoption and implementation is achievable and will contribute to the sustainability of the construction industry			
	Reflective Motivation	***Beliefs about consequences***	Education		
	Economic Factors of SC Perception of SC Social Benefits of SC	Believing that having the knowledge and skills of BIM adoption and implementation is beneficial and will contribute to the sustainability of the construction industry			

Table 7-7: BIMII Toolbox of intervention components, intervention content and mechanisms of action

Phase	Barriers and Drivers	Intervention Components	Intervention Content		Mechanisms of Action	
			Functions	BCTs with Definitions	COM-B	TDF
Pre-BIM Implementation: Group introductory education and training sessions delivered to employees in groups (Phase 1)						
Phase 1	Awareness, Knowledge and Information of SC Interest in SC and Demand for SC	[a] Discuss the concept of Sustainable Construction: Sustainability, sustainability in the construction industry, sustainable construction principles, the importance of adopting sustainability in the construction industry	Education	Information about social and environmental consequences: *Provide information (e.g. written, verbal, visual) about social and environmental consequences of performing the behaviour*	Psychological Capability	Knowledge
	Training availability of SC Access to Education on SC	[a] Discuss the concept of BIM: What is BIM?, BIM and sustainability, How BIM enables sustainable construction, the importance of adopting BIM in the construction industry, Challenges of BIM adoption and implementation	Education	Information about social and environmental consequences: *Provide information (e.g. written, verbal, visual) about social and environmental consequences of performing the behaviour*	Psychological Capability	Knowledge
	Behavioural Change towards SC Confidence in SC implementation	Provide instruction on how and when to implement BIM	Training	Instruction on how to perform a behaviour: *Advise or agree on how to perform the behaviour*	Psychological Capability	Knowledge, Skills
	Economic Factors of SC	Provide examples of BIM implementation success stories	Education	Information about social and environmental consequences	Reflective Motivation	Beliefs about consequences
	Perception of SC Social Benefits of SC	Provide evidence of the impact of BIM implementation	Education	Information about social and environmental consequences	Psychological Capability, Reflective Motivation	Knowledge, Beliefs about consequences

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Phase	Barriers and Drivers	Intervention Components	Intervention Content		Mechanisms of Action	
			Functions	BCTs with Definitions	COM-B	TDF
Pre-BIM Implementation: Group introductory education and training sessions delivered to employees in groups (Phase 2)						
Phase 2	(See Phase 1)	Provide BIM implementation training	Education, Training, Modelling	Demonstration of Behaviour: *Provide an observable sample of the performance of the behaviour, directly in person or indirectly for the person to aspire to or imitate*, Instruction on how to perform a behaviour	Psychological Capability	Knowledge, Skills, Behavioural regulation
BIM implementation strategy development (Phase 3)						
Phase 3	Behavioural Change towards SC Confidence in SC implementation Behavioural Change towards SC	Management should meet to discuss BIM and how it aligns with the organisations sustainability vision and goals and identify factors that influence the adoption of BIM and discuss strategies that will overcome barriers and facilitate adoption.	Enablement	Problem Solving: *Analyse, or prompt the person to analyse, factors influencing the behaviour and generate or select strategies that include overcoming barriers and/or increasing facilitators* Action Planning*: Prompt detailed planning of performance of the behaviour (must include at least one of context, frequency, duration and intensity). Context may be environmental (physical or social) or internal (physical, emotional or cognitive)*	Psychological Capability, Social Opportunity	Behavioural regulation, Beliefs about Capabilities, Social influences

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Phase	Barriers and Drivers	Intervention Components	Intervention Content		Mechanisms of Action	
			Functions	BCTs with Definitions	COM-B	TDF
Phase 3		Management and key employees (internal BIM Champions) identified to facilitate BIM implementation should meet to discuss BIM implementation roadmap which identifies BIM processes and targets across the whole lifecycle of the project and business functions and specify how the targets will be achieved.	Enablement	Problem Solving, Action Planning	Psychological Capability, Social Opportunity	Behavioural regulation, Beliefs about Capabilities, Social influences
		Set target within organisation to achieve successful BIM Implementation to a recognised standard for all new projects	Enablement	Goal Setting (behaviour): *Set or agree on a goal defined in terms of the behaviour to be achieved*	Reflective Motivation	*Goals

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Phase	Barriers and Drivers	Intervention Components	Intervention Content		Mechanisms of Action	
			Functions	BCTs with Definitions	COM-B	TDF
BIM implementation mobilisation (Phase 4, 5 and 6)						
Phase 4	Economic Factors of SC Perception of SC Social Benefits of SC	Management and BIM Champions should identify a pilot project and include measurement at all key stages to understand how BIM has improved the design and/or construction process.	Enablement	*Review outcome goal(s): *Review outcome goal(s) jointly with the person(s) and consider modifying goal(s) in light of achievement.*	Psychological Capability, Social Opportunity	Knowledge, Behavioural regulation, Social influences
		Management should document positive benefits to each stakeholder in the process for any return on investment calculation.	Enablement	*Review outcome goal(s)	Psychological Capability, Social Opportunity	Knowledge, Behavioural regulation, Social influences
		Encourage employees to adopt and implement BIM regardless of their role	Enablement	Social Support (unspecified): *Advise on, arrange or provide social support (e.g. from colleagues or staff) or non-contingent praise or reward for performance of the behaviour.*	Social Opportunity, Reflective Motivation	Social influences, *Social/ Professional role and identity, Beliefs about capabilities
		Encourage employees to seek support from their seniors or internal/external BIM champions regarding implementation issues	Enablement	Social Support (unspecified)	Social Opportunity	Social influences

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Phase	Barriers and Drivers	Intervention Components	Intervention Content		Mechanisms of Action	
			Functions	BCTs with Definitions	COM-B	TDF
Phase 5	**Documents and resources provided to aid implementation**					
	Awareness, Knowledge and Information of SC Interest in SC and Demand for SC	Install software applications on devices to aid implementation of BIM	Enablement, Environmental Restructuring	Restructuring the physical environment: *Change, or advise to change the physical environment in order to facilitate performance of the wanted behaviour or create barriers to the unwanted behaviour*	Psychological Capability, Physical Opportunity	Knowledge, Skills, *Environmental context and resources
	Training availability of SC	Upgrade or replace hardware on devices to suit technical specification required to implement BIM	Enablement, Environmental Restructuring	Restructuring the physical environment	Psychological Capability, Physical Opportunity	Knowledge, Skills, *Environmental context and resources
	Access to Education on SC Behavioural Change towards SC	Provide resources on internal network on BIM implementation process	Education	Instruction on how to perform a behaviour	Psychological Capability	Knowledge
	Confidence in SC implementation	Provide BIM implementation checklist to employees	Enablement, Environmental Restructuring	Self-monitoring of behaviour: *Establish a method for the person to monitor and record their behaviour(s) as part of a behaviour change strategy*	Psychological Capability	Behavioural regulation

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Phase	Barriers and Drivers	Intervention Components	Intervention Content		Mechanisms of Action	
			Functions	BCTs with Definitions	COM-B	TDF
Phase 6	**Ongoing group-level audit and feedback**					
	Confidence in SC implementation Industry peer influences	Compare current performance with performance on BIM projects in terms of time, quality, whole lifecycle cost and sustainability	Enablement	Feedback on outcome(s) of behaviour: *Monitor and provide feedback on the outcome of performance of the behaviour*	Reflective Motivation	*Goals
	Economic Factors of SC	Provide feedback and lessons learnt on BIM implementation	Education	Feedback on behaviour: *Monitor and provide informative or evaluative feedback on performance of the behaviour*	Psychological Capability, Reflective Motivation	Knowledge, Behavioural consequences
	Perception of SC	Generate solutions for better implementation	Enablement	Problem Solving	Psychological Capability, Social Opportunity	Behavioural regulation, Beliefs about Capabilities, Social influences
	Social Benefits of SC	[a] Provide continuous professional development courses and training to employees in sustainability and BIM	Education, Enablement	Self-monitoring of the behaviour	Psychological Capability, Social Opportunity	Knowledge, Behavioural regulation, Beliefs about Capabilities, Social influences
		[a] Continue to provide support, encouragement, access to resources and promote engagement with sustainability and BIM	Enablement	Social support (unspecified)	Social Opportunity	Social influences

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		[a] Formalise BIM strategy development team within organisation to provide ongoing guidance and assistance with the BIM and sustainability vision of the organisation	Enablement	Review outcome goal(s), Social support (unspecified)	Psychological Capability, Social Opportunity	Knowledge, Behavioural regulation, Social influences

* ***Additional BCTs and TDF domains identified and included in intervention toolbox***.

[a] ***Additional intervention components added or edited after interviews with SMEs. For the original version of the toolbox, refer to Appendix H.***

7.5. Evaluation of BIMII Toolbox

The evaluation of the BIMII Toolbox is presented in this section. The toolbox was verified and validated by subject matter experts through semi-structured interviews. The verification process involved assessing the methods and approach used to develop the toolbox and the validation process involved assessing whether the BIMII toolbox addressed the target behaviour. The approach and methodology for the verification and validation is discussed followed by the results from the interviews.

7.5.1. Verification and Validation Approach and Methodology

The validation process forms a critical part of assessing the credibility of the BIMII toolbox. The process of validation aims to assess how accurately the proposed toolbox represents participants' realities of the social phenomena (Creswell & Miller, 2000) and whether it functions as specified. For the purpose of this research, external validation is required to ensure the feasibility, applicability and quality of the BIMII toolbox. Semi-structured interviews were conducted to gather expert opinions from stakeholders in the construction industry. The semi-structured interviews allowed the researcher to explain the concept of a behaviour change intervention and its application to facilitate the adoption and implementation of SC. The interview participants were selected based on their background and current field of expertise. Participants who were linked to fields within the construction industry to promote SC were selected and represented various roles within the industry including the research sector. The semi-structured interviews contained open-ended questions which allowed the researcher to discuss the key findings of the behaviour change intervention design with the participants and for them to provide their feedback on the application of the BIMII toolbox in the construction industry. The open-ended questions allowed participants to elaborate on any shortcomings or improvements to the toolbox. The semi-structured interviews were structured as follows:

i. The background of the research was presented and followed the interview project description (Appendix H) as an outline.
ii. The behaviour change toolbox research methodology and design were presented and discussed with the interview schedule of questions (Appendix I) to prompt the opinions of the participants.
iii. The interview transcripts were analysed to gather the qualitative data to validate the behaviour change intervention toolbox (Appendix J).

7.5.2. Interview Results

This section discusses the results from the interviews with participants who were deemed as subject matter experts (SMEs) in various aspects of sustainable construction and its implementation. The selection of SMEs was based on their relevance to the design and development phase of a building project's life cycle and their involvement in the promotion of sustainability in the construction industry through sustainable construction management processes, sustainable construction technologies, sustainable construction methods, and sustainable construction materials. Table 7-8 provides a list of the interviews conducted during May 2020.

Table 7-8: List of Interviewees

Code	Interview Date	Interviewee Description
SME1	05-05-2020	Lecturer and researcher with a specialisation in foamed concrete and 3D printing of concrete at a university.
SME2	08-05-2020	Owner of a sustainability consulting organisation with a background in mechanical engineering.
SME3	22-05-2020	Structural engineer and BIM Specialist at a consulting engineering organisation.
SME4	22-05-2020	Director and mechatronic engineer at a consulting engineering organisation.

Interview Process

Each of the SMEs received an interview pack containing the: interview consent form (Appendix G), interview project description (Appendix H), interview schedule questions (Appendix I), the Theoretical Domains Framework extracted from Section 3.1.1 and the Behaviour Change Techniques Taxonomy (version 1). The SMEs were given the opportunity to decline their participation in the validation process if they felt that they would not like to participate. The SMEs were subsequently interviewed face to face using a video conferencing software application called Zoom, which recorded the interview.

Prior to starting the interview with the prepared questions, the SMEs were asked if they had any questions or required clarity on any of the information that was provided. It was important to the researcher to ensure that the discussions with the SMEs followed a natural progression to gain as much insight from the SMEs, and to steer the conversation, where required, to address all of the interview schedule questions. The following questions were addressed during each interview which investigated various key aspects of the research:

i. Was the behaviour change wheel and research approach an appropriate choice for developing an intervention toolbox within the context of the research?
ii. What is the potential impact of the BIMII toolbox on construction industry stakeholders?
iii. Is there a need for such a toolbox in the construction industry in South Africa?
iv. Is the toolbox comprehensive and effective in achieving its goals?
v. Is the toolbox functional and applicable within the construction industry?
vi. Is there an opportunity to apply this toolbox in organisations in the construction industry?
vii. Are there any changes or improvements to the toolbox and research approach which you would recommend?

All the interviews were recorded and transcribed to gather the required feedback which was done with the consent of the SMEs. The transcriptions of the interviews are provided in Appendix J. The review of the feedback received during the interviews will be structured and discussed according to the different sections of the interview schedule namely: research design feedback, research impact feedback, overall toolbox feedback, and general feedback.

BIMII Toolbox Design Feedback

The feedback from all the SME's was that the behaviour change wheel (BCW) was an appropriate tool to use to guide the design of the toolbox. SME1 stated that the BCW was a good tool to motivate and facilitate change as it is "*quite extensive*" and SME2 believed it was a good approach, as the outcomes made sense in terms of what the researcher intended to do. SME4 said that the tool made intuitive sense as it is a means to understand and change a certain behaviour. The SMEs mentioned that they would not change anything about the research design approach using the BCW as it "*covered all the bases"* and used a "*systematic approach*". SME2 and SME3 highlighted that it seemed as though there was an implied relationship between SC and BIM and that the toolbox only focuses on BIM as an outcome. SME2 suggested that education about sustainable construction should be added as an intervention component to emphasise the importance of first understanding sustainable construction, or care about sustainability to implement sustainable construction, and then discussing how to do so using BIM as an aid.

BIMII Toolbox Impact Feedback

All SMEs unanimously agreed that the toolbox could influence construction industry stakeholders if there is an awareness and acceptance of the toolbox (SME1) and if it is packaged in a simple way and delivered by a consultant (SME2). On the other hand, SME3 stated that although the toolbox is a good guide, it does not provide a definitive method of action which describes what needs to happen to action the intervention components. SME4 however argues against this by supporting the principle of the toolbox which is not to tell stakeholders exactly what to do, but to explain a process of doing it. By providing a process of targeting a certain behaviour, there's room for stakeholders to interpret how the tool would best suit their organisation, their country, and their method of operation (SME4). The effectiveness of the toolbox to influence construction industry stakeholders to develop their knowledge and skills to adopt SC using BIM was mostly positive. SME1 stated that the toolbox could "*provide a systematic guideline to companies"* that want to become a more sustainable construction practice, and SME3 mentioned that it provides good guidance on what to consider within the capability, opportunity and motivation facets of behaviour.

SME2 and SME3 questioned the effectiveness of the toolbox to implement sustainable construction in an organisation, as opposed to agreeing that it is effective in implementing BIM in an organisation.

> *"I would say that the toolbox could maybe do with a bit more basics first. Personally, I think that would help, with BIM being a sort of secondary, an aid or tool…"* (SME2)

SME3 emphasised a similar sentiment suggesting that if there is an explanation of the link between sustainable construction and BIM, it would provide clarity.

> *"You are going to have to break it down more with focusing specifically on sustainable construction, and then linking the benefits of the BIM process or applying certain BIM uses through certain stages of the project lifecycle, to aid sustainable construction. I think that if you can make that link there, it will be very clear then on what you mean."* (SME3)

SME4 on the other hand found that the toolbox described the exact process of what they had gone through to adopt BIM and successfully implement it in their organisation.

> *"When I was working through this, especially through the toolbox and the different phases, it was quite surreal to have it listed there. It was basically exactly the process that I had gone through and well, lived through, as my adoption with Revit and everyday things. Not get caught up with all the standards and abbreviations you know, get them excited first, then get the tools and then you start implementing it. It was interesting to see how this the process of what I have lived, was summed up into a process."* (SME4)

SME2 highlighted that the biggest barrier to adoption is time and capacity. SME2 proposed that if the toolbox is "*packaged well*" and "*presented as something that is going to make the process easier for people",* then it could be implemented.

BIMII Toolbox Overall Feedback

The general sentiment from all SMEs was that the toolbox was easy to understand even without any previous exposure to the BCW and the terminologies associated with it. The overall process was clear and easy to navigate in the format provided (SME3 & SME4). All the SME's unanimously agreed that there is a definite need for a toolbox like this in the construction industry. SME1 highlighted that there is a reluctance to change the current behaviour in the construction industry and this toolbox will "*make it easier for companies to gain direction if they want to change*". SME3 supported this response by stating that there is a need to change everyone's behaviour and mindset about SC. As suggested by SME2, there is a need to understand sustainable construction better and how to implement it, as well as how to do that using BIM as a tool, the latter being the intent in this research project. SME4 stated that there is a need for the toolbox as it covers aspects of motivating the behaviour, what targets to set and what type of actions to apply to get stakeholders to perform better.

The applicability and usability of the toolbox in the construction industry was echoed by all the SMEs and there is an opportunity to adopt it. Some SMEs suggested that the toolbox could be even more effective if the toolbox is adopted as part of a campaign and if it was adapted into a Java program or dashboard with a checklist feature and SME2 stated that the toolbox could also be useful for the Green Building Council if they adapted the toolbox intervention components to focus on the education, training and implementation of sustainable construction and sustainability only. SME1 stated that the strength in the toolbox lies in its comprehensive and general approach. A similar sentiment was shared by SME4 who advocated that the toolbox is in "*a bit of a sweet spot*", as it is not too strict with how to apply the intervention, but it is also not too vague, and it can therefore be applied anywhere. SME2 mentioned that the toolbox seems like a change management process and it can therefore assist with the change management of integrating new practices in an organisation, and that is what makes it "*really good"*. Similarly, SME3 believes that the strength of the toolbox lies in its ability to effectively change behaviour by identifying elements of behaviour which industry stakeholders are not inclined to think about.

SME2 and SME3 both agreed that although not a weak point, the toolbox requires an additional component which primarily emphasises sustainable construction. SME4 further highlighted that the adoption and implementation may be affected by who the toolbox is proposed to, suggesting that stakeholders who are "*set in their ways*" will be harder to convince to change their behaviour.

