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INVESTIGATION OF THE UTILISATION OF MODULAR CONSTRUCTION IN SOUTH AFRICA

RESEARCH REPORT

Submitted by

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A research report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Science Building.

JOHANNESBURG

November 2017

Declaration

I, Rufaro Patience Dupwa, declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Science Building (in the Field of Project Management in Construction) in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

……
(Signature of Candidate)

…….. day of ……., ……
(day) *(month)* *(year)*

Abstract

The subject of modular construction is largely known internationally. The extent, to which modular construction is used, is partly subject to the capabilities, facilities, expertise and skills available to the project team. Due to the scant use of modular construction systems in the SA industry, these factors might be found wanting. The limitation of the rudimentary approach to construction is an impediment to achieving efficiency and sustainability of construction projects. Additionally, the approach has delayed reaching the project targets and subsequently delays improving quality of life and national development. This study aims to investigate the utilisation of modular construction systems in SA construction industry, and to examine the causes of under-utilisation of modular construction systems by clients of the construction industry.

The study is an exploratory study that collects qualitative data from experienced construction industry professionals, industry major clients and modular system manufactures/suppliers. Semi-structured interviews and questionnaires conducted with these stakeholders produced valuable qualitative and quantitative data on the concept and key findings were drawn from this input. The modular construction systems on the market and the causes of under-utilisation of modular construction by construction industry clients in SA are discussed. The transportation restraints, the inability of making changes onsite, and limited design options appeared to be most significant challenges of using modular construction systems based on the findings. Several recommendations aimed at increasing the utilisation of modular construction systems by construction industry clients in SA were proposed in this study which including eliminating transportation restraints, inability to make onsite changes and increasing the design options.

Dedication

I dedicate this to:

- God Almighty for granting me strength, wisdom and patience to complete this endeavour.
- My beloved parents, words can never be enough to express my sincere gratitude.
- My awesome twins, now I know unconditional love exists within our hearts.

Acknowledgements

My sincere gratitude goes to the following people who were instrumental in the success of my research work:

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- All the professionals/ respondents who took time out of their busy schedule to meet with me and contributed invaluable input into this research study. This study wouldn't have been possible without your expert views, knowledge and experience.
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List of Abbreviations

BMI – Building Information Modeling

CAD – Computer Aided Design

CIDB – Construction Industry Development Board

CII – Construction Industry Institute

ECSA – Engineering Council of South Africa

GDP – Gross Domestic Product

ISO – International Organisation for Standardisation

MBI – Modular Building Institute

MCS – Modular Construction Systems

PMC – Permanent Modular Construction

PVC – Polyvinyl Chloride

SA – South Africa

SABS – South African Bureau of Standards

SASFA – South African Light Steel Frame Building Association

SAIA – South African Institute of Architects

SACQSP – South African Council for the Quantity Surveying Profession

SACPCMP – South African Council for Project and Construction Management Professions

SAICE – South African Institute of Civil Engineering

SANS – South African National Standards

SCI – Steel Construction Institutes

SIP – Structural Insulated Panels

UK – United Kingdom

USA – United State of America

List of Definitions

Client: Either the building owner, employer or person/group financially responsible for the building project.

Engineers: For the purpose of this document it refers to structural engineers except where reference is made to other design engineers.

Modular Construction: involves modular parts assembled in a factory, transported by road and installed on a building site to create a modular building.

Permanent Modular Construction: provides a service comparable to onsite construction where components are attached to a permanent foundation.

Relocatable buildings: maintain their mobility, serving temporary functions for both partial and full building applications usually built on an integrated chassis with detachable wheels, hitch, and axels.

CHAPTER 1 - INTRODUCTION

1.1 Introduction

The construction industry has played a significant role in the past decades in both developed and developing countries due to its link with modern development (Chew, 2001, Deplazes and Wieser, 2005). Several studies have demonstrated the impact of modular construction on productivity on major capital construction projects, the natural environment, human health and economy (Wei and Voellm, 2016; Alwan et al., 2017; Blismas et al., 2006; Dave et al., 2014; Generalova et al., 2016; Palma Olivares, 2010). These studies have focused mainly on modular construction (Knaack et al., 2012), benefits and challenges (Blismas et al., 2006, Lu Na, 2007), feasibility of modular construction (Velamati, 2012), application of modular construction in low and high-rise buildings (Lawson et al. 2012), efficiency of time, cost and quality due to modular construction utilisation (Yoon et al., 2015). However, in most developing countries little is known on the application of modular construction (Kibert, 2016, Lundholm et al., 2014).

Various scholars have shown that modular construction (Kibert, 2016; Musa et al., 2014; Palma Olivares, 2010) is strongly linked to energy and cost effectiveness (Harvey, 2013; Inyim et al., 2014; Kibert, 2016) and withstanding disaster risk reduction (Wagemann, 2012). A point in case is drawn from the works of Musa et al. (2014) who demonstrated in Malaysia that quality of construction project delivery can be enriched by implementing modular construction. Literature has shown benefits associated with modular construction such as improved project efficiency and effectiveness in terms of time, cost and quality, job creation (Yoon et al., 2015), green cities (Volder and Dvorak, 2014), urban tourism (Kibert, 2016), ecological increase (Lundholm et al., 2014) and climate change adaptation (Buratti et al., 2014; Evins, 2013; Harvey, 2013; Kamali and Hewage, 2016; Lee et al., 2014; Yang et al., 2017).