7.6. Discussion: BIMII Toolbox Evaluation

Based on the feedback received from SMEs, some changes were made to the toolbox to enhance the functioning of the toolbox. It should be noted that not all additions or changes proposed by the SMEs were considered beneficial or necessary and therefore the changes were focused on areas which would have the most impact. The general feedback regarding the toolbox was primarily positive. The toolbox was viewed as being comprehensive (SME1) and all the components identified were necessary as it formalised an informal process (SME3 & SME4) and there is opportunity in the industry to apply it. SME2 also recommended that the intervention content should include a focus on sustainability initially to ensure that organisations not only focus on implementing BIM but are also focusing on "*sustainability metrics embedded in the value chain*". Phase 1 of the toolbox was adjusted to include an intervention component specifically focusing on sustainable construction and another component specifically focusing on BIM. This was added to provide clarity to the two areas of research and provide a platform to discuss the link between the two. SME4 mentioned that it is also important to ensure that there is a constant motivation and drive to continue to adopt and implement BIM as a tool to enable sustainable construction. Phase 6 of the toolbox was therefore altered to include three additional intervention components which would focus on continuous professional development, continuous support and engagement for sustainability in the construction industry and establishing an in-house BIM task group to provide ongoing assistance and guidance.

7.7. Conclusion: Chapter 7

The BCW made behaviour change theory tangible and practical in an industry which is dominated by technical standards, regulations, and processes. With the systematic three-stage approach, the BCW provided a platform to first understand which factors currently influence behaviour, how to identify intervention functions which would be applicable to the industry, and then to identify the behaviour change techniques which would guide the intervention content to develop the BIMII Toolbox. Following a detailed behavioural analysis, the BCW was used to identify five intervention functions and 12 BCTs to address the target behaviour. These findings were presented in the BIMII Toolbox to present construction industry stakeholders with a theory-based tool to design interventions that are best suited to adopt and successfully change behaviour within their organisations. The BCW recommends that input is gathered from a diverse group of stakeholders who are closely linked to the research context. In this study, stakeholders were included both during Stage 1 and Stage 3 of the BCW design. The external validation of the toolbox demonstrated the utility of the toolbox within the construction industry for all industry stakeholders to increase their awareness, perception and behaviour towards sustainable construction by using a toolbox such as the BIMII Toolbox to change their current sustainability strategy.

Chapter 8
Conclusion

This chapter provides a summary of the research study and how the research objectives were addressed. It highlights the overall strengths and limitations of the research and provides recommendations and improvements for future research.

8.1. Research Summary

This research study aimed to understand the concept of sustainable construction within the context of the construction industry in South Africa by using behaviour change theory. This research study adopted an explanatory sequential mixed methods approach with three phases linked to the behaviour change wheel (BCW) design phases. Each phase of the research design built on the previous phase to provide a comprehensive understanding and analysis of sustainable construction awareness, adoption, and implementation amongst construction industry stakeholders. This was used to inform the intervention design of the Building Information Modelling Implementation Intervention (BIMII) toolbox.

Chapter 1 introduced the research study by discussing the background to the research, research objectives and the research strategy, as well as discussing the scope and limitations to the study. Through a systematic literature review, *Chapter 2* outlined the current literature about how sustainability is embedded in the construction industry and aimed to clarify the concept of sustainable construction. The literature review further revealed the current barriers and drivers to the adoption and implementation of sustainable construction and provided a brief overview of current legislation and advisory documents available to support sustainable development. In *Chapter 3*, the need for a behavioural change approach to be used as a platform to understand the behaviour of stakeholders in the construction industry and provide insight into what influences the adoption and implementation of sustainable construction practices was discussed. The behaviour change wheel was adopted to guide this research study. *Chapter 4* presented the research design and methodology in detail which guides the strategy of inquiry for *Chapter 5*, *6* and *7*. *Chapter 5 (BCW Stage 1)* described the integrative review of which the results were mapped to the COM-B model and TDF to provide a theoretical basis for the development of the questionnaire in *Chapter 6 (BCW Stage 1)*. *Chapter 6* outlined how the results of the quantitative survey questionnaire provided insight into which domains needs to be targeted to develop an intervention for behaviour change. Using the qualitative and quantitative findings from *Chapter 5* and *Chapter 6*, *Chapter 7 (BCW Stage 2 and Stage 3)* identified the intervention functions and intervention components using the BCW to: develop a toolbox of intervention components for construction industry stakeholders to use to design, implement, and evaluate theory-based interventions that are feasible to assist with change management to promote, adopt and implement sustainable construction practices within their organisations.

The primary aim of this research study was to develop a behaviour change intervention to promote the adoption and implementation of sustainable construction practices. To achieve this, the research study addressed five key research objectives:

RO-1: Investigate the concept of sustainable development and how it is applied within the construction industry
To address RO-1, a systematic literature review was conducted which provided insight into the role of sustainable development within the construction industry. The literature review revealed that although the construction industry is complex in nature, there are ways to effectively contribute to the sustainability of the built environment by adopting sustainable construction principles and practices.

RO-2: Evaluate the current legislation and policies which govern sustainable construction in South Africa
To understand the current approach to sustainable development in South Africa, the current advisory and legislative documents available in the literature was discussed. Although there are regulations and standards available, the adoption of sustainable practices in the South African construction industry has been slow due to conflicting regulations and stakeholders who fear the liability and litigation when it comes to the performance of new sustainable products and systems. On the other hand, there are no mandatory regulations or standards which stipulates that the built environment must cover sustainability within their scope of works. Government should promote and encourage the adoption and implementation of sustainable construction, by developing mandatory policies which enable sustainable construction and offer fiscal support to organisations in the built environment.

RO-3: Identify the drivers and barriers of SC adoption and implementation amongst construction industry stakeholders
An integrative review of 37 articles identified 22 barriers and 45 drivers of sustainable construction. Six key themes were identified which groups the potential barriers and drivers to the adoption and implementation of sustainable construction: i) socio-cultural barriers and drivers comprising of how to improve the lack of knowledge, understanding and awareness of SC; ii) economic barriers and drivers comprising of measures to reduce high initial costs, increased capital costs and the increased time as a result of the adoption of SC practices and technologies; iii) stakeholder barriers and drivers comprising of how to improve the knowledge and capacity of stakeholders to provide their expertise on how to adopt and implement SC; iv) political barriers and drivers comprising of a lack of assessment tools to measure sustainable construction, lack of policy and legislation which governs sustainable construction, and a lack of support and incentives from government and how government can support and encourage SC through tax reliefs, financial incentives and funding; v) technological barriers and drivers comprising of a lack of adequate green technological specifications, limited availability of green suppliers and information, how to improve the access to sustainable products, and the research and development of sustainable products, and vi) environmental drivers which comprises of the various environmental benefits of adopting SC which aims to protect the environment and reduce the environmental impact of the construction industry.

RO-4: Investigate the perception of barriers and drivers of SC by construction industry stakeholders in South Africa

The findings of Chapter 6 highlights that although there is a high level of awareness and familiarity with sustainable construction, there might be lack of demand from clients for sustainable projects, a lack of evidence of the benefits and opportunities of SC, and the perception that SC will increase the project cost. Most participants indicated that they had access to education and training related to SC, but a relatively low percentage have worked on a sustainable building project or implemented SC principles and practices. However, most participants agreed that if they had the skills, they would adopt SC and were highly optimistic about the benefits of SC for the construction industry in the long term. Following an analysis of which domains' need to be targeted in the behaviour change intervention, five key domains were identified: beliefs about consequences, knowledge, social influences, skills and beliefs about capabilities.

RO-5: Develop a behaviour change intervention by identifying the components and/or strategies that can be used by construction industry stakeholders to facilitate the adoption and implementation of SC through a sustainable management process

Chapter 7 described the systematic process of using the BCW to develop an intervention to facilitate the adoption and implementation of SC through a sustainable project management process. Multiple sources of data were merged through an integrative review in Chapter 5 (qualitative), a questionnaire survey in Chapter 6 (quantitative), and semi-structured interviews in Chapter 7 (qualitative). The development of the BIMII toolbox was discussed and validated through interviews with subject matter experts. Improvements were made to the toolbox based on feedback from the subject matter experts. From the interviews, it was evident that there is a need for the toolbox, that the toolbox was easy to use and functional, it is effective in achieving its goals, and there is an opportunity to apply the toolbox within the construction industry.

8.2. Strengths and Limitations of the Study

This research study was strengthened by the adoption of a behavioural change theoretical approach to understanding the behaviour of construction industry stakeholders. The study used a systematic approach to develop and design a behaviour change intervention using the BCW. Utilising the COM-B model and the TDF, the research illustrated the relationship between the TDF domains and stakeholders' capability, opportunity, and motivation to adopt and implement sustainable construction practices and principles. The use of both qualitative and quantitative data helped to provide a better understanding of construction industry stakeholder's awareness, perception, and understanding of sustainable construction and contextualised the findings. Despite these strengths, there are certain limitations which need to be considered when interpreting the research findings. Limitations that arose from the study are discussed in Section 1.5. Additionally, it is important to note that the integrative review adopted in Phase One of the research study only included studies published in English and excluded any studies published prior to 2009. Due to a lack of accessibility to all global research databases, only articles accessible through the University of Stellenbosch's domain were included.

The responses from participants in Phase Two included mainly structural and civil engineers even though various disciplines of stakeholders were recruited. Due to the broad nature of sustainable construction, this research study focused on BIM as a sustainable project management process to facilitate the adoption and implementation of sustainable construction. The following section provides recommendations for future research which also considers some of the limitations discussed.

8.3. Recommendations for Future Research

Throughout the research study and analysis of the findings, some areas were identified as requiring improvement and therefore the following recommendations for future research are made:

8.3.1. Qualitative approach to examine barriers and drivers of sustainable construction

By adopting a qualitative theory-based approach, a future research study may provide greater in-depth detail about which domains should be targeted as the researcher will be able to probe more, using the TDF domains as a guide. The researcher may also be able to identify specific domains which were not highlighted by the quantitative approach, which restricts the participant's responses to a structured set of questions.

8.3.2. Include additional construction industry stakeholder disciplines

Although the research aimed to include all disciplines related to the design and development phase of construction, the majority of stakeholders who participated in the questionnaire survey were structural engineers, civil engineers and mechanical engineers. Future research should include additional disciplines from other stages of the project life cycle such as clients and project managers to understand the context of the research from varying perspectives.

8.3.3. Include stakeholders in Stage 2 and 3 of the BCW design

Future research could include construction industry stakeholders in Stage 2 and 3 of the behaviour change wheel design to identify intervention functions and BCTs which would be feasible within their unique disciplinary or organisational context.

8.3.4. Examine the utility of the behaviour change toolbox

This study is one of the first, to the researcher's knowledge, that has used behaviour change theory to develop a toolbox of intervention functions and behaviour change techniques to address changing behaviour in the construction industry in South Africa. Further research is therefore required to identify implementation strategies for using the BIMII toolbox in practice. It will be important to identify the conditions needed to support the use and implementation of the toolbox. Various case studies could be used to further validate the toolbox.

8.3.5. Include identifying policy categories which could be addressed

Additional research which is suited to further understand and develop the potential policy categories for behaviour change could be considered once the toolbox has been vigorously tested within the context of the construction industry and implementation strategies are successful. Policies could be established both internally within organisations and at public policy level as deemed appropriate.

8.3.6. Application of the behaviour change toolbox to other settings and target behaviours

The evidence presented in the current research provides a platform for future research to apply a behaviour change toolbox to other target behaviours within the realm of sustainable construction. For example, target behaviours could consider the implementation of sustainable construction methods (e.g. precast concrete and 3D printing of concrete), and sustainable construction materials (e.g. timbercrete and hempcrete).

8.3.7. Develop an interactive application or program which guides the use of the toolbox

Utilising an interactive system that manages the process of implementing the intervention components might prove useful to the individual or organisation who facilitates the adoption of the toolbox. The application could be an open system which allows users to add feedback, notes and progress across the various phases of the toolbox.

8.4. Concluding Statement

This research study contributes to the current literature about the awareness, perception and understanding of construction industry stakeholders and intervention design. The qualitative and quantitative methods adopted in this research provide a greater in-depth understanding of the barriers and drivers of sustainable construction adoption and implementation amongst construction industry stakeholders. The research provides proficient detail on the intervention functions and BCTs which will promote behaviour change in the construction industry and builds on the work of the BCW in research and intervention design.

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Appendix A
Psychological Theories Adopted in the Theoretical Domains Framework

Motivation Theories

i. Theory of planned behaviour (including theory of reasoned action, protection motivation theory, health belief model)
ii. Social cognitive theory
iii. Locus of control theories
iv. Social learning theory
v. Social comparison theory
vi. Cognitive adaptation theory
vii. Social identity theory
viii. Elaboration likelihood model
ix. Goal theories
x. Intrinsic motivation theories
xi. Self-determination theory
xii. Attribution theory
xiii. Decision making theories (e.g. social judgment theory, “fast and frugal” model, systematic versus heuristic decision making)
xiv. Fear arousal theory

Action Theories

i. Learning theory
ii. Operant theory
iii. Modelling
iv. Self-regulation theory
v. Implementation theory/automotive model
vi. Goal theory
vii. Volitional control theory
viii. Social cognitive theory
ix. Cognitive behaviour therapy
x. Transtheoretical model
xi. Social identity theory

Organisation Theories

i. Effort-reward imbalance
ii. Demand-control model
iii. Diffusion theory
iv. Group theory (e.g. group minority theory)
v. Decision making theory
vi. Goal theory
vii. Social influence
viii. Person situation contingency models

Appendix B
Summary of Articles used in Integrative Review

Year	Author(s)	Article Title	Journal or Conference	Country of Origin	Research Approach
2009	Pitt	Towards sustainable construction: promotion and best practices	Construction Innovation	United Kingdom	Quantitative
2011	Marchman and Clarke	Overcoming the Barriers to Sustainable Construction and Design Through a Cross-Reference of West Coast Practices	47th ASC Annual International Conference Proceedings	United States	Quantitative
2011	Häkkinen and Belloni	Barriers and drivers for sustainable building	Building Research & Information	Finland	Mixed Method
2012	Ismail *et al.*	Sustainable Initiative and Impediments towards Promoting Sustainable Construction in Malaysia	Colloquium on Humanities, Science & Engineering Research	Malaysia	Quantitative
2012	Shari and Soebarto	Delivering sustainable building strategies in Malaysia: Stakeholders' barriers and inspirations	International Journal of Sustainable Tropical Design Research and Practice	Malaysia	Qualitative
2013	Ahn *et al.*	Drivers and barriers of sustainable design and construction: The perception of green building experience	International Journal of Sustainable Building Technology and Urban Development	United States	Quantitative
2013	Samari *et al.*	The investigation of the barriers in developing green building in Malaysia	Modern Applied Science	Malaysia	Quantitative
2013	Serpell, Kort and Sergio	Awareness, actions, drivers and barriers of sustainable construction in Chile	Technological and Economic Development of Economy	Chile	Quantitative
2013	Shi *et al.*	Identifying the critical factors for green construction – An empirical study in China	Habitat International	China	Quantitative
2013	Wilson and Rezgui	Barriers to construction industry stakeholders' engagement with sustainability: toward a shared knowledge experience	Technological and economic development of Economy	Wales	Mixed Method
2014	Abidin and Powmya	Perceptions on Motivating Factors and Future Prospects of Green Construction in Oman	Journal of Sustainable Development	Oman	Quantitative
2014	Brennan and Cotgrave	Sustainable development A qualitative inquiry into the current state of the UK construction industry	Structural Survey	United Kingdom	Qualitative

Year	Author(s)	Article Title	Journal or Conference	Country of Origin	Research Approach
2014	Djokoto, Dadzie and Ohemeng-Ababio	Barriers to Sustainable Construction in the Ghanaian Construction Industry: Consultants Perspectives	Journal of Sustainable Development	Ghana	Quantitative
2014	Marker, Mason and Morrow	Change Factors Influencing the Diffusion and Adoption of Green Building Practices	Performance Improvement Quarterly	Pacific Northwest	Quantitative
2014	Opoku and Ahmed	Embracing sustainability practices in UK construction organizations Challenges facing intra-organizational leadership	Built Environment Project and Asset Management	United Kingdom	Mixed Method
2014	Windapo	Examination of Green Building Drivers in the South African Construction Industry: Economics versus Ecology	Sustainability	South Africa	Qualitative
2015	AlSanad	Awareness, Drivers, Actions, and Barriers of Sustainable Construction in Kuwait	Procedia Engineering	Kuwait	Quantitative
2015	Ametepey, Aigbavboa and Ansah	Barriers to successful implementation of sustainable construction in the Ghanaian construction industry	Procedia Manufacturing	Ghana	Mixed Method
2015	Gan *et al.*	Why sustainable construction? Why not? An owner's perspective	Habitat International	China	Mixed Method
2015	Khalfan *et al.*	Perceptions towards Sustainable Construction amongst Construction Contractors in State of Victoria, Australia	Journal of Economics, Business and Management	Victoria	Quantitative
2015	Mousa	A Business approach for transformation to sustainable construction: an implementation on a developing country	Resources, Conservation and Recycling	Egypt	Mixed Method
2015	Saleh and Alalouch	Towards sustainable construction in Oman: Challenges & Opportunities	Procedia Engineering	Oman	Mixed Method

Year	Author(s)	Article Title	Journal or Conference	Country of Origin	Research Approach
2016	Jiang and Wong	Key activity areas of corporate social responsibility (CSR) in the construction industry: a study of China	Journal of Cleaner Production	China	Qualitative
2017	Aigbavboa, Ohiomah and Zwane	Sustainable construction practices: ''a lazy view' 'of construction professionals in the South Africa construction industry	Energy Procedia	South Africa	Quantitative
2017	Chan *et al.*	Barriers Affecting the Adoption of Green Building Technologies	Journal of Management in Engineering	Multi-National	Quantitative
2017	Darko *et al.*	Examining issues influencing green building technologies adoption: The United States green building experts' perspectives	Energy & Buildings	United States	Quantitative
2017	Hwang *et al.*	Green commercial building projects in Singapore: Critical risk factors and mitigation measures	Sustainable Cities and Society	Singapore	Mixed Method
2018	Darko *et al.*	Influences of barriers, drivers, and promotion strategies on green building technologies adoption in developing countries: The Ghanaian case	Journal of Cleaner Production	Ghana	Quantitative
2018	Chan *et al.*	Critical barriers to green building technologies adoption in developing countries: The case of Ghana	Journal of Cleaner Production	Ghana	Quantitative
2018	Munyasya *et al.*	Towards Sustainable Infrastructure Development: Drivers, Barriers, Strategies, and Coping Mechanisms	Sustainability	Australia	Mixed Method
2018	Yin *et al.*	An evaluation of sustainable construction perceptions and practices in Singapore	Sustainable Cities and Society	Singapore	Quantitative
2019	Klufallah *et al.*	Sustainable practices barriers towards green projects in Malaysia	IOP Conference Series: Earth and Environmental Science	Malaysia	Quantitative
2019	Lim *et al.*	Awareness and practices of sustainable construction in Australia: Consultant quantity surveyors' perception	AIP Conference Proceedings	Australia	Quantitative