Historically, modular construction has developed following mass housing projects constructed during the 1940's in Europe. Pre-fabricated construction techniques were the method of choice due to their fast, cost effective and efficient nature in European countries (Waskett, 2001). However, they had limitations in terms of occupational safety as the work was hazardous in major projects (Goodchild, 2011). Accordingly, in the Americas and Asia, modular construction evolved progressively since 1960s. Countries such as China and Japan were employing modular construction (Dietz, 1971). Comparatively, in South Africa, modular construction in its most rudimentary sense has been used in modern society since the Industrial Revolution. With the advent of the power saw, predetermined sizes of lumber were cut and delivered to building sites to be assembled into stud-walls using machine-cut nails. Previously, bricks were always manufactured on site from the clay that the building was built upon; this process shifted to the factory, where bricks could be mass-produced to precise dimensions (Bruce and Sandbank, 1972).

In spite of the relative modernity of prefabrication, there is evidence of prefabricated elements on Roman shipwrecks, which suggests that certain building elements were fabricated at quarries and then transported to the construction site for assembly (Molavi and Barral, 2016). Along the same lines, colonial expansion necessitated the rapid deployment of hasty structures, especially for medical purposes. Sketches from the late 1800s depict portable barrack and field hospitals envisioned as quick ways to set up infrastructure and facilities for military purposes (Dietz, 1971). Evidently, in SA construction industry, the application of modular construction is noted significantly responsible for national development (Akinboade and Mkowena, 2012). Examples of what is obtaining on the ground are; modular blocks for road, dam wall and bridge construction, sewer and waste water reticulation modular concrete piping, waste management facilities such as landfill and slimes dams, prefabricated houses and refugee camps modular houses (Akinboade and Mkowena, 2012, Jurgens, 2008). The main aim of this study is to investigate the utilisation of modular construction systems in SA construction industry, and to examine the causes of under-utilisation of modular construction systems by clients of the construction industry.

1.2 Background and Significance

The study will contribute to improving value to construction projects, social change through informing policy and decision makers to adopt modular construction in order to actualize productivity goals through modular buildings. The rudimentary construction methods are time consuming and less economic and thus cannot provide an equitable distribution of housing for both corporate and public community. Accordingly, materials which are used in basic modular construction are expensive and the infrastructure coverage is limited to small areas (Blismas et al., 2006). In addition, modular prefabricated material may not be readily available in remote areas as in most developing countries.

Thus the application of modular material in construction and associated fast, cost effective and efficient production capabilities for construction projects will help to establish sound project planning and green urban measures. Ultimately, modular construction provides for better construction project delivery and better quality of life through an increased housing for all, both corporate and public communities. Accordingly, this should aim to reduce the skilled labour shortages, abbreviated building schedules and tighter budgets that are leading to undue cost overruns, delays and a loss of productivity on major capital construction projects. In this thesis, the cause of under-utilisation of modular construction systems by clients in the construction industry in SA are investigated to enable them to take advantage of the benefits presented by this system. The recommendations aimed at increasing the utilisation of modular construction systems by construction industry clients in SA were also provided.

1.3 Problem Statement

The subject of modular construction is largely known (Generalova et al., 2016; Ho, 2001; Kennedy, 2016; Yoon et al., 2015). The extent, to which modular construction is used, is partly subject to the capabilities, facilities, expertise and skills available to the project team. Due to the scant use of modular construction in the SA industry, these factors might be found wanting (Anthony et al., 2013, Goodchild and Glass, 2004, Kibert, 2016). The limitation of the rudimentary approach to construction is an impediment to achieving efficiency and

sustainability of construction projects. Additionally, the approach has delayed reaching the project targets and subsequently delays improving quality of life and national development (Hsieh, 1997).

Accordingly, the conventional construction method has not adequately provided infrastructure that is adapted for the economic recession (Harvey, 2013) and global environmental change (Jeong et al., 2015). To this end, construction companies face a range of challenges on site such as, skilled labour shortages (Blismas et al., 2006), abbreviated building schedules and tighter budgets leading to undue cost overruns (Deplazes and Wieser, 2005), delays and a loss of productivity on major capital construction projects (Said et al., 2014). As a result, the construction project delivery and uniform distribution of energy conserving buildings tends to significantly vary geographically (Roskruge, 2011). Previous studies reported economic and environmental concerns of the construction industry (Inyim et al., 2014; Jeong et al., 2015; Russell-Smith et al., 2015).

Findings from these studies indicated the economic and energy dynamics in which these approaches bear on national development and standard of living (Said et al., 2014). However, little is known on the benefits associated with modular construction particularly in SA. Elsewhere in the world (Inyim et al., 2014; Velamati, 2012; Lawson et al., 2012) studies were carried out on the impact of modular construction as means to realise efficiency and sustainability of construction projects. Given the significance of the construction industry to the SA economy, with output approaching 13% of GDP (Statistics South Africa, 2016) and over 500 000 South Africans employed (Statistics South Africa, 2016), solving these problems is imperative. While modular construction is improved in several countries, in SA it appears to be underutilized. Thus this study will apply the concept of modular construction for productive construction projects which will benefit the community in SA.

1.4 Aim

To investigate the utilisation of modular construction systems in SA construction industry, and to examine the causes of under-utilisation of modular construction systems by clients of the construction industry.

1.5 Specific Objectives

- To identify the modular construction systems on the market in SA.
- To identify the causes of under-utilisation of modular construction systems by clients of the construction industry in SA.
- To provide recommendations aimed at increasing the utilisation of modular construction systems by construction industry clients in SA.

1.6 Research Questions

Three research questions were formulated in line with the specific objectives:

- What range of modular construction systems are available on the market in SA?
- Why are modular construction systems under-utilised by clients of the construction industry in SA?
- What steps should be taken to increase the utilisation of modular construction systems by clients of the construction industry in SA?

1.7 Brief Overview of Research Approach

The approach taken by this research is driven by the notion that most new ideas, such as the one this research proposes, are in nature all innovative. Innovative ideas are generally born as a remedy to a problem to which no current solution exists (Leedy and Ormond, 2014). A mixed method approach was taken in this research. It concerned itself with information contained in literature, most of which was peer-reviewed together with semi structure interviews and questionnaires with industry professionals, industry major clients and modular system manufactures/suppliers. A clear understanding and consensus of the literature was achieved to provide the support needed to formulate educated assumptions and proposals. The overall research approach is summarised in Figure 1.1 below.

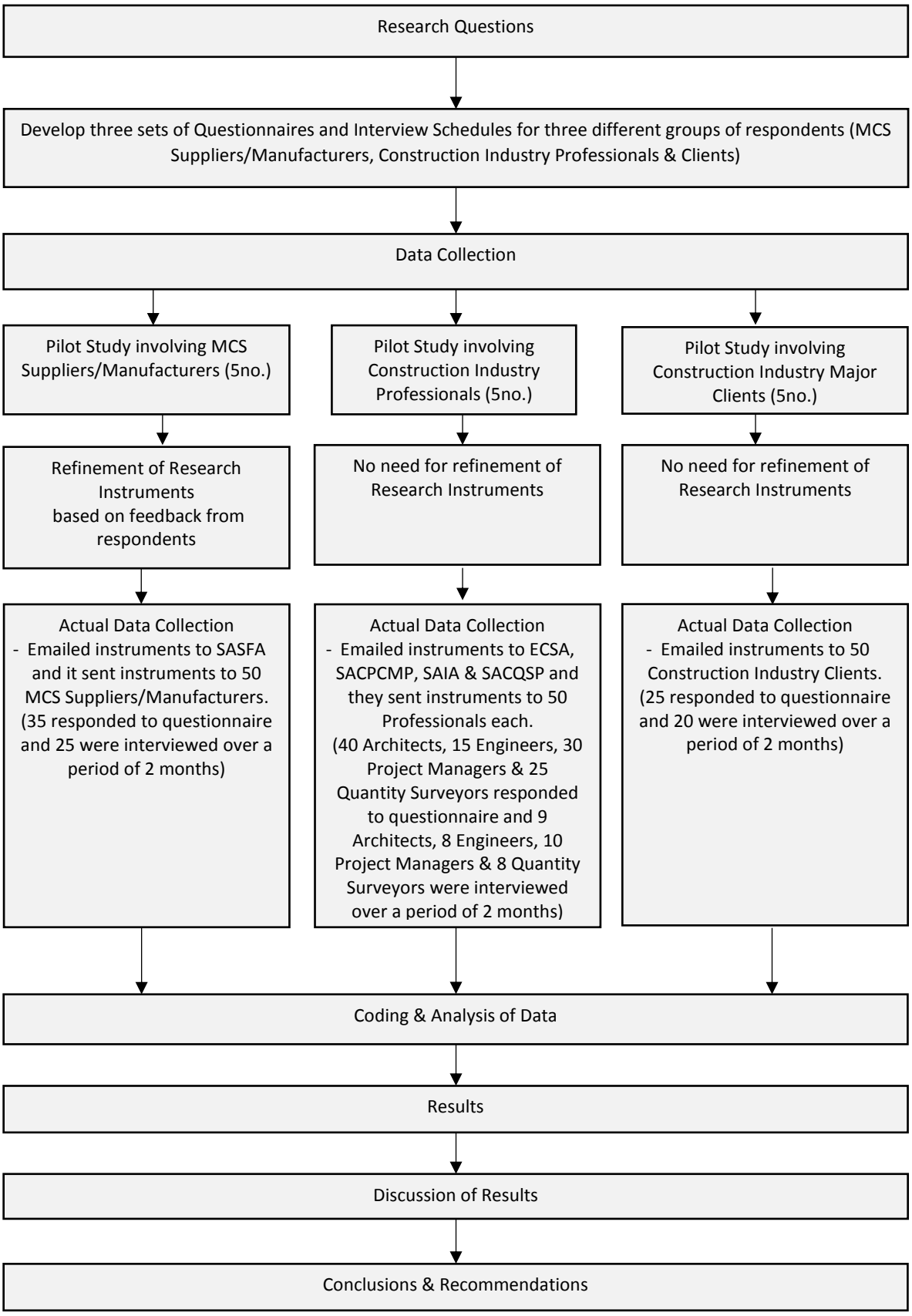


Figure 1.1: Overview of Research Approach and Methodology

Different methods were used to obtain the required information. Regardless of the limitations, the research included the following:

- An extensive literature review of hardcover books, scientific journals, periodicals and websites.
- Surveys and interviews with industry professionals, industry major clients and modular system manufactures/suppliers on modular construction projects, analysis of this information to develop findings, and extending these to present the suitable solutions to overcome the barriers for utilisation within construction firms in SA construction industry in terms of innovation.