Year	Author(s)	Article Title	Journal or Conference	Country of Origin	Research Approach
2019	Martek *et al.*	Barriers inhibiting the transition to sustainability within the Australian construction industry: An investigation of technical and social interactions	Journal of Cleaner Production	Australia	Qualitative
2019	Pham *et al.*	Managerial perceptions on barriers to sustainable construction in developing countries: Vietnam case	Environment, Development and Sustainability	Vietnam	Quantitative
2019	Oke *et al.*	Drivers of Sustainable Construction Practices in the Zambian Construction Industry	Energy Procedia	Zambia	Quantitative
2019	Zhang, Oo & Lim	Drivers, motivations, and barriers to the implementation of corporate social responsibility practices by construction enterprises: A review	Journal of Cleaner Production	Australia	Qualitative

Appendix C
Code List for Barriers to Sustainable Construction Categories

Code Group	Code	Code Descriptor	Code Description
Socio-Cultural (Awareness, Knowledge and Information)	**KN**	Knowledge	Lack of Knowledge of Sustainable Construction Practices and its benefits
	UN	Understanding	Lack of Understanding of Sustainable Construction Practices and its benefits
	AW	Awareness	Lack of Awareness of Sustainable Construction
	TE	Training and Education	Lack of training and education in sustainable construction
	UC	Uncertainty	Uncertainty and scepticism about the necessity for sustainable construction practices
	DI	Distrust	Distrust in information sources including consistency, validity, authority, and timeliness
	IC	Increased Cost	Perceived increased cost of sustainable construction
	IN	Interest	Lack of Interest in green initiatives and sustainable construction
Economic (Economy, Market, Investment)	**PR**	Delayed Profits	Long pay-back periods of adopting green technologies
	CSM	Cost of Sustainable Materials	Increased cost of sustainable materials and products increases the capital cost
	PD	Project Delays	Implementing sustainable construction practices is time consuming which causes project delays
	RI	Risk of Investment	Risk of investment with implementation of new sustainable materials and methods
	DE	Demand	Lack of Demand for Sustainable Construction Projects from Clients
Stakeholder (Leadership, Management, Professionals)	**PE**	Professional Expertise	Lack of professional knowledge and expertise
	RE	Resistance to Change	Resistance to change traditional construction processes
	IT	Integration and Collaboration	Lack of integrated work environment and communication among all stakeholders
Political (Government Regulations, Incentives, Policies)	**CR**	Codes and Regulation	Lack of building codes and regulation
	MR	Monitoring and Enforcement	Lack of monitoring and enforcement through building codes and regulation
	GS	Government Support	Lack of government support and incentives
Technological (Products, Materials, Technological Specifications)	**TS**	Technological Specifications	Lack of adequate green technological specifications
	PS	Product Suppliers	Limited availability of green product suppliers, materials and technologies
	DA	Databases and Information	Lack of databases and information for green technologies

Appendix D
Code List for Drivers to Sustainable Construction Categories

Code Group	Code	Code Descriptor	Code Description
Socio-Cultural (Awareness, Knowledge and Information)	**KN**	Knowledge	Increase Knowledge of Sustainable Construction Practices and its social, environmental and economic benefits
	AW	Awareness	Increase Awareness of Sustainable Construction amongst construction industry stakeholders
	ED	Education	Increase education programmes about sustainable construction for construction industry stakeholders
	TR	Training	Provide sustainable construction training programmes for construction industry stakeholders
	EUB	End User Benefits	Adopting and implementing sustainable construction on building projects has benefits to end users' productivity
	QU	Quality of Life	Adopting and implementing sustainable construction on building projects improving indoor environmental quality, enhance occupants' health, comfort and well-being
	DI	Demand and Interest	Increased client and stakeholder demand and interest
Economic (Economy, Market, Investment)	**JO**	Job Opportunities	Venturing into SC will ensure more opportunities by developing a market for it and the creation of job opportunities
	RWLC	Reduced Whole Lifecycle Costs	Adopting and implementing SC reduces the whole lifecycle costs of a building
	HRI	High Return on Investment	There will be a high return on the investment of a building project if SC is adopted and implemented
	IPV	Increased Property Value	SC will enhance the value of the property due to better rental income.
	IE	Improved Economy	Improve the performance of the national economy and creating regional centres of excellence
	AF	Access to Funding	Support from financial institutions and government to introduce lending schemes customized for SC building projects
Environmental (Energy, Water and Resource Conservation, Waste Reduction)	**EP**	Protecting the Environment	SC promotes protecting the environment and reducing environmental impact of the construction industry
	EC	Energy Conservation	SC promotes energy conservation and energy-efficiency of buildings

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Environmental	**WC**	Water Conservation	SC promotes water conservation and water-efficiency of buildings
	RC	Resource Conservation	SC promotes environmental and resource conservation and resource-efficiency
	WR	Waste Reduction	SC promotes waste reduction
	RMU	Reduced Material Use	Reduced use of construction materials in the economy
Stakeholder (Leadership, Management, Professionals)	**CI**	Corporate Image	SC could provide a good corporate image and reputation in the industry
	CA	Competitive Advantage	SC could provide a competitive advantage and market differentiation
	CSR	Corporate Social Responsibility	SC shows the organisation's commitment to their environmental and social responsibility
	ID	Integrated Design	SC provides a whole/integrated building design approach with multiple project stakeholders
	EMS	Executive Management Support	Encouraging and supporting implementation of SC from executive management
	DSC	Develop Sustainability Culture	Encourage an organisational culture and awareness about SC through continued organisational learning and training
	SSS	Set a SC Standard	SC provides an opportunity to set a standard for future development, design and construction in the built environment
	BPS	Best Practice Sharing of SC	Organisations should facilitate a culture of best practice sharing of SC methods and processes
	CO	Commitment	SC implementation requires a mutual understanding and commitment of SC procurement and cooperation amongst all project professionals
	BI	Build Internal Capacity	Dedicated resources, sustainability expertise for facilitating green procurement & decision making
	CB	Change Behaviour	Commit to changing behaviour
	CCP	Change Construction Processes	Specifications and construction methods should consider environmental requirements
Political (Government Regulations, Incentives, Policies)	**IS**	Incentives	Government should encourage and support SC through financial and further market-based incentives
	LUP	Land Use and Planning Policies	Updated land use regulations and urban planning policies
	RSS	Rating Systems and Standards	Performance-based measurements such as green building rating systems, sustainable design guidelines and construction standards
	MBP	Mandatory Building Policies	Mandatory SC building and planning policies and regulations
	ESP	Enforce Policies	Better enforcement of green building policies after they have been developed

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Political	**DRM**	Develop regulatory mechanisms	Developing and strengthening regulatory mechanisms through policy monitoring
	SIM	Strengthen implementation mechanisms	Develop and strengthen implementation mechanisms through policy implementation efforts such as benchmarking
	IF	Institutional Framework	Availability of institutional framework to guide the effective implementation of SC
	TR	Tax Relief	Tax relief should be available for developers and contractors for the use of sustainable building products, systems, and technologies
	SURD	Subsidies for R&D	Government should provide subsidies for research and development of sustainable building products, systems, and technologies
Technological (Products, Materials, Technological Specifications)	**PCI**	Product Certification and Innovation	Product and material innovation and/or certification for SC purposes should be readily available to improve access to sustainable technology
	DSM	Develop Sustainable Materials	Materials manufacturers should play a proactive role in the creation of sustainable technologies to mitigate the environmental impact
	SRD	Strengthened R&D	A collaborative and strengthened research & development (R&D) within the construction industry is necessary for new and/or improved sustainable building technologies
	AI	Availability of Information about SC	Availability of better information on cost and benefits of sustainable building technologies and sustainable product information from a reliable database

Appendix E
Barriers and Drivers mapped to COM-B and TDF

COM-B	Capability			Opportunity	Motivation		
	Psychological			Physical	Reflective		Automatic
TDF	**Know**	**Cog**	**Beh Reg**	**Env**	**Id**	**Bel Cons**	**Reinf**
Knowledge of SC	■						
Understanding of SC		■					
Awareness of SC	■						
Training in SC		■					
Education of SC		■					
Uncertainty about necessity of SC						■	
Scepticism about necessity of SC						■	
Distrust in SC information sources				■			
Increased cost of SC Implementation						■	
Interest in SC and green initiatives				■			
End user benefits such as productivity						■	
SC implementation improves the quality of life of occupants of sustainable buildings						■	
Demand for SC in the construction industry	■						

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Long pay-back periods after adopting SC							
Sustainable products and processes increase capital cost							
SC implementation will cause project delays							
Risk of investment with sustainable products and processes							
SC will provide job opportunities through the growth of a green market							
SC reduces the whole lifecycle cost of a building							
Adopting SC on a building project will generate a high return on investment							
Adopting SC on a building project will enhance the value of the property							
SC will improve and boost the national economy							
Access to funding for adopting sustainable alternatives will increase adoption							
SC promotes reducing environmental impact of the construction industry							
SC promotes energy conservation and energy-efficiency of buildings							
SC promotes water conservation and water-efficiency of buildings							
SC promotes environmental and resource conservation and resource-efficiency							
SC promotes waste reduction							
SC promotes the reduced use of construction materials in the economy							
Professional expertise with knowledge and understanding of SC is required							
Resistance to change traditional construction products and processes which do not consider environmental requirements							
SC provides integration and collaboration amongst construction industry stakeholders							
SC could provide a good corporate image and reputation in the industry							
SC could provide a competitive advantage and market differentiation							
SC shows an organisation's commitment to their environmental and social responsibility							

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SC requires encouragement and support from executive management							
Organisations should encourage an organisational culture and awareness about SC							
SC provides an opportunity to set a standard for future development, design and construction in the built environment							
Organisations should facilitate a culture of best practice sharing of SC methods and processes							
SC implementation requires a mutual understanding and commitment amongst all project professionals							
Organisations should build internal capacity with sustainability expertise to facilitate SC implementation							
Stakeholders in the construction industry should commit to changing behaviour							
Building codes, regulations and legislation							
Monitoring and enforcement of SC							
Government support and incentives for SC building projects							
Performance-based rating systems and standards will promote the adoption of SC							
Mandatory SC building policies and regulations and environmental regulations should be implemented							
Better enforcement of SC building policies after they have been developed is required							
Developing and strengthening regulatory mechanisms and policy monitoring systems will improve SC adoption							
An institutional framework should be made available to guide the effective implementation of SC							
Tax relief should be available for the use of sustainable building products, systems and technologies							
Government should provide subsidies for research and development of sustainable building products, systems, and technologies							
Product and material innovation and/or certification for SC purposes should be readily available							

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Materials manufacturers should play a proactive role in the creation of sustainable technologies							
A collaborative and strengthened research & development (R&D) within the construction industry is necessary							
Availability of better information on cost and benefits of sustainable building technologies from a reliable database							

Appendix F
Online Consent Form and Questionnaire Survey

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STELLENBOSCH UNIVERSITY
ELECTRONIC CONSENT TO PARTICIPATE IN RESEARCH

TITLE OF RESEARCH PROJECT:	**Development of a Behaviour Change Intervention Toolbox to improve the Adoption and Implementation of Sustainable Construction Practices by stakeholders in the South African construction industry**
REFERENCE NUMBER:	ING-2019-1504
PRINCIPAL INVESTIGATOR:	Ralmar Marsh
ADDRESS:	Department of Industrial Engineering, 145 Banghoek Rd, Stellenbosch Central, Stellenbosch, 7600
CONTACT NUMBER:	+353 89 486 2420
E-MAIL:	ralmar119@gmail.com

Dear Prospective Participant

Kindly note that I am a MEng student at the Department of Industrial Engineering at Stellenbosch University, and I would like to invite you to participate in a research project entitled "*Development of a Behaviour Change Intervention Toolbox to improve the Adoption and Implementation of Sustainable Construction Practices by stakeholders in the South African construction industry*".

Please take some time to read the information presented here, which will explain the details of this project and contact me if you require further explanation or clarification of any aspect of the study. This study has been approved by the Research Ethics Committee (REC) at Stellenbosch University and will be conducted according to accepted and applicable national and international ethical guidelines and principles.

1. **INTRODUCTION:**

   Sustainable construction can be broadly defined as how the construction industry and built environment professionals can contribute to the sustainability of our environment, our economies and our societies. It involves considering and adopting sustainable alternatives in design and technologies throughout the life cycle of a project. The product of sustainable construction is in the form of green buildings which is most commonly referred to in the construction industry. By adopting sustainable construction principles, we reduce our impact on the natural environment whilst still providing increased economic activity for a growing economy. We can therefore provide longevity and quality of life for both society and the environment and those of generations to come.

2. **PURPOSE:**

   While sustainable construction has gained increasing attention internationally, there are still limited studies which address sustainable construction in the South African context, and how to introduce and effectively implement sustainable solutions. This study aims to provide an overview of what currently drives the adoption of sustainable construction and which challenges need to be addressed in the construction industry.

3. **PROCEDURES:**

   I would like to invite you to take part in an online survey, the results of which will contribute to my research project in order to complete my Masters in Engineering Management.

   The online survey questionnaire will take approximately 20 minutes to complete and will contain a combination of questions covering: *Section 1*. General information about yourself relating to your experience as a built environment professional, *Section 2 through to Section 5*. Rating statements about *Knowledge, Skills and Social/Professional Role and Identity*, *Beliefs about capabilities, Optimism, Beliefs about Consequences*, *Reinforcement, Intentions, Goals, Social Influences, Behavioural Regulation and Environmental Context and Resources* based on your understanding of sustainable construction. A brief description of all the terms used in the survey will be available at the start of the survey to provide context and clarification.

4. **TIME:** The online survey questionnaire will take approximately **20 minutes** to complete.

5. **RISKS:** There are no risks to participating in this study which will be of any harm to any participant.

6. **BENEFITS:**

   The research study aims to increase the awareness of how built environment professionals view sustainability and perhaps consider sustainable alternatives in their designs. This in turn will ensure that we reduce our impact on the natural environment whilst still providing increased economic activity to sustain the growing economy. It provides longevity for the livelihoods and quality of life of our society and those of generations to come which benefits all individuals in our society. To show my gratitude for your participation, 4x R500 Takealot vouchers will be given to four participants who will be chosen randomly. Please provide your email at the end of the survey to be entered into the lucky draw. Please note that your email address will not be linked to your survey responses. If you do not wish to be a part of this lucky draw you do not need to provide your email address.

7. **PARTICIPATION & WITHDRAWAL:**
   It is very important that participants feel completely comfortable before or during the online questionnaire. If you choose to no longer participate in the study, you can withdraw your participation before or during the online questionnaire without feeling any pressure or guilt for choosing to withdraw. If you do choose to withdraw at any point before or during the study, any information provided by yourself through the questionnaire before withdrawal from the study will not be used in the research study. No personal information will be collected during the study and therefore the information you provide will purely be to aid the study which would not harm you in any way. If the questionnaire is incomplete, the information will be omitted from the research study and recorded as an omission for reference purposes only.

8. **CONFIDENTIALITY:**

   The information and responses to the survey will be protected by being kept on a personal, password encrypted computer. All information collected will be confidential and anonymous and there is no way to link responses back to any participant or organisation as no personal identifiable information will be requested. Only myself and my research supervisors will have access to the survey responses. All the data collected will be safely stored by the researcher and supervisors for the duration of the study. Your email address will not be linked to your survey responses and will be kept confidential and destroyed after the winners have been contacted.

9. **RECORDINGS:** There will be no audio or video recordings of the online survey questionnaire.

10. **DATA STORAGE:**

    Each participant's completed questionnaire will be stored separately a password protected laptop as well as a password protected virtual drive. This ensures that during data collection and analysis, the data is stored in at least more than one location so that in the event of data loss on one of the storage locations, the data can be retrieved on another. Data files will primarily be electronic files of information extracted from the online survey results in Microsoft Excel Format. All the information from the online survey results will be grouped according to codes related to categories of built environment professionals (such as Engineer or Architect) to provide a reference point throughout the data analysis. Only myself the primary researcher and my research supervisors will have access to the survey responses. All the data collected will be safely stored by the supervisors for the duration of the study and will be destroyed after 5 years.

If you have any questions or concerns about this research project, please feel free to contact the researcher Ralmar Marsh at ralmar119@gmail.com or +353 89 486 2420 and/or the Supervisors, Mrs Imke de Kock and Prof Alan Brent at imkedk@sun.ac.za and acb@sun.ac.za respectively.

RIGHTS OF RESEARCH PARTICPANTS: You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché (mfouche@sun.ac.za / 021 808 4622) at the Division for Research Development. You have the right to receive a copy of this Consent form.

If you are willing to participate in this research project, please select the relevant box in the Declaration of Consent below which confirms that you have read and understood the above explanation about the study, and that you agree to participate. You also understand that your participation in this study is strictly voluntary.

Declaration by the participant

As the **participant** I hereby declare that:

- I have read the above information and it is written in a language with which I am fluent and comfortable.
- I have had a chance to ask questions and all my questions have been adequately answered.
- I understand that taking part in this study is voluntary and I have not been pressurised to take part.
- I may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- If the principal investigator feels that it is in my best interest, or if I do not follow the study plan as agreed to, then I may be asked to leave the study before it has finished.
- All issues related to privacy, and the confidentiality and use of the information I provide, have been explained to my satisfaction.

As the **participant** I hereby select the following option:

	I accept the invitation to participate in your research project, and if I decide to complete the questionnaire it would automatically mean that I have given consent for my responses to be used confidentially and anonymously.

Questionnaire Survey

Introduction to Project

This questionnaire examines the awareness and understanding of sustainable construction by built environment professionals. It aims to help identify the challenges facing the construction industry in adopting sustainable alternatives to design and development and how to overcome them.
Please read the definitions below for a better understanding of the terms used in the survey.

What is Sustainable Construction?

Sustainable construction can be broadly defined as how the construction industry and built environment professionals can contribute to the sustainability of our environment, our economies and our societies. It involves considering and adopting sustainable alternatives in design, construction methods and technologies (which include products and materials) throughout the life cycle of a project.

What are the principles of Sustainable Construction?

The key principles of sustainable construction are:

1. Minimise resource consumption (Conserve)
2. Maximise resource reuse (Reuse)
3. Use renewable or recyclable resources (Renew/Recycle)
4. Protect the natural environment (Protect Nature)
5. Create a healthy, non-toxic environment (Non-Toxics)
6. Pursue quality in creating the built environment (Quality)

What is Green Building?

Green Building can be defined as a resource-efficient, energy-efficient, and environmentally responsible building. Green buildings are representative of the structures designed and constructed to address environmental concerns whereas sustainable construction incorporates economic and social concerns as well.

What is Sustainable Building?

The product of sustainable construction is in the form of a sustainable building which requires more than identifying solutions to specific problems, but changes to attitudes, processes and systems to deliver the project. This involves the participation of all construction industry professionals collaborating to achieve an integrated sustainable design. By adopting sustainable construction principles, we reduce our impact on the natural environment whilst still providing increased economic activity for a growing economy and take into consideration the needs of society.