1.8 Scope of the Study

This study was focused on the degree of current utilisation of modular construction systems in the building sector of SA's construction industry, and the architects', engineers', quantity surveyors', project managers' and major clients' perceptions of using these systems. The research scope included the market segments of single and multi-family residential, commercial, institutional and industrial buildings in SA's construction industry. Manufactured civil work were not included in the scope of this study.

The purpose of this thesis is not to promote or demote any company and therefore no company names were mentioned. Some comments and experiences from companies were used to assist with the research. Research in SA regarding modular construction is new, resulting in a shortage of literature. An alternative method to investigate the industry was used to obtain subjective opinions from industry professionals, major clients and modular system manufactures/suppliers by means of surveys and interviews.

Information regarding modular construction projects in SA was found in engineering magazines and not from peer reviewed journals. The purpose of this information was not to provide project facts, instead the magazines were used to establish the amount of exposure the industry experiences of modular construction projects in South Africa.

1.9 Limitations

The limiting factor for this study is the lack of data for comparison. Only approximately 3 – 4% of all commercial buildings built annually in South Africa are built using modular construction systems (Statistics South Africa, 2016). Another limitation is a lack of data with respect to the operation of these modular buildings. To get a more complete, life-cycle view of each project, there needed to be consistent operational data that documents the building life-cycle. Such information is not available for a project with only a few years of use. It simply has not been operating long enough to provide consistent annual data.

1.10 Structure of Research

The research report is structured into the following chapters:

Chapter 1 – Introduction

Chapter 2 – The Literature Review

Chapter 3 – The Research Design and Methods

Chapter 4 – Data Collection, Analysis and Results

Chapter 5 – Discussion of Results

Chapter 6 – Conclusions and Recommendations

CHAPTER 2 - LITERATURE REVIEW

While the previous chapter provides a broad framework of this thesis, this chapter presents a review of the available literature pertaining to the following main topics:

1. Definition of Modular Construction Systems
2. Utilisation of Modular Construction Systems internationally
3. Utilisation of Modular Construction Systems in South Africa.

The terms Modular Construction Systems is defined extensively. This is followed by exploring the advantages and disadvantages of utilising these systems to the construction industry. Lastly the different types of MCS utilised internationally and in South are explored in depth. The information was obtained from journal articles, reports and internet sources. Before discussing the utilisation of modular construction internationally and in South Africa, it is important to analyse modular construction as a building technique. This is discussed in the next section.

2.1 Definition of Modular Construction Systems

Modular buildings normally have multi-rooms with three-dimensional units, which are constructed and pre-assembled complete with trim work, electrical, mechanical, and plumbing installed (O'Brien, 2000). Upon the completion by the manufacture, these units are shipped to the site for installation on permanent foundations. The Modular Building Institute categorizes commercial modular buildings as being 60-80% completed offsite before being shipped to an end destination (Permanent Modular Construction 2015: Annual Report, 2-4). Van Gassel (2006) writes modular construction involves much more and can be characterized further as follows:

- Modular construction involves modular parts assembled in a factory, transported by road and installed on a building site to create a modular building.
- Modular parts have established grid dimensions.
- Parts just small enough to be transported by road are called modules.
- The modular buildings are assembled, transported and installed by specially trained professionals.

- The components on the modular parts and modules are kept in stock at the factory.
- The point at which an order can be broken down into its individual components precedes the assembly of modular parts.
- Modular parts and modules are according to customer specification.
- A modular building can be taken apart then reused to create the same or other type of building.

Schoenborn (2012) divides the modular construction industry within the following categories:

Permanent Modular Construction (PMC) provides a service comparable to onsite construction where components are attached to a permanent foundation. Components can be integrated into site built projects or stand-alone buildings. While costs are likely competitive to an onsite construction process, the time savings accrued from the simultaneous scheduling of offsite and onsite work enables clients to turn profits quicker and save the money spent on employee displacement. PMC buildings are the most likely to involve the assistance of an architect. A typical job will be financed by a private owner with the work being coordinated between an architectural and engineering group, a modular manufacturer, and an onsite general contractor (unless the manufacturer is licensed and staffed to work outside of the factory) (Permanent Modular Construction 2015: Annual Report 2015, 2).

Relocatable buildings maintain their mobility, serving temporary functions for both partial and full building applications usually built on an integrated chassis with detachable wheels, hitch, and axels. While the industry has a history of providing temporary solutions for construction sites and schools, the current trend is to provide durable buildings that will serve multiple functions throughout its life cycle. Modules are largely complete with finishes done in the factory and require minimal onsite work (Relocatable Buildings: 2015 Annual Report 2015).

2.1.1 Advantages and Disadvantages of Modular Construction

Over the last twenty-five years, there have been many publications on the issues that modular building present to project delivery. Blismas et al., (2006) and Lu Na (2007) offered advantages and disadvantages of modular construction, a review of modular construction activity at the time, and an industry survey of modular construction.

Benefits commonly associated with modular construction include the reduction of onsite labour congestion and onsite labour volume, the overall cost reduction of construction as a result of efficient work scheduling, and the accessibility to advanced computer technology and equipment (Haas et al., 2000).

While modular construction is known to provide the above mentioned advantages, many additional advantages of modular construction do exist. Although additional design effort and contractual flexibility are required for modular construction projects, the advantages result in a satisfied project team and a best value project (Goodchild and Glass 2004).

The advantages of modular construction are as follows (Lawson et al. 2012; Lu Na, 2007; Blismas et al., 2006):

1. Cost and construction time
2. Improved quality and finish
3. Environmentally friendly
4. Improved health and safety
5. Improved workmanship

Cost and construction time

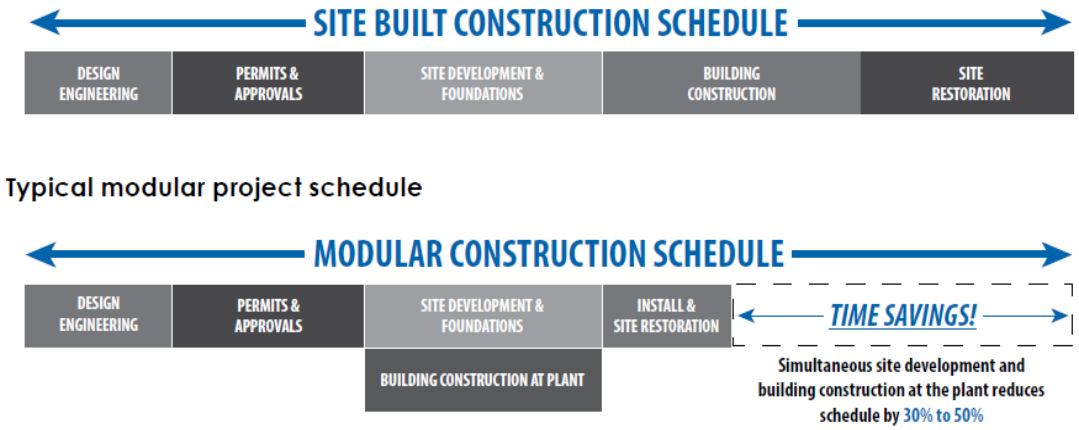
Bowen et al., (2007) found that the objectives, management and procurement strategies in South Africa are driven by the cost, time and quality that are specified by the client. Further investigations found that a bias exist towards the time constraints and project cost during the decision making processes.

The use of modular elements at a project allows cost savings at every stage of the production chain due to mass production, for instance, material savings at the procurement stage and labour savings at the construction stage. A study of industrial projects found that in some cases costs were reduced by as much as 10% of overall

project costs and 25% of onsite labour costs (Velamati, 2012). Cost reductions were largely attributed to the lower cost of offsite labour. In addition, savings may be associated with site overhead reduction, installation efficiencies, and the standardization of design (CII, 2015). Cost reductions can also be explained in terms of craft productivity increasing and labour rates decreasing on site.

The advantage of modular construction is that parallel construction is possible. While normal construction continues on-site, the modular elements can be constructed off-site, that causes for reduced construction times (Permanent Modular Construction 2015: Annual Report). Working in parallel provides the opportunity for fabrication and assembly to occur at various fabrication shops for the same project. In addition, various modules within one shop can be worked on simultaneously (Generalova et al., 2016).

Figure 2.1: Typical modular construction schedule (Permanent Modular Construction 2015: Annual Report)



Quality and finish

Modular systems are constructed in controlled environments, better quality and finishes are obtained (Chew, 2001). The improved quality and finishes according to the client's specification, allows for minimal additional work after installation. An increase in quality that can also be achieved in a fabrication shop by providing for inspection in the fabrication shop supervised by an independent body and module testing in the fabrication shop (Lawson et al., 2012).

These quality controls are according to national or international standards such as the SABS 1200 (or the new SANS 2001) or ISO 9001 standards respectively. Not

only do these inspections provide assurance regarding the quality or the products, it allows for quality with respect to procedures such as testing, accuracy, handling and storing. (Fédération Internation du Béton 2004).

Environment friendly

Part of the ISO 9000 series, includes standards for recycled materials used in the factories. Recycling the materials in the controlled environment such as a factory provides for a greener construction method than with traditional methods (Fédération Internation du Béton 2004). Making use of pre-assembled modules provides additional green advantages during construction and in the final structure such as less water usage. There is minimal environmental impact of the construction process on the site in the case of prefabricated modules.