For the purposes of this survey, the term sustainable construction will be abbreviated as SC for ease of reference and includes green buildings and sustainable buildings.

Section 1: General Background Information

1. **What is your current professional discipline?**
    a. Property Developer/Consultant
    b. Contractor
    c. Quantity Surveyor
    d. Architect
    e. Landscape Architect
    f. Structural Engineer
    g. Civil Engineer
    h. Mechanical Engineer
    i. Electrical Engineer
    j. Geotechnical Engineer
    k. Environmental Engineer
    l. Façade Engineer

2. **Number of years of professional experience *(after first qualification)***
    a. Between 0-5 years
    b. 5-10 years (Including 5 and less than 10)
    c. 10-20 years (Including 10 and less than 20)
    d. More than 20 years (Including 20)

3. **Number of employees in your organisation**
    a. Up to 10
    b. 11-50
    c. 51-250
    d. Above 250

4. **Please select all discipline services available in your organisation (Tick all that apply)**
    a. Property Developer/Manager
    b. Contractor
    c. Quantity Surveyor
    d. Architect
    e. Landscape Architect
    f. Structural Engineer
    g. Civil Engineer
    h. Mechanical Engineer
    i. Electrical Engineer
    j. Geotechnical Engineer
    k. Environmental Engineer
    l. Façade Engineer

5. **Has your organisation ever been involved in a green building project?**
    a. Yes
    b. No
    c. I am not sure

6. **Have you ever been involved in a green building project at your current organisation?**
    a. Yes
    b. No
    c. I am not sure

Section 2: Knowledge, Skills and Social/Professional Role and Identity

Please rate the statements in the following Sections about sustainable construction based on your understanding of sustainable construction. ***(Likert scale provided: Strongly Disagree (1), Disagree (2), Neutral (3), Agree (4), Strongly Agree (5))***

CF1	I am aware of the content and objectives of SC principles and sustainable building design
CF2	I know the content and objectives of SC principles and sustainable building design
CF3	I am familiar with the content and objectives of SC principles and sustainable building design
CF4	There is an interest in the construction industry to adopt and implement SC principles on building projects
CF5	There is a demand in the construction industry to adopt and implement SC principles on building projects
CF6	I understand what SC is and how it benefits society, the environment and the economy
CF7	The skills required to adopt and implement SC principles are within the scope of a contractor [include other stakeholder titles separately]
CF8	There are education programmes, workshops and conferences (and other platforms) available to learn about SC for construction industry stakeholders
CF9	Training is available through my organisation to enhance the skills required to adopt and implement SC principles
CF10	Training is offered through various platforms outside my organisation to support the development of my skills to adopt and implement SC principles on building projects
CF11	It is my responsibility as a professional in the construction industry to adopt and implement SC principles on building projects
CF12	Protecting the environment, improving the growth in the economy and improving the quality of life of society is part of my work as a construction industry professional.
CF13	I have a role to play as a construction industry professional to consider sustainable alternatives in construction processes within my field of expertise.
CF14	Adopting and implementing SC could provide a good corporate image and reputation for my organisation in the construction industry
CF15	SC could provide a competitive advantage and market differentiation for my organisation in the construction industry
CF16	Adopting and implementing SC principles would show my organisation's commitment to the environment and social responsibility.
CF17	The principle of SC would provide an opportunity for myself to develop new partnerships and collaborations within industry sectors and amongst project stakeholders
CF18	Adopting and implementing SC principles would allow me to form part of an integrated and whole building design approach with multiple stakeholders on building projects
CF19	SC provides me with an opportunity to set a standard for future development, design and construction in the built environment.

Section 3: Beliefs about capabilities, Optimism and Beliefs about Consequences

Please rate the statements in the following Sections about sustainable construction based on your understanding of sustainable construction. ***(Likert scale provided: Strongly Disagree (1), Disagree (2), Neutral (3), Agree (4), Strongly Agree (5))***

CF20	I am confident that if I had the skills and expertise I would adopt SC principles on building projects
CF21	I am confident that if I had the skills and expertise I would adopt SC principles even when there are time constraints on a building project
CF22	I am confident that if I had the skills and expertise I would adopt SC principles even when there is no incentive to do so on a building project
CF23	If SC principles are adopted and implemented on building projects I would expect positive outcomes for the economy, society and the environment
CF24	SC represents a positive change for the construction industry in South Africa
CF25	When SC is implemented there on building projects it improves end users' productivity
CF26	There are improvements on indoor environmental quality, enhanced occupants' health, comfort and well-being when SC is implemented
CF27	Venturing into SC will ensure more opportunities by developing a market for growth in the construction industry and the creation of job opportunities
CF28	There is a necessity to adopt and implement SC principles on building projects
CF29	Implementing SC practices is time consuming which causes project delays
CF30	Adopting and implementing SC will increase the capital cost of construction of building projects
CF31	Sustainable products and materials will increase the capital cost of building projects
CF32	There is a risk of investment with implementation of new sustainable materials and construction methods
CF33	I am sceptical about the necessity to adopt and implement SC principles on building projects
CF34	Adopting and implementing SC reduces the whole lifecycle costs of a building
CF35	There are long pay-back periods of adopting SC on building projects as profits are only derived during the maintenance and operations phase
CF36	There will be a high return on the investment of a building project if SC is adopted and implemented
CF37	SC will enhance the value of the property due to better rental income
CF38	SC will improve the performance of the national economy by creating a demand for green construction and developing the green technology market

Section 4: Reinforcement, Intentions, Goals, Social Influences and Behavioural Regulation

Please rate the statements in the following Sections about sustainable construction based on your understanding of sustainable construction. ***(Likert scale provided: Strongly Disagree (1), Disagree (2), Neutral (3), Agree (4), Strongly Agree (5))***

CF39	Support from financial institutions and government to introduce lending schemes customized for SC building projects will increase the adoption and implementation thereof
CF40	Government should encourage and support SC through financial and further market-based incentives
CF41	Tax relief should be available for developers and contractors for the use of sustainable building products, systems, and technologies
CF42	Government should provide subsidies for research and development of sustainable building products, systems, and technologies
CF43	I intend to develop my knowledge and skills that will equip me to adopt and implement SC principles on building projects in the future.
CF44	I will consider adopting SC principles on building projects in the future.
CF45	I intend to promote the education of SC in my organisation to adopt and implement SC principles on building projects.
CF46	I intend to promote the training of SC in my organisation to adopt and implement SC principles on building projects.
CF47	Increasing my knowledge and awareness on SC is an important goal in my career as a professional in the construction industry.
CF48	Most professionals in the industry whose opinion I value would support and encourage SC
CF49	My superiors in the construction industry would like me to develop my skills and knowledge about SC
CF50	My colleagues in the construction industry demonstrate an interest in adopting and implementing SC
CF51	There is a resistance in the construction industry to change traditional construction processes to more SC specifications and construction methods which consider environmental and societal requirements as well.
CF52	Professionals in the construction industry should commit to changing their behaviour as industry representatives to adopt sustainable alternatives to design and construction.

Section 5: Environmental Context and Resources

Please rate the statements in the following Sections about sustainable construction based on your understanding of sustainable construction. ***(Likert scale provided: Strongly Disagree (1), Disagree (2), Neutral (3), Agree (4), Strongly Agree (5))***

CF53	There is a lack of interest in sustainable construction initiatives in the construction industry
CF54	There is a lack of an integrated work environment and communication amongst construction industry professionals
CF55	There is a lack of adequate sustainable technological specifications
CF56	There is a limited availability of sustainable product suppliers
CF57	There is a lack of databases and information for sustainable construction technologies
CF58	Adopting SC promotes the protection of the environment and reduces the environmental impact of the construction industry
CF59	Adopting SC promotes energy conservation and energy-efficiency of buildings
CF60	Adopting SC promotes water conservation and energy-efficiency of buildings
CF61	Adopting SC fosters more efficient use of resources and promotes environmental and resource conservation and resource-efficiency
CF62	Adopting SC promotes waste reduction and reduces the use of construction materials in the construction industry
CF63	Encouraging and supporting implementation of SC from executive management through the development of internal capacity is necessary
CF64	Organisations should encourage an organisational culture and awareness about SC through continued organisational learning and training
CF65	Organisations should facilitate a culture of best practice sharing of SC methods and processes
CF66	Effective implementation requires the mutual understanding and commitment of SC procurement and cooperation of all project professionals in the construction industry
CF67	Performance-based measurements such as green building rating systems and sustainable design guidelines and construction standards will promote the implementation of SC
CF68	Mandatory SC building policies and regulations and environmental regulations by the government will increase the adoption and implementation of SC
CF69	Better enforcement of SC building policies after they have been developed will ensure the adoption and implementation of SC
CF70	Developing and strengthening regulatory mechanisms and policy monitoring systems will improve the adoption and implementation of SC
CF71	An institutional framework should be made available to guide the effective implementation of SC
CF72	Product and material innovation and/or certification for sustainable construction purposes should be readily available to improve access to sustainable technology
CF73	Materials manufacturers should play a proactive role in the creation of sustainable technologies to mitigate the environmental impact
CF74	A collaborative and strengthened research & development (R&D) within the construction industry is necessary for new and/or improved sustainable building technologies
CF75	Availability of better information on cost and benefits of sustainable building technologies and sustainable product information from a reliable database

Thank you for taking the survey.

Appendix G
Interview Consent Form

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STELLENBOSCH UNIVERSITY
ELECTRONIC CONSENT TO PARTICIPATE IN RESEARCH

TITLE OF RESEARCH PROJECT:	Barriers and Drivers of the adoption and implementation of Sustainable Construction Practices: A view of construction industry stakeholders in South Africa
REFERENCE NUMBER:	ING-2019-1504
PRINCIPAL INVESTIGATOR:	Ralmar Marsh
ADDRESS:	Department of Industrial Engineering, 145 Banghoek Rd, Stellenbosch Central, Stellenbosch, 7600
CONTACT NUMBER:	+353 89 486 2420
E-MAIL:	ralmar119@gmail.com

Dear Prospective Participant

Kindly note that I am a MEng student at the Department of Industrial Engineering at Stellenbosch University, and I would like to invite you to participate in a research project entitled "Barriers and Drivers of the adoption and implementation of Sustainable Construction Practices: A view of construction industry stakeholders in South Africa".

Please take some time to read the information presented here, which will explain the details of this project and contact me if you require further explanation or clarification of any aspect of the study. This study has been approved by the Research Ethics Committee (REC) at Stellenbosch University and will be conducted according to accepted and applicable national and international ethical guidelines and principles.

1. **INTRODUCTION:**

   Sustainable construction can be broadly defined as how the construction industry and built environment professionals can contribute to the sustainability of our environment, our economies and our societies. It involves considering and adopting sustainable alternatives in design and technologies throughout the life cycle of a project. The product of sustainable construction is in the form of green buildings which is most commonly referred to in the construction industry. By adopting sustainable construction principles, we reduce our impact on the natural environment whilst still providing increased economic activity for a growing economy. We can therefore provide longevity and quality of life for both society and the environment and those of generations to come.

2. **PURPOSE:**

   While sustainable construction has gained increasing attention internationally, there are still limited studies which address sustainable construction in the South African context, and how to introduce and effectively implement sustainable solutions. This study aims to provide an overview of what currently drives the adoption of sustainable construction and which challenges need to be addressed in the construction industry.

   This interview aims to examine the potential application and effectiveness of utilizing the Behaviour Change Wheel and Behaviour Change Techniques to understand the behaviour of construction industry professionals with regards to the adoption and implementation of sustainable construction. The behaviour change intervention toolbox designed in this research study aims to assist construction industry stakeholders with a guide to adopt and implement building information modelling (BIM) as a sustainable project management process within their organisation.

3. **PROCEDURES:**

   I would like to invite you to participate in an interview, the results of which will contribute to my research project in order to complete my Masters in Engineering Management.

   The interview will take approximately 45 minutes and will contain a combination of questions covering the applicability and practicality of applying the behaviour change intervention toolbox within an organisation in the built environment. The aim of the toolbox will be to increase the awareness, adoption and implementation of sustainable construction through the adoption of BIM. A brief description of the research methodology used, the Behaviour Change Wheel and Behaviour Change Toolbox and Techniques will be provided at least two weeks before the interview. This will provide sufficient time before the interview for the interviewee to review the information. If the interviewee cannot attend the interview for any reason, there will be option for the interviewee to submit the completed interview schedule which will be provided as an open-ended questionnaire, similar to the interview schedule guide the researcher would have used.

4. **TIME:** The interview will take approximately 45 minutes and might vary depending on the outcomes at the time.

5. **RISKS:** There are no risks to participating in this study which will be of any harm to any participant.

6. **BENEFITS:**

   The research study aims to increase the awareness of how built environment professionals view sustainability in the construction industry and to consider alternative solutions to project management and design solutions on future projects. This in turn will ensure that we reduce our impact on the natural environment whilst still providing increased economic activity to sustain the growing economy. It provides longevity for the livelihoods and quality of life of our society and those of generations to come which benefits all individuals in our society.

7. **PARTICIPATION & WITHDRAWAL:**
   It is very important that participants feel completely comfortable before or during the interview. If you choose to no longer participate in the study, you can withdraw your participation before or during the interview without feeling any pressure or guilt for choosing to withdraw. If you do choose to withdraw at any point before or during the study, any information provided by yourself throughout the interview before withdrawal from the study will not be used in the research study. If the interview schedule is not completed, the information obtained prior to withdrawal will be omitted from the research study and recorded as an omission for reference purposes only.

8. **CONFIDENTIALITY:**

   The information and responses to the interview will be protected by being kept on a personal, password encrypted computer. All information collected will be confidential and each participant's information will be stored separately on a password protected laptop. Audio data recorded will be removed from the audio device as soon as it is possible, encrypted, password protected and stored securely. Transcription will be carried out in a private space. All personal identification information will be removed or changed during transcription. When transcriptions are completed they will be handled with caution, stored on a secure laptop and the full transcripts will only be accessible to myself, the primary researcher and my research supervisors. Digital copies of the files will be encrypted, password protected and stored securely.
9. **RECORDINGS:** There will audio recordings of the interview which only be used to disseminate information from the interview.

10. **DATA STORAGE:**

    Each participant's interview schedule will be stored separately a password protected laptop as well as a password protected virtual drive. This ensures that during data collection and analysis, the data is stored in at least more than one location so that in the event of data loss on one of the storage locations, the data can be retrieved on another. Data files will primarily be electronic files of information extracted from the audio recordings and Microsoft Word documents, PDFs and Microsoft Excel Format. All the data will be safely stored by the researcher and supervisors for the duration of the study and will be destroyed after 5 years.

If you have any questions or concerns about this research project, please feel free to contact the researcher Ralmar Marsh at ralmar119@gmail.com or +353 89 486 2420 and/or the Supervisors, Mrs Imke de Kock and Prof Alan Brent at imkedk@sun.ac.za and acb@sun.ac.za respectively.

RIGHTS OF RESEARCH PARTICPANTS: You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché (mfouche@sun.ac.za / 021 808 4622) at the Division for Research Development. You have the right to receive a copy of this Consent form.

If you are willing to participate in this research project, please select the relevant box in the Declaration of Consent below which confirms that you have read and understood the above explanation about the study, and that you agree to participate. You also understand that your participation in this study is strictly voluntary. Declaration by the participant

As the **participant** I hereby declare that:

- I have read the above information and it is written in a language with which I am fluent and comfortable.
- I have had a chance to ask questions and all my questions have been adequately answered.
- I understand that taking part in this study is voluntary and I have not been pressurised to take part.
- I may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- If the principal investigator feels that it is in my best interest, or if I do not follow the study plan as agreed to, then I may be asked to leave the study before it has finished.
- All issues related to privacy, and the confidentiality and use of the information I provide, have been explained to my satisfaction.

As the **participant,** you can select one of the options below and copy it into the email I have sent to respond and confirm or decline your participation in the research study.

I accept the invitation to participate in your research project, and if I decide to be interviewed it would automatically mean that I have given consent for my responses to be used confidentially and anonymously.
I accept the invitation to participate in your research project, and if I decide to complete the questionnaire it would automatically mean that I have given consent for my responses to be used confidentially and anonymously.
I decline the invitation to participate in your research project.

Appendix H
Interview Project Description

1. Interview Project Background

This interview aims to examine the potential application and effectiveness of utilizing the Behaviour Change Wheel and Behaviour Change Techniques to understand the behaviour of construction industry professionals with regards to the adoption and implementation of sustainable construction. The behaviour change intervention toolbox developed is called the Building Information Modelling Implementation Intervention (BIMII) toolbox. This interview schedule will provide insight into the development of the BIMII toolbox and follow with a questionnaire.

1.1 The need for Behavioural Change

At the core of how the construction industry interacts with the environment, economy and society is human behaviour. The construction industry is one of the largest consumers of natural resources through the extraction of raw materials, consumption of raw materials to produce building materials and construction activities on building project sites. Decisions about various types of construction materials, reusing and recycling of construction materials as well as choosing alternative sustainable materials is directly influenced by stakeholders at project level. Due to the high level of energy, water and land consumption in the construction sector, there is a need for built environment stakeholders to assess the current design and development of buildings and provide innovative solutions to ensure the sustainability of the environment. Given the extent of the environmental challenges faced by many countries, the transition towards the adoption of sustainable alternatives in the construction industry must include dimensions of changing human behaviour (Klaniecki *et al.*, 2018).

1.2 Behaviour Change Wheel

Michie, van Stralen & West (2011) conducted a systematic review of 19 behaviour change frameworks with theoretical constructs that help explain and predict behaviour and developed the behaviour change wheel (BCW) shown in Figure H-1. The BCW is a framework which is centred on a "behaviour system" involving three essential conditions: **Capability** (the psychological and physical capacity to engage in the behaviour), **Opportunity** (the physical and social environment that enables the behaviour) and **Motivation** (reflective and automatic mechanisms that activate or inhibit behaviour) (termed as the COM-B system). Nine intervention functions around the central COM-B system is aimed addressing the shortfalls in one or more of the conditions of the COM-B system and around this are seven policy categories. The policy categories are provided to facilitate the intervention functions to occur. The development of a behaviour change intervention is based on the three-stage process to intervention design which the BCW follows which is discussed below as; *Stage 1*: Understanding the behaviour, *Stage 2*: Identifying intervention options and *Stage 3*: Identify components and implementation options.

Stage 1 encompasses the sources of behaviour related to capability, opportunity and motivation and provides a guide to identify and understand the behaviour of construction industry professionals in relation to the adoption and implementation of sustainable construction practices and principles.
Stage 2 aims to identify which intervention functions and supporting policy categories are likely to be appropriate and an effective measure of change based on the potential barriers and enablers of sustainable construction identified in Stage 1.
Stage 3 provides prescriptive intervention content which prescribes behaviour change techniques (BCTs) that would be most appropriate to the intervention functions and modes of delivering the interventions.