Improved health and safety

Modular construction practices improve safety by reducing the exposure of workers to inclement weather, height, hazardous operations, and onsite working time. Reducing the amount of work that is performed at a significant height above the ground in the field allows the majority of the work to be performed at ground level. Pre-assembled modules, which consist of a complete story of beams, columns, bracing, equipment, platforms, stairs, handrails, and so on are assembled at ground level. Upon completion, each story is erected onto the lower one and placed into its final position with the use of a patented safety pinhole connection (De La Torre et al., 1994). Pre-assembled modules are installed with limited scaffolding requirements resulting in a safer working environment and a decreasing risk of slippage and falling (Goodchild and Glass, 2004).

Improved workmanship

Modular construction can offer opportunities to alleviate the problem of skilled labour shortages. In factory environments the quality of the finished product is much easier to assure than on-site. All that remains is to ensure that the on-site assembly meets the required standards to allow the product to perform as designed. Compared to the traditional construction approach, modular construction practices has lower workmanship requirements on-site owing to simplified work content (Blismas, 2006).

The disadvantages of modular construction are as follows (Lawson et al. 2014; Lu Na, 2007; Blismas et al., 2006):

1. Project Planning and Coordination
2. Transportation Restraints
3. Negative Perceptions
4. Flexibility to make changes onsite

Project Planning and Coordination

The biggest disadvantage of modularization in construction is the increase of pre-project planning stage. There is a need for increased engineering effort upfront (CII, 2015). Therefore, design work and extensive planning must be precisely conducted before fabrication. In addition, coordination of design, transportation, and onsite installation are critical components for successful implementation.

Transportation Restraints

Transportation logistics plays a large role in determining offsite construction feasibility. The method and route of transportation impose size and weight limitations as well as width and height restrictions during transit (CII, 2015). Roadway transport, as the most common method utilised, usually restricts the size of modular building or preassembled building components to 3.5 - 4 metres in width, and 15 – 16.5 metres in length. In addition, and their weight also restricted by the capacity of lifting equipment usually between 10 to 30 tons. In addition, there exist South Africa's highway restraints along with lifting capacity of crane. Manufactured building components have to be overly designed to alleviate possible damage during transit, which likely to increase design and construction cost (Lawson et al., 2014).

Negative Perceptions

Based on the literature studied, the general negative perceptions of modular construction systems was one of the most significant challenges in both the South Africa and overseas with the exceptions of in Germany and Japan. In the U.S., modular buildings have always been confused with manufacture houses, "mobile homes", even though there is a big different between these two types of buildings (O'Brien, 2000). A history of cheap manufactured buildings and a long associating

with trailer-type mobile homes has tainted modular construction with the stigma of poor building quality (Kobet, 2008).

Flexibility to make changes onsite

The inability to make changes onsite during construction may decrease the use of modular construction systems. Modular buildings, require a well-defined scope early the project planning stages (CII, 2015).

2.1.2 Application of Modular Construction Systems

Potentially, modular buildings can be dismantled and reused, thereby effectively maintaining their asset value. The current range of applications of modular construction is in cellular-type buildings such as private housing, social housing, apartments and mixed use buildings, educational sector and student residences, key worker accommodation and sheltered housing, public sector buildings, such as prisons, health sector buildings, hotels and military accommodations, where the module size is compatible with manufacturing and transportation requirements (Lawson et al., 2014). The current application of modular construction of all types is reviewed in a recent publication (Lawson et al., 2014). Lawson et al., (2005) describe the mixed use of modules, panels, and steel frames to create more adaptable building forms. Anthony et al., (2013) described the three different ways of applying modular construction in residential as follows;

Stackable Modular Units

The most common method used to construct low rise modular structures is stacking. Similar to building blocks, load bearing modular units can be stacked and bonded to form a complete structure. Modules are typically arranged in a story floor plan such that they border a central corridor or common area. This allows easy service connection and common access for maintenance of modules or module connections (Lawson et al., 2012). The structure shown below (Figure 2.2) is an example of a typical low-rise modular design.

Figure 2.2: SoMa Studios, a 23-unit apartment building in San Francisco's trendy South of Market district (MBI, 2012)



Concrete Core Construction

Concrete cores are used to transfer lateral loads and provide story access in mid-rise and high-rise structures. Modules are typically arranged around a core in one of two ways. They can be clustered around the central core, with modules attached to the core via embedded connections, or they can be bordering a common corridor and attached via bracing elements. Typically, gravity loads are transferred through the modules. Module connections and bracing elements are designed to transfer lateral loads from the module to the core or corridor (Lawson et al., 2012).

Concrete core construction is the most common structural system used for modular high-rise construction. An example of a 19-story modular high-rise concrete core design is shown in Figure 2.3 (MBI, 2013a). Cores that is visible on the left with rendering of completed structure on the right, can be constructed onsite with reinforced concrete or can be prefabricated and assembled onsite

Figure 2.3: Concrete core construction Victoria Hall, UK (MBI, 2013a)



Hybrid Modular, Panel and Primary Steel Frame

A hybrid modular design incorporates the benefits of a primary steel frame with the benefits of 2D and 3D modular components. The primary steel frame is typically used as the stabilizing structure and provides the designer flexibility when planning internal spaces. 2D modular panels can be incorporated to make up open areas in the floor plan, and the 3D volumetric modules can be used for the core use spaces or highly-serviced spaces such as bathrooms. Two generic forms of construction are typically used with a hybrid modular design (Lawson et al., 2005):

Podium Structure – These structures are intended for mixed commercial/residential use. The first one to two stories are steel or concrete framed and are used to provide commercial space. Load-bearing modules are then stacked on top of the podium and used for accommodations.