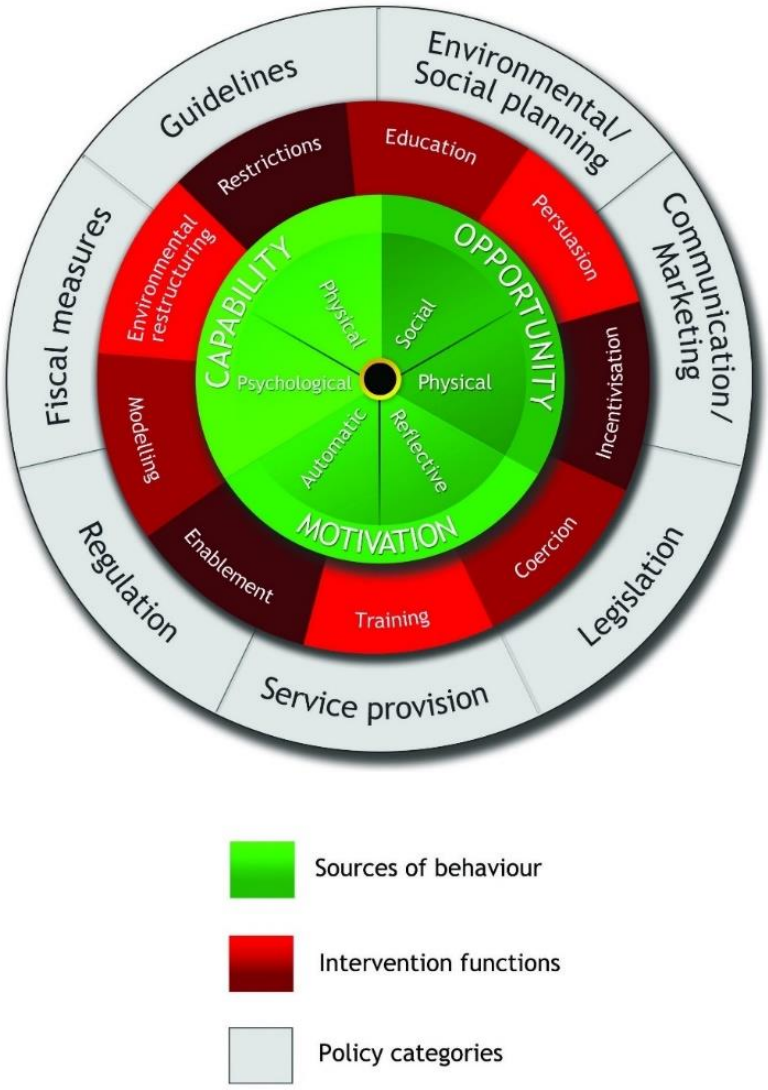

Figure H-1: The Behaviour Change Wheel

1.3 Stage 1: Understanding the Behaviour

The first phase of this research study involved an integrative review of the published literature to understand the key barriers and drivers to the adoption and implementation of SC. The second phase of the research studied the perception and understanding of SC amongst construction industry stakeholders in South Africa aimed at identifying the key barriers and drivers based on responses to a survey questionnaire. Based on the quantitative analysis of the survey questionnaire, the following ten barriers and drivers were identified:

Capability (Psychological)

- Awareness, Knowledge and Information of SC (TDF: Knowledge)
- Interest in SC and Demand for SC (TDF: Knowledge)
- Training availability of SC (TDF: Skills)
- Access to Education on SC (TDF: Skills)
- Behavioural Change towards SC (TDF: Behavioural Regulation)

Opportunity (Social Opportunity)

- Industry peer influences (TDF: Social Influences)

Motivation (Reflective Motivation)

- Confidence in SC implementation (TDF: Beliefs about Capabilities)
- Economic Factors of SC (TDF: Beliefs about Consequences)
- Perception of SC (TDF: Beliefs about Consequences)
- Social Benefits of SC (TDF: Beliefs about Consequences)

By adopting the COM-B system and TDF to conduct an analysis of the behaviour of construction industry stakeholders, this research study identified the following COM-B components and Theoretical Domains Framework (TDF)[18] as key targets for behaviour change: *Psychological Capability* (Knowledge, Skills and Behavioural Regulation), *Social Opportunity* (Social Influences), and *Reflective Motivation* (Beliefs about Capabilities and Beliefs about Consequences). Through the analysis of Phase One and Phase Two of the research design, the following specified target behaviour for the behaviour change intervention was identified: *Construction industry stakeholders involved in the design and development phase of the life-cycle of a building project should implement sustainable construction practices on building projects within their organisations through the adoption of a sustainable project management process called Building Information Modelling (BIM).*

1.4 Stage 2: Identify Intervention Function Options

An intervention function can be described as the broad categories through which an intervention can change behaviour such as *education*, *persuasion* and *training* (Michie, Atkins & West, 2014). The BCW includes a matrix that links each COM-B component and TDF domain to the intervention functions which are most likely to be effective in bringing about behaviour change. Mapping the COM-B components and TDF domains to the intervention function matrix identified five of the intervention functions that needs to be considered: *education*, *enablement*, *environmental restructuring*, *modelling* and *training*.

[18]The TDF was developed to provide access to a theoretical basis for implementation research. The TDF is an integrated framework grounded in psychological theory which synthesises 128 theoretical constructs from 33 theories relevant to implementation.

Using this matrix and applying the APEASE criteria (affordability, practicability, effectiveness/cost-effectiveness, acceptability, safety and equity), each intervention function was analysed to determine its suitability within the context of the construction industry.

1.5 Stage 3: Identify Components and Implementation Options

In order to develop the components of the behaviour change intervention, the BCT taxonomy (BCTTv1) was used to identify the potential BCTs that would best serve the intervention functions along with the potential modes of delivery. Using the APEASE criteria the following 12 BCTs were deemed to be relevant: *information about social and environmental consequences, feedback on behaviour, feedback on outcome(s) of the behaviour, self-monitoring of behaviour, social support (unspecified), goal setting (behaviour), goal setting (outcome), problem solving, action planning, restructuring the physical environment, demonstration of the behaviour,* and *instruction on how to perform a behaviour*.

BIM will be used as a tool to influence the behaviour of construction industry stakeholders at an organisational and individual level towards adopting sustainable construction. A matrix which summarises the links between the TDF, COM-B model, BCW intervention functions and BCTs from Stage 1, 2 and 3 with descriptions is presented in Table H-1, which provides insight into the Building Information Modelling Implementation Intervention (BIMII) toolbox. The matrix highlights that the intervention content will be linked to all the components of the COM-B model, specifically *psychological capability*, *social opportunity* and *reflective motivation* and 6 of the 14 TDF domains (*knowledge, skills, behavioural regulation, social influences, beliefs about capabilities* and *beliefs about consequences*). Psychological capability will be targeted through the intervention functions of *education* (increasing knowledge or understanding), *enablement* (increasing means/ reducing barriers to increase capability (beyond education and training) or opportunity (beyond environmental restructuring)) and *training* (imparting skills). Social opportunity will be targeted through the intervention functions of *enablement*, *environmental restructuring* (changing the physical or social context) and *modelling* (providing an example for people to aspire to or imitate). Lastly, reflective motivation will be targeted through *education*. The BCTs which best serve the intervention functions based on the barriers and drivers have been provided along with the proposed modes of delivery for the intervention.

Table H-1: Matrix of TDF, COM-B Model, BCW and BCTT (v1)

Behavioural analysis using COM-B and TDF – barriers and drivers of SC adoption and implementation (Stage 1)			Intervention Functions (Stage 2)	Behaviour Change Techniques (BCT v1) (Stage 3a)	Modes of Delivery (Stage 3b)
COM-B		TDF domains linking to COM-B components			
CAPABILITY	***Psychological Capability***	***Knowledge***	Education, Enablement, Training	**Education:** *Information about social and environmental consequences; Feedback on behaviour; Feedback on outcome(s) of the behaviour; Self-monitoring of behaviour* **Enablement:** *Social support (unspecified); Goal setting (behaviour); Problem solving; Action planning; Self-monitoring of behaviour* **Training:** *Demonstration of the behaviour; Instruction on how to perform a behaviour*	Face-to-face Documents Environment Changes Feedback delivered face-to-face Feedback delivered through documentation
	Limited awareness, knowledge and information about SC Lack of interest in SC and demand for SC	Develop scientific knowledge about SC to increase the interest and demand for the adoption and implementation of SC through BIM			
	Psychological Capability	***Skills***	Education, Enablement, Training		
	Lack of training availability of SC Limited access to education on SC	Develop skills to improve competency to adopt and implement SC through BIM			
	Psychological Capability	***Behavioural regulation***	Education, Enablement, Training		
	Behavioural Change towards SC	Develop skills of goal setting, problem solving, action planning and self-monitoring to change current unsustainable practices in the construction industry through BIM adoption			

Behavioural analysis using COM-B and TDF – barriers and drivers of SC adoption and implementation (Stage 1)			Intervention Functions (Stage 2)	Behaviour Change Techniques (BCT v1) (Stage 3a)	Modes of Delivery (Stage 3b)
COM-B		TDF domains linking to COM-B components			
OPPORTUNITY	***Social Opportunity***	***Social influences***	Enablement, Environmental restructuring, Modelling	**Environmental Restructuring:** *Restructuring the physical environment* **Modelling:** *Demonstration of the behaviour*	
	Industry peer influences	Provide opportunity and encourage the adoption and implementation of SC through BIM implementation strategy			
MOTIVATION	***Reflective Motivation***	***Beliefs about capabilities***	Education		
	Confidence in SC implementation	Believing that improving knowledge and skills of BIM adoption and implementation is achievable and will contribute to the sustainability of the construction industry			
	Reflective Motivation	***Beliefs about consequences***	Education		
	Economic Factors of SC Perception of SC Social Benefits of SC	Believing that having the knowledge and skills of BIM adoption and implementation is beneficial and will contribute to the sustainability of the construction industry			

1.6 BIMII Toolbox Development

The BIMII toolbox content is characterised by the behavioural analysis of the barriers and drivers using the COM-B model and TDF, the intervention components linked to each phase of the intervention toolbox, intervention functions, and BCTs which will target a wide range of theoretical mechanisms of action. It is based on the specified target behaviour to implement sustainable construction practices on building projects by using BIM which is a sustainable project management process to facilitate the adoption and implementation of SC amongst construction industry stakeholders. The BIMII toolbox is split into three key stages which define the six phases of the implementation toolbox: i) Pre-BIM Implementation; ii) BIM implementation strategy development and iii) BIM implementation mobilization in Table H-2.

Pre-BIM Implementation

The first stage (Phase 1 and Phase 2) provides a basis for organisations to equip employees with the necessary knowledge and training required to adopt and implement BIM as a tool to facilitate the transition towards a more sustainable construction industry. The mechanisms of action identified in this stage were *knowledge, skills, beliefs about consequences* and *behavioural regulation* which will be targeted through providing *information about social and environmental consequences, instruction on how to perform the behaviour* and *demonstration of the behaviour.*

BIM implementation strategy development

The second stage (Phase 3) provides an opportunity for construction industry stakeholders at management level to consider BIM as part of their organisations' strategic vision and goals to achieve sustainability and contribute to a sustainable construction industry. The mechanisms of action identified in this stage were *behavioural regulation, beliefs about capabilities, social influences* and *goals*. Although goals were not part of the behavioural analysis in Stage 1 of the BCW design, it was identified as a mechanism of action which is required to develop an implementation. It provides a function to set goals to achieve the target behaviour which can be monitored and evaluated. The BCTs identified in this stage were *problem solving, action planning* and *goal setting (behaviour)*.

BIM implementation mobilisation

The third and last stage of the BIMII toolbox (Phase 4 to 6) illustrates the requirements to mobilise a BIM implementation strategy within an organisation and demonstrates the key factors to achieving successful BIM adoption and implementation through a pilot project, support from management and peers, providing the resources required to aid implementation and to ensure ongoing audits and feedback on projects. The mechanisms of action identified in this stage were *knowledge, skills, behavioural regulation, social influences, beliefs about capabilities, beliefs about consequences, social/professional role and identity, environmental context* and *resources and goals*. Like Phase 3, *social/professional role and identity, environmental context and resources* and *goals* were identified in addition to the six TDF domains identified in Stage 1 of the BCW design.

Providing social processes of encouragement, pressure and support within in an organisation to adopt and implement BIM positively influences the employee's role and identity within the construction industry by allowing them the opportunity to contribute to the sustainability of the industry. Furthermore, by restructuring the physical environment within an organisation through the provision of resources (technology and documentation) provides a physical opportunity to employees to engage in the adoption and implementation of BIM. During the audit and feedback process, it is important for organisations and employees to set targeted goals of BIM implementation which can be measured and evaluated to provide feedback on how BIM implementation has impacted building projects. The BCTs identified in this stage were *review outcome goal(s), social support (unspecified), restructuring the physical environment, instruction on how to perform a behaviour, self-monitoring of behaviour, feedback on outcome(s) of behaviour, feedback on behaviour* and *problem solving*. *Review outcome goal(s)* was identified as an additional BCT which could be useful to an organisation to identify how implementation goals have progressed and what the impact of adopting BIM was on a project in terms of time, whole lifecycle cost, quality and overall sustainability.

Table H-2: BIMII Toolbox of intervention components, intervention content and mechanisms of action

Phase	Barriers and Drivers	Intervention Components	Intervention Content		Mechanisms of Action	
			Functions	BCTs with Definitions	COM-B	TDF
Pre-BIM Implementation: Group introductory education and training sessions delivered to employees in groups (Phase 1)						
Phase 1	Awareness, Knowledge and Information of SC Interest in SC and Demand for SC	Discuss what SC is and the importance of adopting BIM in the construction industry	Education	Information about social and environmental consequences: *Provide information (e.g. written, verbal, visual) about social and environmental consequences of performing the behaviour*	Psychological Capability	Knowledge
	Training availability of SC Access to Education on SC	Provide instruction on how and when to implement BIM	Training	Instruction on how to perform a behaviour: *Advise or agree on how to perform the behaviour*	Psychological Capability	Knowledge, Skills
	Behavioural Change towards SC Confidence in SC implementation	Provide examples of BIM implementation success stories	Education	Information about social and environmental consequences	Reflective Motivation	Beliefs about consequences
	Economic Factors of SC Perception of SC Social Benefits of SC	Provide evidence of the impact of BIM implementation	Education	Information about social and environmental consequences	Psychological Capability, Reflective Motivation	Knowledge, Beliefs about consequences

Phase	Barriers and Drivers	Intervention Components	Intervention Content		Mechanisms of Action	
			Functions	BCTs with Definitions	COM-B	TDF
Pre-BIM Implementation: Group introductory education and training sessions delivered to employees in groups (Phase 1)						
Phase 2	(See Phase 1)	Provide BIM implementation training	Education, Training, Modelling	Demonstration of Behaviour: *Provide an observable sample of the performance of the behaviour, directly in person or indirectly for the person to aspire to or imitate*, Instruction on how to perform a behaviour	Psychological Capability	Knowledge, Skills, Behavioural regulation

Phase	Barriers and Drivers	Intervention Components	Intervention Content		Mechanisms of Action	
			Functions	BCTs with Definitions	COM-B	TDF
BIM implementation strategy development (Phase 3)						
Phase 3	Behavioural Change towards SC Confidence in SC implementation Behavioural Change towards SC	Management should meet to discuss BIM and how it aligns with the organisations sustainability vision and goals and identify factors that influence the adoption of BIM and discuss strategies that will overcome barriers and facilitate adoption.	Enablement	Problem Solving: *Analyse, or prompt the person to analyse, factors influencing the behaviour and generate or select strategies that include overcoming barriers and/or increasing facilitators* Action Planning*: Prompt detailed planning of performance of the behaviour (must include at least one of context, frequency, duration and intensity). Context may be environmental (physical or social) or internal (physical, emotional or cognitive)*	Psychological Capability, Social Opportunity	Behavioural regulation, Beliefs about Capabilities, Social influences
		Management and key employees (internal BIM Champions) identified to facilitate BIM implementation should meet to discuss BIM implementation roadmap which identifies BIM processes and targets across the whole lifecycle of the project and business functions and specify how the targets will be achieved.	Enablement	Problem Solving, Action Planning	Psychological Capability, Social Opportunity	Behavioural regulation, Beliefs about Capabilities, Social influences
		Set target within organisation to achieve successful BIM Implementation to a recognised standard for all new projects	Enablement	Goal Setting (behaviour): *Set or agree on a goal defined in terms of the behaviour to be achieved*	Reflective Motivation	*Goals

Phase	Barriers and Drivers	Intervention Components	Intervention Content		Mechanisms of Action	
			Functions	BCTs with Definitions	COM-B	TDF
BIM implementation mobilisation (Phase 4, 5 & 6)						
Phase 4	Economic Factors of SC Perception of SC Social Benefits of SC	Management and BIM Champions should identify a pilot project and include measurement at all key stages to understand how BIM has improved the design and/or construction process.	Enablement	*Review outcome goal(s): *Review outcome goal(s) jointly with the person(s) and consider modifying goal(s) in light of achievement.*	Psychological Capability, Social Opportunity	Knowledge, Behavioural regulation, Social influences
		Management should document positive benefits to each stakeholder in the process for any return on investment calculation.	Enablement	*Review outcome goal(s)	Psychological Capability, Social Opportunity	Knowledge, Behavioural regulation, Social influences
		Encourage employees to adopt and implement BIM regardless of their role	Enablement	Social Support (unspecified): *Advise on, arrange or provide social support (e.g. from colleagues or staff) or non-contingent praise or reward for performance of the behaviour.*	Social Opportunity, Reflective Motivation	Social influences, *Social/Professional role and identity, Beliefs about capabilities
		Encourage employees to seek support from their seniors or internal/external BIM champions regarding implementation issues	Enablement	Social Support (unspecified)	Social Opportunity	Social influences

Phase	Barriers and Drivers	Intervention Components	Intervention Content		Mechanisms of Action	
			Functions	BCTs with Definitions	COM-B	TDF
Phase 5	**Documents and resources provided to aid implementation**					
	Awareness, Knowledge and Information of SC Interest in SC and Demand for SC Training availability of SC Access to Education on SC Behavioural Change towards SC Confidence in SC implementation	Install software applications on devices to aid implementation of BIM	Enablement, Environmental Restructuring	Restructuring the physical environment: *Change, or advise to change the physical environment in order to facilitate performance of the wanted behaviour or create barriers to the unwanted behaviour*	Psychological Capability, Physical Opportunity	Knowledge, Skills, *Environmental context and resources
		Upgrade or replace hardware on devices to suit technical specification required to implement BIM	Enablement, Environmental Restructuring	Restructuring the physical environment	Psychological Capability, Physical Opportunity	Knowledge, Skills, *Environmental context and resources
		Provide resources on internal network on BIM implementation process	Education	Instruction on how to perform a behaviour	Psychological Capability	Knowledge
		Provide BIM implementation checklist to employees	Enablement, Environmental Restructuring	Self-monitoring of behaviour: *Establish a method for the person to monitor and record their behaviour(s) as part of a behaviour change strategy*	Psychological Capability	Behavioural regulation

Phase	Barriers and Drivers	Intervention Components	Intervention Content		Mechanisms of Action	
			Functions	BCTs with Definitions	COM-B	TDF
Phase 6	**Ongoing group-level audit and feedback**					
	Confidence in SC implementation Industry peer influences	Compare current performance with performance on BIM projects in terms of time, quality, whole lifecycle cost and sustainability	Enablement	Feedback on outcome(s) of behaviour: *Monitor and provide feedback on the outcome of performance of the behaviour*	Reflective Motivation	*Goals
	Economic Factors of SC Perception of SC	Provide feedback and lessons learnt on BIM implementation	Education	Feedback on behaviour: *Monitor and provide informative or evaluative feedback on performance of the behaviour*	Psychological Capability, Reflective Motivation	Knowledge, Behavioural consequences
	Social Benefits of SC	Generate solutions for better implementation	Enablement	Problem Solving	Psychological Capability, Social Opportunity	Behavioural regulation, Beliefs about Capabilities, Social influences

Appendix I
Interview Schedule Questions

Section 1: General Background Information

1. What is your current professional discipline?
2. What is your current job title?
3. How many years of professional experience do you have?
4. Has your organisation ever been involved in a green/sustainable building project?
5. Have you ever been involved in a green/sustainable building project at your current organisation?

Section 2: Research Methodology

1. To what extent do you think the behaviour change wheel is an appropriate method to understand the barriers and drivers of sustainable construction and to develop an intervention toolbox?
2. Are there any improvements that you would propose to the research methodology?
3. To what extent do you agree with the process followed in identifying all the various components of the behaviour change intervention design?

Section 3: Impact of the Behaviour Change Toolbox

1. To what extent do you think this toolbox can influence construction industry stakeholders?
2. Do you think the toolbox provided is an effective tool that could be used to influence construction industry stakeholders to develop their knowledge and skills to adopt SC using BIM?
3. Do you think the toolbox is compelling enough as a guide to enable the transition towards adopting and implementing SC through BIM?

Section 4: Behaviour Change Toolbox

1. Considering the research methodology that was followed, what is your opinion of the potential of the toolbox as a guide to facilitate the adoption and implementation of sustainable construction through the adoption of BIM? Do you think that there is a need for a toolbox like this to facilitate the adoption of SC by using BIM?
2. Do you believe that the critical components identified in the behaviour change toolbox provides a comprehensive guide for improving the current awareness, adoption and implementation of sustainable construction in the construction industry? (Please provide feedback on the toolbox phases 1 to 6.)
3. Are there any additional components that you feel must be included in the behaviour change toolbox?
4. Please comment on the following structural aspects of the behaviour change intervention toolbox.
    a. How would you rate the ease of understanding the behaviour change toolbox?

   b. How well does the behaviour change toolbox allow an increase in awareness, adoption and implementation of sustainable construction amongst construction industry professionals?
   c. In your opinion, what are strengths of the proposed behaviour change toolbox for construction industry professionals?
   d. In your opinion, what are weak points of the proposed behaviour change toolbox for construction industry professionals?
   e. In your opinion, how can the behaviour change toolbox be improved?
5. Please provide feedback on the applicability and usability of this behaviour change toolbox, from your professional viewpoint, to promote the adoption and implementation of sustainable construction amongst professionals in the construction industry.
6. Do you think there is an opportunity to use a toolbox like this at an organisation to assist with their adoption of BIM? Would you apply this at your organisation?
7. Please provide any further comments should you deem it necessary.

Appendix J
Interview Transcriptions

Interview Transcription – SME 1

Table J-1: SME 1

Speaker	Text
Interviewer	Okay, so you like you said your research is essentially about foamed concrete and 3d printing and as you mentioned before, it is a disruptive technology. So, would you say that it contributes to the sustainability of the construction industry?
SME 1	Most definitely, one could really approach it from that side, which is what we are trying to do. We also looking at it in terms of labour intensity, but the technology allows for one to save on your materials that you use. You can be quite efficient in that way, we are thinking that it is more sustainable as there is less raw material usage and less waste.
Interviewer	To what extent do you think the behaviour change wheel is an appropriate method to understanding the barriers and drivers of sustainable construction?
SME 1	I think it is a good tool, to motivate change, to facilitate change. It provides guidelines, how one can go about evaluating or going towards a sustainable construction practice. That it is quite extensive, covers the important bits, which is the capability, opportunity, and the motivation. I normally think that it should be intrinsic your motivation. I suppose one sometimes goes with the status quo and there is always some resistance. Things have been done a certain way and it continues to be done in that same way. But I did see the behaviour change wheel did incorporate it. It seems like there are three levels to it. The outer layer considers legislation, which provides one to be able to have change. When we wanted to implement or go about doing foam concrete, our problem is that they are no codifications. So, you have this where you have to run into a performance-based design, which is quite difficult because you have to prove first how it works. So I believe to wheel is quite appropriate as it is.
Interviewer	As you were speaking, I just wanted to touch on something you mentioned about intrinsic motivation. Under motivation in the COM-B model, there is reflective motivation and automatic motivation. So automatic motivation is the intrinsic motivation to you, it is about feeling that it's the right thing to do. Based on the barriers and drivers in my research, the targeted behaviour leaned more towards reflective motivation, where people have to believe that they are capable of doing it and then secondly, believe that the consequences are beneficial. So it's not focusing on the intrinsic motivation, but I would say the automatic motivation is much harder to change. But if you can give someone the information to try to convince them that it's beneficial or that it is achievable, they might then consider that and then subsequently be more, or have more automatic motivation or intrinsic motivation to do good.
SME 1	I think this, too, could be used to decide or for a company to decide "Yes" or "no". In the absence of anything, people will revert to the status quo status. So, I think it is a good tool.

Interviewer	Are there any improvements that you would propose for the research design approach based on what I have done?
SME 1	No, I believe it's sound. You covered all the bases. So that's why I say I think this could be nice journal article.
Interviewer	Okay, that's good. The next question is to what extent do you agree with the process followed in identifying all the various components of the behaviour change intervention design?
SME 1	Again, I agree with it 100%. Our normal approach, well as a researcher, mine is more systematic whereby you do the reading up about the background and I saw this from reading your approach.
Interviewer	Okay. So, the next few questions are just going to be about the impact of this toolbox and what you think about it. To what extent do you think this toolbox can influence construction industry stakeholders?
SME 1	Well, it depends on the companies themselves. This could provide a tool for change. And that would come with the acceptance and awareness of the tool. So, it's difficult to say, but its impact can grow in the industry and it can be far deeper than what one considers. I believe that it does give you the tools to make the decision now. I don't want to say that that is enough, but I think it can make a significant impact.
Interviewer	Okay. And do you think it's effective in what it's trying to achieve, would you say?
SME 1	When I initially thought about this, just the overall concept of a toolbox, I thought of it in terms of a checklist. And if one thinks about it, it encompasses a whole lot of issues. It's quite comprehensive in it's approach. And I go back to where I said that I think it can provide a systematic guideline to companies that want to go into being a more sustainable construction practice.
Interviewer	Yes, I think it sort of ties into the next question and I think you've answered this already about it being compelling enough as a guide. It's like you said, when there's nothing available, it's much harder for people to see that something is required, like people will just go with the status quo. But once you actually provide someone with something easy, just a guide or an outline. You get them to think about it.
SME 1	Yes, all topics underneath this is relevant. Like I said, if you think of it as a checklist, and go through it.
Interviewer	Okay. Do you want me to go through the phases in the toolbox again, just briefly for you? Do you understand what was said or do you have any questions?
SME 1	Let's go through the phases, there are six phases, right?
Interviewer	Yes, there are. Ok I will run through a brief overview of it. (Interviewer discussed the six phases of the toolbox with SME 1)
SME 1	I think like, if you are dealing with a design of a building, that it is a multi-disciplinary, yeah. So that is the value in using it.
Interviewer	And the big thing with this phase (Phase 3) is, a company has to provide or have sustainability as part of the core values and goals and objectives that they want to achieve in the organisation because if sustainability is not part of it, then it'll be hard for them to justify why they should be adopting and implementing sustainable practices, or to justify considering sustainable materials for example if it's not something that they feel like is part of their business strategy or there are no regulations or standards to govern it, they won't adopt it.
SME 1	Was it in the third in the second phase, or the third or fourth phase that I saw the reflective part on it?

Interviewer	So, phase three is basically reflective motivation, which is setting the target, setting the goals, it's tying into people's thoughts about their capabilities and the consequences of their behaviour. So if you're not setting a goal that people can define as, it's an achievable goal in the organisation, that we can actually do this, there's nothing stopping us from doing it based on the tools, the hardware, the resources, that is achievable, then it's hard to then determine whether or not you would actually be implementing it.
SME 1	I suppose after that one can normally reflect on what you want to do. Because now it's either you decide that in future you might need this or you develop an approach like that, or you just, again, neglect it if it's something you don't want to do.
Interviewer	Yes, so this is all pre-BIM implementation, so before even mobilising it within the organisation. If you haven't set that target, or developed that approach like you said, then that's like getting to a T junction, where you are deciding, are you going left or right. Considering the research methodology that was followed, what's your opinion on the potential of the toolbox as a guide to facilitate to facilitate adoption? Do you think there's a need for a toolbox like this?
SME 1	I most definitely think there is a need for a toolbox like this. Look, what we find is that, I want to say that there is a reluctance to change and this toolbox might make it easier for companies to gain direction if they want to change. So, in that sense, it is very much needed, this toolbox.
Interviewer	Okay. And do you think that the components identified in the toolbox, provides a comprehensive guide for improving awareness and adoption?
SME 1	Yes, the toolbox is quite comprehensive, extensive. I think it covers all the all the bases.
Interviewer	Okay, and there's nothing that you feel within any of the phases that needs improvement or needs further expansion perhaps?
SME 1	No, not at the moment. What I do think is that the approach is good. What I'd like to say, well, in my opinion, is that is general and that is what it should be. Because once you become to project specific, because this is exactly what we are facing with our thoughts on how to prepare the construction industry for 3d printing technology. So, one has to approach it systematically, or generally and not a specific approach. So I think it's good, it covers the general concept.
Interviewer	Okay, and there's no additional components or anything that you think should be added?
SME 1	No, I don't think so.
Interviewer	Like you said, this is a more general approach and I think for the context, it makes more sense.
SME 1	This thing is sustainability is quite a huge concept. And to just specify a certain thing here would not do it justice.
Interviewer	I agree with you. The next questions are about the structural aspects of the toolbox. How would you rate the ease of understanding the toolbox?
SME 1	Well, I'm much more technical in terms of calculations. So from that point of view, it's not too difficult. But once you get to understand , once you get into it, just Initially, I had to think of certain terminologies, the behaviour change wheel is a new concept. It's not something that Ihave thought about or have come across before this. But once I got to everything and saw the headings inside the toolbox, it made sense. I would have classified it as moderate, just initially in terms of ease of understanding. But once you get to learn it then it's fairly easy.

Interviewer	I believe that about your initial interaction because it's taking a lot of theoretical constructs and it's actually from, I would say, from completely different discipline. And then bringing it into this field of research, but it's not that it's unrelated at all, because at the core of everything that we do is behaviour and trying to change behaviour. What do you think in your opinion, what would you say are the strengths of this toolbox?
SME 1	That was actually one of the things that I had to think about. Strengths of the of the toolbox: I think it provides a guideline, it's quite comprehensive as a general approach, general overview.
Interviewer	Would you say that there are any weaknesses or weak points that need to be addressed?
SME 1	No, I think it's good as it is. There's no weaknesses for me.
Interviewer	Okay. And would you say, or in your opinion, how do you think it can be improved? Do you think there's any improvements to be made or do you have any suggestions or ideas?
SME 1	None, but one could probably think about moving towards as a follow up, but then it becomes a little bit more specific, which is not what to what one wants to see in this. When it moves to more the quantification side of what one could achieve. But that might include if you, for instance, if you are doing a building design, that might just be on the financial aspect for example this method gives this, etc. But otherwise, I think, good as it is.
Interviewer	Okay. I think also like you are saying, to quantify the impact, and I think that's in phase six specifically, which speaks about making comparisons between the current performance and the performance of implementing and adopting this. So, in terms of time, and does it actually improve the amount of time they say it does, and the quality and, and it's obviously considering the whole life cycle and sustainability. Also, just to mention, like you were saying earlier about the behaviour change wheel, there's three layers. The outer circle I actually didn't touch on in my research because it deals with policy and regulation. I will be adding it as a recommendation for further research.
SME 1	I definitely see a lot of good coming from this work. Especially that it can be adopted for different types of practices.
Interviewer	Even like with what you're doing as well. If you just take this and you change the target behaviour to adopting 3D printing.
SME 1	Yes, and that would actually be great.
Interviewer	The next question is, for you to provide feedback on the applicability and usability from your professional viewpoint.
SME 1	You know what I'm thinking about, making this into a Java program. Like I can see the checklist and going through each of the phases.
Interviewer	Like you said, because it's so general you can actually take it and you can expand it in your own way. There are standards and specifications published by the UK, specifically on BIM implementation. And with Java, you could probably tie each of those components into this and take a step further. The key for me though is to get people on board first because that is what we are struggling with.
SME 1	Yes, it's the engagement thereof, which in the initial stages of adoption that is quite critical, that you get that audience to get this on a roll. That's why I was struggling to think about the impact of what this could have because it can be massive, or if it gets the engagement that it needs.
Interviewer	I agree with you. Do you have any other questions or comments?
SME 1	I think its worthy of doing a PHD on it.

Interviewer	That's great. I will keep that in mind. Thank you so much for your time. I appreciate it.
SME 1	It's a pleasure.

Interview Transcription – SME 2

Table J-2: SME 2

Speaker	Text
Interviewer	Do you have any questions before we start?
SME 2	Um, no, I think the questions will come as we go through.
Interviewer	Okay, so do you think that the behaviour change wheel is an appropriate method to understand the barriers and drivers of sustainable construction and to develop an intervention toolbox?
SME 2	I think it's a good approach. Your outcomes instinctively sort of made sense to me in terms of sustainable construction in the industry. I think in terms of what you do intended to do, yes. I think it's appropriate.
Interviewer	Okay. So, do you agree with the process that was followed in identifying the various components?
SME 2	Yes, I mean, the one question, and I don't know really at which phase it would come in, the only part that I perhaps don't agree with is… I'm interested to know at what point you know, BIM comes into the picture or came into the picture. I get the feeling that there's almost an implied relationship between sustainable construction and BIM, and I thought that was quite interesting where the research starts with, if I understand it correctly starts with understanding the drivers or barriers for sustainable construction, but that the outcomes are very much BIM focused. And I found that quite interesting. And I'd maybe just unpack that, I'd recommend unpacking that a little bit more.
Interviewer	Okay, actually yes, it's great that you touched on that because, well, as I was doing the research, obviously, the process it sort of develops as you go along and you find like, you need to make changes and adjust things, obviously. I realized that I didn't include in it the project description, but in my research itself, I discussed what BIM is how BIM ties into sustainable construction in terms of the different dimensions. So, the economic dimensions and environmental dimension. The core of it ultimately is that BIM is a sustainable project management process. And that overarching body of literature would then tie into that being an influencer in sustainable construction. As I was going through my research, it is tricky because sustainable construction and sustainability is a very broad concept. And I think depending on which industry you're in, and even which discipline you in, it's, it's very different. So, it's trying to bring it all together. And for me, the key was to try to involve as many stakeholders as possible in this toolbox, which is why it's quite general in the sense that you could take this to an M&E consultancy, you can take it to civil and structural consultancy. And then from there they can actually further develop this and create more definitive objectives and goals related to their industry.
SME 2	I think from my perspective, and maybe I'm digressing here, but in my experience, yeah, I think BIM is a very useful tool. You first need to understand sustainable construction or care about sustainability to implement sustainable construction and in order to achieve it using BIM. I think I've worked on a lot of projects that are using BIM and are not using it to improve sustainability in any way, really. I think it's one of those things that, it's a very useful tool if used correctly to improve sustainability in construction. But I think just using BIM, wont necessarily give a more sustainable outcome. So, one thing the toolbox could maybe have a bit more focus on is sustainable construction. There's a little section on it initially but, perhaps developing understanding of sustainable

	construction quite well. And how it, how BIM can be used, to deliver sustainable construction and then to go through the BIM implementation process. My experience with BIM so far is that people are using it for mostly other reasons, you know. And unless they care about sustainable construction, or understand what to do, you don't necessarily get a more sustainable outcome as a result.
Interviewer	Thank you for sharing that. The next few questions will be about the impact of the toolbox itself. Do you think that this toolbox could influence construction industry stakeholders?
SME 2	I think it could, depending on how it's packaged. So I was thinking, but my company or many of the engineering companies that I work with for example, architectural companies, they're very busy doing what they do. And they very seldom have resources to apply these kind of management processes. I think if it's packaged in a very simple way, or if it's delivered by a consultant, perhaps. Like, I know some of the BIM, you know, some of the software companies have consultants that can actually come in to management consultants and apply a toolbox like this for you in your organisation. Yeah, I think it's really useful in those sort of contexts. But if it's not very simple, or if it's not done for them, it could be overwhelming.
Interviewer	Yes, I think it's because they are trying to do as little as possible with maximum benefits.
SME 2	Yes, which makes a lot of sense.
Interviewer	And do you think it's effective in its intent and what it's trying to achieve?
SME 2	I think this is maybe where my comment comes in around sustainable construction versus BIM. I think it seems like an effective toolbox to implement BIM in an organisation, but I would maybe just question with it's an effective toolbox to implement sustainable construction in an organisation. So I would say that the toolbox could maybe do with a bit more basics first. Personally, I think that would help BIM a sort of secondary…
Interviewer	I heard when you said BIM being secondary basically, and bringing in the actual sustainable construction components and the understanding of that.
SME 2	Yes and within the toolbox, I think, if the goal is focused on sustainable construction, as the primary goal, then I'd say maybe put a bit more focus on sustainable construction first, and then get into BIM. But if the goal is to focus on, you know, integrating BIM for sustainable construction, then I think it's structured quite well.
Interviewer	Do you think it's compelling enough as a guide, and you basically mentioned, depending on how it's how its packaged, will it actually be driving a change in the industry among stakeholders?
SME 2	Yes, I think so depending on how it's packaged because I think one of the biggest barriers and the big barrier I'm talking about there is time and capacity. So if it's presented as something that's going to make the process easier for people. Then Yes. I do think it could be implemented. So I think if it's packaged well, yes.
Interviewer	And do you think that there is a need for something like this in the industry?
SME 2	I'm going to come at it from two directions again. And the one being BIM, so as your research showed, there definitely is a need for something like this in terms of sustainable construction. And I think in implementing BIM, I think companies have found it quite challenging to integrate BIM processes into their work. I think a toolbox would be very useful as well. So, rambling here, I guess yes, there is a need. I think there's two needs. I think there's a need for understanding sustainable construction better and how to implement it in an