Skeletal Structure – This type of structure is used to provide flexibility of floor planning to the owner. A steel skeleton is used for the superstructure and to frame out any intended open areas. Modules are then placed as needed. Both load-bearing and non-load-bearing modules are used with this type of design.

Shown in Figure 2.4 is a student housing project for Manchester University, in the UK. This 7-story building was constructed with a primary steel frame and a two-story podium. The first story was constructed below grade for parking. The second story has retail space, and the remainder of the stories contain 3D modular student housing units. A total of 1425 modular units were used for the construction of this building. The Steel Construction Institutes (SCI) claims a construction time reduction of 60%, for this project, over site-intensive construction methods (SCI, 2003a).

Shown in Figure 2.5 is a housing project located at Lillie Road, Fulham, in the UK. This particular hybrid design incorporated light steel framed 2D cassette panels for wall and floor systems with 3D modular bathroom units. The apartments are a maximum of six stories, and 16 weeks were saved from the overall construction period of 68 weeks (SCI, 2003b) for this project.

Figure 2.4: Podium Design Manchester University (Lawson and Ogden, 2008)



Figure 2.5: Hybrid Structure, Lillie Rd. Fulham (Lawson and Ogden, 2008)



Open Building Systems

The concept of "open building" originated in the Netherlands in the 1960's (Cuperus, 2001). The philosophy of open building systems strives to decouple the base-building (support) and fit-out (infill). This concept can be seen in the construction of modern day leasable office space. Modular methods are at the heart of the open building philosophy and can be implemented in many ways. Many of the hybrid steel-framed structure types discussed previously are based on elements of this philosophy (Lawson and Ogden, 2008).

Many forms of open building systems exist. The Swedish system known as "The Open House 3D Modulus system" is based on a "flexible mass production idea" (Birgerrson 2004). Flexibility comes in the form of many available arrangements of the modules, whereas mass production is a result of modularization. The modules are placed between steel columns spaced on a grid pattern. The system can be used for structures under eight stories. Figure 2.6 shows a rendering of the concept.

Figure 2.6: Proposed "Mutant Vertical City" (DesignBuild, 2012)



2.2 Utilisation of Modular Construction Systems Internationally

Na Lu, (2007), Waskett, (2001) and Lawson et al., (2014) examine the use of modular construction systems in several international construction industries including those in the United States, United Kingdom, Japan, Germany, Asia and other European countries. The development of the use of modular construction systems in the international construction market may have implications for the use of these systems in South Africa.

Utilisation of Modular Construction Systems in the United States

The use of modular construction systems in the United States construction industry originated about 100 years ago with the development of them wood frame house (Bruce, 1972). One of the major benefits of these houses was that every piece and component could be manufactured in the factory, transported and then assembled on-site. During the mid-1800's prefabricated components were shipped from the east coast of the United States to California during the gold rush, as were army field barracks during the American Civil War (O'Brien, 2000).

In 1908, Sears Roebuck and Company began selling kit homes through its popular catalogue. This was called the Modern Homes program. From 1908–1940 Sears Roebuck and Company sold more than 100,000 homes. Over that time Sears designed 447 different housing styles.

Home owners could also modify houses according to their own needs based on Sears' popular home designs. Individuals could even design their own homes and submit the working drawings to Sears who would then ship the appropriate pre-cut and fitted materials, including standard 2×4" studs or 2×8" studs for framing, pre-cut timber, fitted pieces, and even nails. Sears Modern Homes Program offered distinct advantages with mass-customized construction methods which greatly reduced purchase costs and shortened construction time up to 40% (Lawson et al., 2012).

A review of the current utilisation of modular construction systems included five different types of prefabricated building products. They are offsite preassembly, pre-cut housing, manufactured housing and panelised building systems. Each of them is different in design, on-site installation, and code requirements. The site-

built home, often called “stick-built”, dominates the market with over 75% of the 1.2 million annual new homes built in the United States in the year of 2000. Prefabricated housing represented approximately 25% of new single family housing, in both 1998 and 1999, and approximately 20% over the last 20 years (Manufactured Housing Institute, 2015).

In the commercial sector, H.B. Zachry Construction Company is one of the pioneers using modular construction systems. In 1968 the company constructed the Hilton Hotel in San Antonio, Texas. It was the most sophisticated modular building in the world by then (Lawson et al., 2014). The construction started 7 miles away at the 6 acres of factory yard, where all hotel rooms were constructed. Each room was finished with concrete structure, drywall, plumbing, interior and exterior finishing, windows, doors, and balconies, and then delivered to site by train. All the modular rooms were put into place by using lifting cranes, and then assembled together by welding pre-structured steel bars. A helicopter was used to assure that each room was assembled within designed horizontal and vertical dimensions. The construction work was finished in 202 days, breaking the previously conventional construction record far ahead. After that, Zachry construction company used this “Zachry modular system” for building and installing 1,600 rooms for Holiday Inn in Texas in six months, and eight story nursing rooms in Texas within in 45 days, and a metropolitan hospital in Texas in 15 months (Lu Na, 2007).