	organisation. And then there is the need for how to do that with BIM as a tool. So maybe those are two separate toolboxes, I don't know. I think it's almost a case of maybe choosing the intent here.
Interviewer	Thank you for that, I'll take that on board. Definitely. And think about that as well, what you're saying makes complete sense.
SME 2	I think take what I'm saying with a massive pinch of salt. You've spent a lot of time researching this and I've had a quick scan through. Also, if you take it from a sustainability perspective, I'm interested in sustainable construction principles. And I don't use BIM all that much. So something to bear in mind is that is that I'm coming from the perspective of not necessarily being pro-BIM individual.
Interviewer	I think the big thing about this is actually getting different opinions from different people. And I think it's valuable even though, like you said, you come from a completely different perspective which I think provides a more transparent validation. So the next question is do you think that the components identified in the toolbox provides a comprehensive guide to perhaps improve the current awareness and also the adoption and implementation of sustainable construction practices and using BIM as a tool to do so?
SME 2	I think what's in the toolbox is very much around how do you get BIM practices integrated. But I think when developing the detailed content, if that content is very focused around sustainability outcomes of BIM, then yes. It could then be effective. But I think this content being focused, mostly on BIM, and I think I think a lot of organisations struggle just to get BIM integrated, the ability features within BIM is almost seen as like an advanced level of usage. And therefore, I think there is a risk that people will go through the toolbox and effectively implement BIM in the organisation. But the advanced levels of BIM you know, where they're actually looking at sustainability metrics embedded in the value chain.
Interviewer	So I think that the next question probably ties in with that. So as you mentioned, it's basically speaking about any additional components that you feel should be added. And I think I've got the information to add it into this. I think it's perhaps just to highlight a bit more and add it as a sort of an upfront requirement.
SME 2	Yes. And I think there's a lot of existing content out there. Green Building rating tools and those kind of things. So, I think it would be good to have a sustainable construction fundamentals. You know, education element that comes in and then BIM is introduced as a tool to achieve those.
Interviewer	So, next part is just about the sort of structural aspects of the toolbox. So how would you rate the ease of understanding the toolbox?
SME 2	I think it's reasonably easy to understand. Look, I didn't spend too much time unpacking it, but I think it's quite easy to understand.
Interviewer	What do you think, if there any, are strengths of this toolbox?
SME 2	I think it's very helpful to set out, I'm trying to think what the word is for it, it almost provides management consulting steps or change management. It seems like a change management process almost for an organisation and I think that's really good because often the technology or the concepts are put forward, and the way in which that change is managed within an organisation is not really thoroughly thought about and then it fails. So I think the real strength of the toolbox is that it can assist with change management of integrating new practices to an organisation. I enjoyed that.

Interviewer	Okay. And is there anything that you would say is perhaps a weak point of the toolbox?
SME 2	I think from my side, it's just what we discussed but I don't know if it's a weak point, but I think it's got a little bit of an identity crisis. If you look at the barriers and drivers it's awareness, information of sustainable construction, and then the intervention is about adopting BIM. I think if the barriers and driver was awareness and knowledge of sustainable construction in BIM, you know, then that delivers it well. Or otherwise, I think it needs more focus on sustainable construction, or it needs toolbox for sustainable construction. Because sustainable construction is a lot broader than BIM. And people that highlighted concerns or lack of knowledge etc. wouldn't actually get their fix from BIM. They may actually be looking for something else, they may be looking for other information or tools.
Interviewer	Like I said earlier, so you can almost take this into construction materials, like sustainable construction materials and you can look at sustainable construction methods like precast and off-site manufacturing. And I think a lot of that would probably be prescribed in things like the green building rating tools where you have to comply with certain elements. But I hear what you are saying, perhaps to add a bit more focus on sustainable construction initially.
SME 2	Yes I think so. But you make you make a good point, I think you have to, I guess what you're getting at is, you have to choose an implementation point because otherwise sustainable construction is so broad that the toolbox would be including everything and anything. Maybe it just didn't come across strong enough that I think, at some point there should be a recommendation that BIM is a means of addressing the barriers and drivers of sustainable construction and then with BIM in mind, here's a toolbox for BIM.
Interviewer	Yes I completely agree with you. Initially, when I was going through sustainable construction on its own, and then I got to the point of developing this intervention…Because the aim of the behaviour change wheel is to have an actual intervention designed, but you have to specify a target behaviour. And then it has to be designed for that target behaviour, and the more specific the target behaviour is, the more effective your tool or intervention will be.
SME 2	Yes, that that makes a lot of sense. And makes a lot of sense because it would be very difficult to apply this, just completely broad to sustainable construction. Yes, it's kind of the perspective that I came from previously, I worked at the Green Building Council. And, for example, a toolbox like this would be quite useful for them. But not focused on BIM, just focused on sustainable construction and sustainability, you know, how can you do the training around sustainable construction as opposed to how to implement it in BIM.
Interviewer	I think also, it's probably, I think, like, this toolbox can probably be adjusted for multiple focuses, like, you said you can change your target behaviour, the structure of it won't change that much. It will just be altered to suit whatever element it is you're looking at. Do you think there's this opportunity in the industry to adopt something like this or to use this?
SME 2	Look, I think to be honest, my organisation is very small. And like I said, this is very much a sort of change management process almost of integrating these things. And it seems well suited to larger organisations. In my organization specifically, it may serve as sort of inspiration but we wouldn't apply it.
Interviewer	Okay. And do you have any other further comments or questions that you'd like to add?

SME 2	No, I think that's it. Like I said, I really enjoy the approaches, coming at it from a management consulting perspective and not just technical, which people try and throw technical sustainability elements at organisations, where it actually requires change management. So I think you're doing good work and I think it can really be useful, especially in large organisations.
Interviewer	Thanks so much for that. I appreciate to your feedback.
SME 2	Good luck!

Interview Transcription – SME 3

Table J-3: SME 3

Speaker	Text
Interviewer	Can you explain what your day to day time is spent on as you say that you are a structural engineer and also a BIM specialist?
SME 3	People don't usually have issues now with just doing what they used to in terms of engineering. If you're doing engineering for a long time, people who are in those roles know how to do it. So the questions regarding structural engineering problems or something like that, that is very little that actually comes through to me. The questions regarding BIM implementation and software, that is a lot because that's where the whole issue lies. That's where the upskill issue lies. People struggle to adapt and change from a 2D-based environment without objects to a 3D-based environment where you need to take ownership for not only the graphical part, but also the non-graphical part of the information. People struggle to not only grasp that concept, but it's also new software to learn. So it's a big transitional phase. And that's where all the questions lie. So, for myself, the time I spend there is a bit ad hoc but for the rest I would perform the role of a BIM lead on a project, I would be responsible. It's mainly like what you would refer to as information manager.
Interviewer	Okay. (Interviewer discussed research methodology)
SME 3	Under your stage 1.4 "understanding the behaviour" in the questionnaire which you sent out, did you sent it to guys in the construction industry or construction and consulting industry?
Interviewer	I sent it to both construction and consulting. I only got 108 responses though which included mostly consultants and, if I recall correctly, 1 or 2 contractors. My aim was to get a broad perspective from not just consultants, but also contractors to include all stakeholders involved in the design and construction phase of a building project.
SME 3	Let me ask you this. Your the deliverable at the end of the day of your research project, who would be the target variable to use that, is it is it for the South African construction industry? Is it a generic tool, or is it for maybe third world countries in the construction industry? Or is it anyone, global? Have you thought about that?
Interviewer	Yes. So, I actually did, because my when I started my research, I obviously started well, I was looking at the South African context, because that was where I was physically located. But since then, and you know how research develops and changes over time, essentially, my aim was for this to be a global, more of a generic tool. So, within research, I've seen a lot of people develop these specific frameworks that can only be implemented for example, at a manufacturing plant in South Africa, because it deals with South African standards and South African protocols. And, you know, like in the South African context, where it's labour intensive work and all of that. So, this was initially I think, it was pretty much targeted at South Africa. But as my research developed and continued, I tried to make it as general as possible so that in any organisation, whether this is a contractor, or whether this is a consultancy. It's something to take into an organisation, and this is why I didn't call it a framework, I called it a toolbox. I didn't expand on all the intricate details of, for example, the BIM implementation strategy. Because in your organisation, every organisation has their own set of, or their way of doing things or the way

	they work and processes. So you can adapt this to suit to what would work best in your organisation.
SME 3	Because I think that obviously, coming from South Africa and being involved in this industry, I think that we are in dire need of such an intervention as what you are aiming to provide or a tool to guide the process. I dont really know they need in other countries and, there is a lot of cultural differences between countries and demographics and all of that, it comes into play. And in South Africa, the whole construction industry, I mean, and the government than, you know, the labour that you need to employ in certain areas and skill levels, and then you need to train. So, there's a lot of moving parts, and it is difficult to navigate that. Because any generic tool can only take you so far. If this is a generic tool, you will need to adapt it to make it work here. Because of all the cultural influences, the governmental policies, the socioeconomics. It's difficult to navigate South Africa because its very unique in that sense. So if it was more tailored for South Africa, I'd say that it's a big task but it is also something which I see a big need for. The other comment I can make is that I think that for me, there's a split between the sustainable construction and what goes with. And then there's a big other half of it, which is the BIM adoption. And I mean, there's a couple of ways to do that. There's a lot of literature, I can send you a couple of stuff as well. And stuff if you need more. What I'd say is, that is the two parts for me. I'm struggling to see the link between the two. So, are you, would you say you more focused on a driver for sustainable construction and changing the behaviour to promote sustainable construction or for the use of BIM in sustainable construction.
Interviewer	So basically, the key objective is like the overarching objective is to promote and adopt and implement sustainable construction practices. But because of the behaviour change wheel that I've used as a platform to sort of guide implementation toolbox, you have to specify a target behaviour. Because you can't develop an implementation without specifying or based on this method, you can develop it without specifying that specific target behaviour, my target behaviour is targeting construction industry stakeholders in South Africa and targeting the sustainable project management process of which BIM is a tool do that.
SME 3	BIM sits outside of the project management process, it's more like a method and there's a lot of benefits and add-ons and obviously all the BIM users have got their own definitions and experience. But people have been managing projects without BIM for years without them as well. And the other thing is that you can promote sustainable construction intervention without the use of BIM as well. What I'm saying actually is that BIM adoption and the use of BIM does not necessarily equals sustainable construction. I think you should define more what you mean by BIM, because BIM is quite broad, and I don't agree with the statement that BIM is a project management system. It's not a project management system. But there are aspects of using BIM in projects which will definitely aid sustainable construction. So I would see it more as BIM being an aid to promote sustainable construction and sustainable construction or changing behaviour for sustainable construction be your main focus point, with BIM being a key aid, or using the aspects of BIM to do that.
Interviewer	So, I know I didn't actually include it in my project description as a whole, but in my dissertation, obviously it's a more expanded version of all of this. So, in my dissertation what I did was, just to explain to you my thought process as well was, when I got to stage one and I found these are the drivers these are

	the barriers etc, I was thinking about the target behaviour. And then I looked at what is BIM, so I defined what BIM is. And obviously there's various definitions, but for me BIM is a process, it's a product. And I also think it's a way of managing information and tasks and data and the distribution of that information. So it's got multiple subsets and obviously you as a BIM specialist understands that. And then what I did with that was, I provided a brief paragraph about what the role of BIM is in sustainable construction. So, I specify the three sustainability pillars. So, the economic, environmental and social pillars of sustainability, and how BIM then ties into or aids each of those sustainability pillars. I went through that process of going through the different stainability phases and then based on that saying, that, in order to, what I think is the key focus of the research is to promote sustainable construction adoption and implementation using BIM as a tool. So, that's why the implementation toolbox is focused on BIM. I know at the start, another person just commented I should first go through the knowledge and training of sustainable construction and then do BIM and take it from there.
SME 3	The idea of behaviour change, which promotes more sustainable construction, that's like the core part. And then the then stuff like what I've mentioned here, when you link that all these instances. But I think also that your toolbox relies on it, it seems like there's a big reliance on BIM adoption. So it's more like, adopt BIM and then you can achieve sustainable construction, and not, lets achieve sustainable construction and then a good way to do that would be to adopt these aspects of the BIM process.
Interviewer	Thank you, I'll go through the questions now and I know you have covered a lot of it, but just for consistency, you can briefly answer. Do you think the behaviour change wheel is an appropriate method to understand the barriers and drivers of sustainable construction?
SME 3	I think it is. Yes, I think it is. Obviously, there's a lot more that one can elaborate on. And obviously there's a lot that is also country specific like the socioeconomics. I wouldn't say you need to necessarily bring in South Africa but I would say you can add more about the socioeconomic part. And maybe something about the contract as well. I think if I'm correct, the way your contracts are structured there is there is engineering at the front and then the contractor also does his own design.
Interviewer	So, there is a mixture actually. It's very similar to the way contracts are in South Africa, except here they do have a lot more design and build contracts where the contractor is the main designer as well, and would subcontract the engineering consultancy to do design work, or they have in house design engineers.
SME 3	Ok, because I would say that a design and build contract where the contractor takes ownership of the design and the construction in one contract, is more conducive to promoting sustainable construction. As opposed to the usual way that we do it where a professional team gets appointed and then there is a tender and then that is handed over to the contractor. As the contractor has no input.
Interviewer	Ok. And do you agree with the process followed in identifying the components of the toolbox with reference to Stage 1 to 3 of the behaviour change wheel design?
SME 3	Yes, I think that's well thought out and it's based on the behaviour change wheel which is a proven way of evaluating and putting a system in place.
Interviewer	Are there any improvements that would propose?

SME 3	Maybe also split the data from the questionnaire survey so that you can understand from what perspective they come from, like construction or from consulting. Because different industries because they will have differing opinions.
Interviewer	I did distribute the surveys to various consultants and contractors, and I do discuss the split in another Chapter in my dissertation. The data mostly reflects the perspectives and views of civil and structural engineers with respect to the survey, but the behaviour change toolbox is aimed at all stakeholders. So, the next section is about the impact of the toolbox. Do you think this toolbox can influence construction industry stakeholders?
SME 3	I think that it provides a good guide, it's a good tool to use. But I think and I don't know, if you have that in your big dissertation, where you have resources or literature that's available or examples like. Because in the tool, like if you follow every one of those steps it says what to do, but it doesn't go into a more definitive way of doing it. So the actual action that needs to happen to action, this box or this guide or this, whatever. Yeah, it needs more meat. Like if you want to achieve this behavioural change, within this group or whatever, this is the process you should follow. Like, this is an example, just a bit more definition behind it on how to actually achieve change.
Interviewer	Well that is the behaviour change technique which is the action. You looking at what is the action you need to do and the taxonomy provides various actions or ways of changing the behaviour, which then influences the capability, motivation and opportunity.
SME 3	So if you say that Okay, BIM adoption is stage one. You obviously need to get the user adoption and then under that there is there's an investment to be made. There are people to be trained. So there's a whole change management that needs to happen to take them from zero BIM, through the BIM adoption stage to a reasonably low level of BIM use. Because the only way they will get better is to actually use it, and apply it. So just breaking down exactly what's behind BIM adoption. And you don't have to elaborate too much on it. You can just put point wise what it entails. And it's usually around technology, people and process. And then you can reference industry documentation. Probably the easiest way to do that.
Interviewer	Ok, so the next question is, do you think it is an effective tool that can be used?
SME 3	I think the knowledge it does provide is, what to consider when you actually want to change, not only a person's behavior but a group's behaviour. So getting the whole explanation behind the action that needs to take place, that's one thing, but getting to grips with how do you actually, of all the ways of influencing the capability, opportunity and motivation. I think it provides good guidance on what to consider within that. I mean, not everyone is a psychologist, so how would you know, if you don't have this tool. So in that sense it does provide guidance I would say.
Interviewer	Do you think it's compelling enough to enable a transition towards adopting and implementing sustainable construction through BIM.
SME 3	I think the whole implementing sustainable construction through BIM, like I said previously, I don't see the link, a direct link. So you're gonna have to break it down more with focusing specifically on sustainable construction, and then linking the benefits of the BIM process or applying certain BIM uses through certain stages of the project lifecycle, to aid that to get sustainable construction. I think that's if you can make that link there it will be very clear then on what you mean.

Interviewer	So do you think that should be added within the toolbox or prior to presenting the toolbox?
SME 3	I think you can add it in the toolbox, not under barriers ad drivers but under intervention components. BIM shouldn't be a driver it should be a way to aid it, so it should be an intervention component. I think that's a shift that could help.
Interviewer	Okay, and then the next part is about the application and functionality of the toolbox. So do you think that there's a need for toolbox like this in the industry?
SME 3	I think so. I think there's a big need for the toolbox to change engineers and contractors and everyone in this industry's behaviour around sustainable construction. That's the focus for me. BIM is an aid to achieve that. So the big goal is, people need to change their behaviour and mindset about sustainable construction.
Interviewer	Ok, do you think the components identified provides a comprehensive guide to improve the current to awareness, adoption, and implementation?
SME 3	Yes I think it's a good, all the components are there. I didn't find more components.
Interviewer	Ok and how would you rate the ease of understanding the toolbox?
SME 3	I think it is quite easy to understand, I mean a table is always easy to really understand because you just look for things by through the process and so on, so it's easy to understand.
Interviewer	And what would you say are the strengths of this toolbox?
SME 3	Yes, I think the strengths are, I mean people in our industry, they don't have the background of the psychological part of it, like the behavioural change stuff. It's psychological stuff. So they don't have a knowledge of how you actually effectively change behaviour. And that's what it's good for. By really identifying those things which you can think about for people who aren't really inclined to think about soft skills and soft parts of it. And that's where the strength lies in it.
Interviewer	And would you say there are any weak spots?
SME 3	I think the weakness currently, and I think we've addressed this is the whole thing about finding the links between what you mean with BIM driving sustainable construction. Say we move that to a specific topic under the BIM umbrella as intervention aiding sustainable construction. That will be more clear and at the end of the day, that line item pointing to a more specifically defined action or example or an industry standard, something like that. So that's the rest of the meat on the bone.
Interviewer	Ok and then how do you think the behaviour change toolbox can be improved?
SME 3	Putting it in an online dashboard setup. But I think that's at the end of the day. So maybe when you actually have your deliverable, if one can put that into an online app, where you just typing away. So making it an online interface is one way of making it more effective.
Interviewer	Ok, and then can you provide feedback on the applicability and usability, from your professional viewpoint. Will you be able to use this?
SME 3	In an organization I think it is, I think this needs to be adopted as part of a campaign and this tool guide that campaign which will aim to make its resources and staff more sustainable. If we had to start a campaign and our management was advised by this toolbox and I would go through all of these motions in order to change our behaviour and how we design and make it more sustainable, even though that is not asked in the brief. Yeah. And probably the same with the construction guys. They have a lot more to consider with all of the moving parts at that level. Even for guys like the management consultants,

	because usually when there's a big change coming, you get them in and they devise a whole change management plan based on all these types of tools and then they do the whole campaign.
Interviewer	Okay, so would you say that there is actually an opportunity to use this in your organisation? Let's say you were to run a campaign. Do you think specifically at your organization, this would be something you'd consider using?
SME 3	For sure, yes.
Interviewer	Ok. Do you have any other comments or feedback?
SME 3	Maybe in your dissertation, I think mention the barriers and the resistance of BIM adoption itself. Because people are resistant to change.
Interviewer	So my topic is developing a behaviour change intervention toolbox to facilitate the adoption implementation of sustainable construction.
SME 3	Yes, so see, there's no need to rely too much on the open thing. I think it's very valid that that's brought into…because it's the way we are going. So if you can sneak that in, it is a very valid aid, to begin to adopt sustainable behaviour. I mean, your goal is for people to be able to think more sustainably and I think that's a very valid topic and I see a lot of potential for that because currently in the world we live in that's what's needed. BIM adoption is happening in the background but behaviour change for sustainable construction is not happening.
Interviewer	Thank you for that and thank you for participating. I appreciate your time.
SME 3	It's a pleasure. Let me know if you need anything else or would like to chat further.
Interviewer	Will do so.

Interview Transcription – SME 4

Table J-4: SME 4

Speaker	Text
Interviewer	I tried to keep the toolbox as general as possible because I feel like it can improve a lot of organisations across the board, and not just for instance a civil and structural consultancy, but you can use this in an M&E consultancy or even as architect's, because it's a process and I feel like it can be adopted to suit your organisation using this as a platform and building on that and then using it.
SME 4	That's a nice thing I picked up about it as well. At first I thought it was vague. But then as I worked through it, it actually became apparent that the whole purpose of it is not to be targeted to a specific or at one discipline or one company or one country for that matter, you know, the whole BIM process is a global tool, everybody can get in on it or should be in on it.
Interviewer	And also the way BIM works, it doesn't work differently, you know, in a different country. It's exactly the same process.
SME 4	Yes it's just the application of it changes where in South Africa, for example, you've got your consultants, trying to push BIM and from what I understand from other countries, you've got the contractor that's pushing BIM. And then in places like UAE or UK, you've got the actual government mandating certain processes as well, so it's being viewed from different angles and with that, you know, it's a bit of a different approach as to how to best implement it. But the overall principle of it remains the same. It's just about where you're going to start or at what point you're gonna start from.
Interviewer	Yes, exactly. So I'll get into the questions now. The first questions are about the research methods that I used. I will go through the design process with you… So do you think that the behaviour change wheel is an appropriate method to understand the barriers and drivers sustainable construction?
SME 4	I understand the backing behind it and it makes a lot of sense you know, if you want a certain type of change, target a certain type of either behaviour or function or action. So, I do understand it. I think from the discussion, it makes a lot of sense. But trying to roll this out to, well depending on the levels of education. I mean, if you're talking to a bunch of engineers or consultants, you know, you can understand this quite fairly easily. But going down to the labour force, for example, and on the construction site and to try and bring this across might be a bit tricky. But I think it's a good tool because I mean, you don't just want to lead straight from the top down. You want to spread the information through different teams to achieve the goal. And the more I look at it this, it makes intuitive sense. It is about human behaviour. Like we were saying earlier if you've got, if you're in the engineering field, you know, you have your strict schedules and performance specifications, but life doesn't work like that anymore. You rewind 10/20 years, sure, you know, it was the appropriate method of action at that time. But now, you can't force things down on people anymore. You can't force a process down, you need to, to motivate the process and sort of get them excited about the process as well. And you can't tell him what to do, but you can try and explain to them the benefits of doing it in a certain way.
Interviewer	So would you say the design process used, which is the behaviour change wheel, do you agree with the process? Do you think that it is appropriate, and do you think there are any improvements that I should make?

SME 4	I think, to me, it's quite spot on. It gets the message across, the goal is clear. There's no fluff surrounding it to try and make it look pretty. It gets to the point of what you need to do, how you need to do it, and what are the goals of you doing it in said manner.
Interviewer	Okay. Do you think this toolbox can influence construction industry stakeholders?
SME 4	I do. I definitely think so. Especially from, like we were saying earlier, there's different ways of influencing different people at the moment. What's gonna work for a 55 year old construction professional who has been in the game his whole life, you know, he wants a set process, it must be black and white, cut and dry. It is or it isn't. But then you bring it forward a couple of years, people are little bit more open to change and different ideas. And I think once they understand the process behind it, then, you know, there's actually a process to target certain behaviours. Yeah, and I definitely think there's this space for this to become applicable. I was just thinking, you're not telling them exactly what to do. You're explaining a process of doing it. And in doing that you open it up to everyone to put their not their own twist on it, but their interpretation of it of how it would best suit them. There's room that one can tweak it a little bit to suit the organisation, their country, their method of operation. Yes, I definitely think there's room for that.
Interviewer	And you so would you say it's actually an effective tool and compelling enough to sort of get people to think differently and perhaps the ultimately change their behaviour?
SME 4	So when I was working through this, especially through the toolbox at the bottom and the different phases, it was quite surreal to have it listed there. It was basically exactly the process that I had gone through and well, lived through as my adoption with Revit and everyday things. Not get caught up with all the standards and abbreviations you know, get them excited first, then get tools and then you start implementing it. So it was interesting to see how this the process of what I have lived was summed up into a process. That was quite interesting.
Interviewer	So I actually went through the behaviour change wheel design and then was trying to figure out, how am I going to change a specific behaviour? And the first thing that came to mind was, and I was thinking about BIM, because I'm an advocate for it. And I really wanted, I want to see it more. And I want to see it adopted effectively, and actually have successful implementation. So the steps were, it was in my mind, I was thinking like, what have I gone through? And what would I do to enable it better? And I think, like you said, it all starts with getting people aware, getting them excited, getting them to first go through educating themselves. Changing the knowledge, awareness, and perception is the first barrier to entry. And only once you do that, you know, get the computer specs up, download the software, decide what software you are going to use. Because it's senseless doing all of that first and BIM isn't even part of your management or company strategy. So, yes, I'm glad you mentioned that. It's quite interesting that you say that because I think as a whole I've lived through it as well. And it sort of just flowed in that sense because that's my experience. So, yes, working in the industry, I think you'd probably be best suited to do this. When you've gone through it…
SME 4	Yes, exactly. You've personally experienced the pitfalls and the issues that come with it. What you were saying about getting people excited, we've got a, I wouldn't say a motto but a little saying in our office, pretty pictures sell projects. So whether that project is implementation of BIM or a new pitch

	we're doing to a client, a couple of pretty pictures in there from Revit, from navisworks you name it. It sells.
Interviewer	It does, it definitely does. And I think we need to do that more, because we're not doing it enough. I think it's like in the literature they say that there is no client demand for it. So why would I, as an organisation, adopt this if the clients are not demanding it, there is no need for me to do. But if you bring it to them, that's the only way, as they're not aware of it either. So you have to bring it to them, you have to be that change agent.
SME 4	So that is something that we committed ourselves to on day one, when we opened the doors, we said we are committing ourselves to BIM, we committing ourselves to 3D Revit design, all of that. So even if the clients are not requesting it, if the rest of the team is not on it, we've already got our process and we are to use it. So it doesn't matter who else is on it or not. We are still gonna go that way, and it works for us and it's put us to the forefront of a lot of consultants in the Western Cape at the moment.
Interviewer	I think it's the way forward. I think at some point everyone is going to have to upskill themselves to get to that point. And by then, it might be too late.
SME 4	That's the thing. When I started with this whole training endeavour now, it is shocking to see how little people actually know about this process that's been around for 10/15 years already. And no one knows about it. And I can't see myself working without it. It's two completely different working methods. It's crazy.
Interviewer	Yes, I think that there is a group of people that have no idea, and there's a group of people that know about it but is not doing anything about it. And then there's the people that know about it and are actually doing something about it. So there is almost like this three tiered prong. So it's like shifting people into getting out of the "no knowledge" into the "knowledge" but then now that you've got the knowledge, what do I do with that knowledge? What should I be doing with that knowledge?
SME 4	I find one of the reasons for that, that three-tiered prong you are talking about now is the way the… So, one thing a lot of people get confused is, you know, they think Revit is BIM, but Revit is a tool of BIM. And what I find is a lot of the software resellers who actually, you know, get you into the market, they, its bells and whistles, they tell you all of these amazing things that the software can do. But what they don't tell you is that 90% of those bells and whistles, in your industry, you never going to use. A silly example is a ducting manufacturer. So at the moment, Revit is, I feel concentrated in South Africa among consultants, they are very few contractors who are capable or willing to get onto this bandwagon. And just now with the training in the last week or two, I found the design manufacturer, so in ducting, when they provide us with shop drawings of how this whole system is currently put together, a process that takes weeks normally can be all but automated in Revit. And it's gonna take you less than a day. So why isn't that feature being pushed under the contractors? Why are you trying to sell the contractor on bells and whistles that are going to get the engineer or the architect excited? The whole way of marketing, it's just not working in South Africa at the moment.
Interviewer	I understand what you mean. It's like the way in which they targeting the information and the standards and specs, like I can say, as a structural engineer, no one's telling me, you need to use BIM, it's efficient, you can do this. Personally, I use Revit to do all my conceptual buildings, I would start it in Revit, because once I've built it, I've already got the model. I don't have to do redraw that model again, I take that model and I export it to Tekla to do the analysis.

	But that is not currently happening because I am limited to the software that I can access because I am viewed as a designer only. So I spend a lot more time marking up information as opposed to sharing information that has already been done between software packages and limiting errors and checking.
SME 4	So it frustrates me because that's such an old school way of approaching the engineering field. You know, you had your lead engineer, your engineer, and then your drafting department. And it's gone. Yeah. And then back up and then back down. So it's this whole knock on effect that takes weeks to get something resolved. When now, if you've got, we personally don't have drafting departments, if you're the engineer on the project, you are the modeler, you're the drafter, you the engineer, so you've got a complete understanding of everything happening in that project.
Interviewer	It only makes sense to do that because you reduce a lot of errors. I'll move on to the next set of questions. Do you think that there's a need for the toolbox facilitate the adoption of sustainable construction using BIM?
SME 4	I think so. I think the application process at the moment is still a bit wishy washy. Everyone gets it into their mind that you know get a BIM champion, and then it goes, you don't have to intervene again, or something along that line. And depending on the type of person you choose to be that BIM champion, you might need constant motivation, you know, something along those lines. So having something formalized in a step by step, not a process like a procedure of how to motivate this person, what type of targets to set or what type of actions to apply to, to get them to perform better. I think it formalizes the process quite nicely. And again, it's nice to see this process because that's sort of whatI went through without really knowing what I was going through at that point of time. And it worked for me perfectly. So seeing that in a nice neat, in a presentation format, I think there's definitely space to apply that.
Interviewer	So do you think that it's convincing enough in that it'll increase awareness, will increase adoption and potentially increase implementation as well?
SME 4	I think it's, it's actually in quite a bit of a sweet spot at the moment. It's not too strict that you know, it has to be applied this way. But it's also not too vague. So you can apply it anywhere you want. There's a few things you know, it's, it's targeted enough so you can still read it and interpret it in a way that suits you, but not something that devalues the whole process of implementation.
Interviewer	Do you think there's any additional components that you would add, as you've said you've gone through this process?
SME 4	I think it's something that could maybe be added is just the, you know, once you've now implemented the BIM process and it's working, how do you keep it going? How do you, keep it fresh, keep people interested, how do you, because the technology is changing at the speed of light. Or an update, or something new that's come through. So I think just the constant updating, etc.
Interviewer	So like basically if you just looked at the toolbox, that'll fall under phase six like ongoing discussions and audited feedback. Under there, my goal was to say, so this is how you've been doing it as an organisation, and this is your performance before BIM. This is what your performance is using BIM, and then measuring that against like certain quantitative variables. Now, obviously, you can go into so many different things. But I get what you're saying. You're doing the comparisons using the lessons learned. And I think that's something that we need to definitely do more is have feedback sessions on lessons learned on projects and what we do, what works, what doesn't work, what we need to improve.

SME 4	I mean, the only constant in construction is change. So how do you deal with change, because the software is always changing, BIM loves it's acronyms. So the acronyms keep on changing, the software changes, the updates happen, the socio economic change, everything changes. I think it's important, just keeping on top of it, and knowing what's new and improved in the process.
Interviewer	So I think things like CPD sessions and continuing to go through learning initiatives to keep updated with what is happening in the industry is important.
SME 4	Yes, I think it was this year, the first time in 8 years, that I received a CPD point for a course related to BIM. I feel like 8 years after the fact it is sort of only getting traction now, and it's not avoidable anymore because everyone is going in this direction. So the regulatory bodies, they're also responsible to ensure that this type of training is available.
Interviewer	Yes. The next question is how would you rate the ease of understanding the toolbox?
SME 4	I think it's understandable. I mean, even for me with no psychological or behavioural specialist background, if that makes sense, I can see how to apply it and see what the overall process is from left to right, what do I need to do? How do I implement it? So it works, I don't really see a need for improvement on the navigation of it.
Interviewer	Okay and what would you say are the strengths of this toolbox?
SME 4	It's a formalisation of a very informal process, especially in a third world country. Like the guys who are really advanced with it or come with overseas resources. So it's formalised over there. They bring it back and it's not shared with other companies. So you've got to international conglomerates just leading the way all the way through. And the South African people are sort of just falling by the wayside. Because there's no process, how do you do it? How do you implement it? And the only way or not the only way but what a lot of people are doing is they just throwing money at the problem, and saying come get us BIM ready. Where, if you've got a process like this, I mean any manager or director, anyone can understand this and, you know, try to apply it themselves first, in house, you know, to get a bit of a footing, a bit of base understanding of it, and then if you run into problems, then you get someone else in to try and sort out the problems.
Interviewer	Okay, and do you think there's any weak points in the toolbox?
SME 4	Depending on the age, well, it's not the age gap but where this is to be applied. Again, you know, open minded consultants or professionals, yes, spot on. You try and explain this process to, I'm going to use it again, just a 55 year old contractor who's done it a certain way his whole life and the moment you start talking to him about behaviour, behavioural changing techniques, and behaviour change wheel. Well you know he's just gonna say I don't need this in my life right now. I don't know how you'd relate it to them as well. And what I mean by they, just being a broad term of anyone who's very set in their way.
Interviewer	Do you think that's something that you think maybe just needs to be clarified in terms of where this needs to be addressed in an organisation?
SME 4	I think, say finding the right person to take to take this up with or to run with this, I think is crucial. Because it could fall on deaf ears, or it could really, you know, someone could read this and be like, yes, this is exactly the process we need. We are going to run with it this way. The thing is just to try and broaden the field of relatability to different people. And again, for me, this makes sense but for someone else who's stuck in their ways…
Interviewer	So I think following on that is how do you think the toolbox can be improved?

SME 4	Look, the basic principle of it is great. It's just when it's now, when this process is targeted to a certain company, then you bring in that to suit them, you know, so they can interpret it in their own way and then expand on it. That's perfect.
Interviewer	Do you see the link between sustainable construction and using BIM to aid that?
SME 4	I definitely think there's a place for that. Not just information tracking and making sure all the information's managed. One of the advantages of BIM is the reduction of paper. You know, printing drawings, all these manuals that you print out, stacks of paper like this, is all put together in one central model. You can put it on a flash drive. So that in itself is already a huge saver. The coordination, the collaboration that happens before you even break ground, that's also a huge saver time and money and wastage of materials for that matter. Two out of the three green projects I've worked on before, which were Revit based, were huge successes. And the one project that was not on Revit, it was sort of a legacy project that we took over had constant issues, constant problems, Whether it's, you know, there was a clash on site, so they did a quick little reroute on site, but now it's a pinch point, it's an absolute nightmare. So there's definitely a link. And again, your process is going to make or break it.
Interviewer	Do you see them as a sustainable project management process?
SME 4	I think so. The whole process behind it, like I said earlier was that feedback loop that you're shortening, so there's no, the problem doesn't start here and it grows and grows and grows and grows, and eventually it gets to the right person and by that time it's two weeks down the line and then the problems have just grown bigger. So the information sharing of BIM that I enjoy is the common data environment. So you've got, instead of different silos, everyone's doing its own thing. You've got one place that feeds information into that and it's accessible to everyone. So that I find is a big cost saver, time saver, frustration saver and it really helps the whole process because you don't have this tiers going down all the way, so shortening that feedback loop.
Interviewer	Do you think I need to expand more on like sustainable construction in this toolbox? From another interview they said that it was lacking and they struggled to see the link between sustainable construction and the toolbox focusing on implementing BIM. So I would like your opinion as well.
SME 4	I think a big part of sustainable construction in today's day and age is the use of technology. The use of technology and the application of the right technology at the right times. You're targeting sustainable construction or just overall better construction techniques. Why put on blinders and ignore everything happening around you. So by incorporating BIM, which is an information sharing or management process, and I mean, it's computers and networks, its not called information technology for nothing. So, you know, applying the right technology and extracting information and for information management. It can only be better, I don't see how, it is a learning curve at the start, and they might be some hidden costs that you're not expecting. But once you get over that hill, I can't go back to thinking of working without it. So, in my mind, there is definitely a link.
Interviewer	Okay, and you don't think I need to add anything, you can see the link just by looking at it, at the toolbox specifically?
SME 4	From my side, like I just said, just the application of technology and sustainable construction. Those to go hand in hand, you can't have one without the other.
Interviewer	I agree with you. That is sort of how I rationalised it. So you would say this is applicable, it's usable within an organisation?

SME 4	Like I said, it's exactly the process that well, not just that I followed, but that was sort of set out in front of me by the higher ups at that point. So, I mean, it's worked for me and it's exactly the same process. I don't see why you need to change it.
Interviewer	It definitely gives me greater confidence because this is the process you have followed. It has been tried and tested almost in a sense.
SME 4	Yes it's definitely the way to go.
Interviewer	Thank you so much for your time. I appreciate it. Hopefully you have a better understanding of the theoretical viewpoint of behaviour change and the theories associated with it.
SME 4	No problem. And yes thank you. I definitely have a better appreciation for it. Good luck and hope all works out. I have great respect for people who are studying part time.
Interviewer	Thank you. I'll keep following what you are up to on LinkedIn and maybe in the future we can chat again.