One of examples for the use of modular construction systems in the commercial sector is precast prison and jail cell modules, which invented by Tindall Corp. Tindall Corp. is a family-owned company headquartered in Spartanburg, South Carolina. Started from 1963, it has emerged as one of the largest U.S. precast concrete producers, with upwards of 800 employees and five plants occupying more than 350,000 square feet of manufacturing area (Manufactured Housing Institute, 2015).

Utilisation of Modular Construction Systems in the United Kingdom

Utilisation of modular construction systems in England can be traced back to 1624 when the English brought with them to Cape Ann a panelised house made of wood

for use by the fishing fleet. Since then, this house was subsequently disassembled, moved, and reassembled several times (Peterson, 1948).

In the early part of the 20th century, major activity in mass prefabrication systems for buildings occurred in the United Kingdom. The impetus was a huge market demand for new housing after World War I. The traditional building approach could not provide enough houses due to the construction duration and the lack of availability of skilled workers. The low production of traditional methods and destruction caused by the war created a climate for innovative construction methods and processes (Waskett, 2001).

However, modular construction systems were not consistently developed in the UK after World War I because much of the early effort focused on the development and use of alternative construction materials other than masonry and concrete. Therefore, at the time there was no significant change in the approach to building that would move the technology forward (Waskett, 2001).

Following the destruction caused by World War II, the UK government was pressured to make available homes for soldiers returning from abroad, which also matched the need to find employment opportunities for them. In September 1942, the U.K. Interdepartmental Committee on House Construction was formed to take charge of developing alternative construction materials and methods in terms of improving efficiency, economy, and construction speed (Waskett, 2001). The Committee significantly promoted the development of modular construction systems.

Another great impetus of the use of modular construction systems was the innovation of timber framing systems that occurred from 1927 to 1941. The fact that timber has always been easy to form into panels provided the possibility of fabricating accommodation units in the factory and then assembling them on site. In addition, the innovation of large panel systems in 1948 significantly pushed the development of prefabrication and preassembly systems.

Within the last few years there has been a great increase in the use of modular construction systems for buildings, driven by a range of factors including demands for faster construction and shortages of skilled craft workers. The implementation

of modular construction systems in the United Kingdom construction industry has been dominated by large construction companies whose incentive for using prefabrication and standardisation systems was to improve productivity and reduce construction time. Often these systems have been utilised in large urban areas on very congested jobsites. Modularisation or modular design has been described as the key to offsite construction systems in UK because it offers customers distinctive advantages over traditional construction systems in terms of labour productivity, project schedule, product quality and a safer working environment (Gibb, 2001).

In the UK, the use of modular construction systems are more widely accepted in the commercial sector than the residential and industrial sectors, due to the fact that in England and Wales masonry systems are used for the majority of the residential buildings. Rapid commercial development in London in the late 1980's created a great opportunity for increasing the use of modular construction systems. Commercial clients demanded a better quality product, faster delivery, and at a reasonable cost. The use of modular construction systems was one of effective approaches to meet their needs (Lawson et al., 2012).

Increased labour costs and decreased availability of skilled labour at the worksite were two contributing factors of the development of modular construction systems in the late 1980's. Prefabrication has been identified as a way of achieving faster completion on commercial premises. For example, McDonald's restaurants use modular technology to build their new outlets. Recently they set a record of a completed outlet being built and opened for business within 13 hours of starting construction on a prepared building site (Blismas, 2006). Currently, in the UK, modular construction systems have considerable commercial implications for businesses and a range of clients from hotels to retail outlets are using some forms of prefabricated procurement (Lawson et al., 2004).

In addition, modular construction systems have been applied in the UK industrial construction sector as well, predominately for assembling heating and cooling equipment and other building services. Traditionally the installation of building services is time consuming and labour intensive, while prefabricated modular

construction can overcome these challenges and meet aggressive schedules (Blismas, 2006).

Utilisation of Modular Construction Systems in Japan

The Japanese residential construction industry has a long tradition of craft production based on woodworking skills (Gann, 1996). In the late 1950s, the Japanese housing market began to utilise modular construction systems because of the shortage of skilled carpenters, depletion of indigenous supplies of timber, low quantity housing production, and rapid economic growth. This large market demand triggered a need to modernise conventional construction methods and adopt the efficient production methods from Japanese manufacturing industries (Gibb, 2001).

By 1955 the Japanese government acknowledged that productivity growth in housing production was low relative to other manufacturing industries. The Japan Housing Corporation was founded in 1955 and focused mainly on developing medium-rise reinforced concrete apartments. This organization developed standardised concrete panel systems. However, early forms of houses incorporating these panelised systems could not compete with conventional timber buildings because they failed to provide enough various designs to meet the homeowners' needs (Gann, 1996).

By 1970 the housing market, in terms of quantity, had been satisfied. Therefore, the Japan Housing Corporation shifted its focus to improve the housing quality and reduce project costs. Meanwhile, industrialised housing producers invested heavily in improving the flexibility of designs to satisfy each individual consumer's choices, which doubled the market share for prefabricated wood panel housing between 1980 and 1992. By 1995 industrialized housing accounted for almost one quarter of all new dwellings (Coaldrake, 1996). Industrialised housing market growth in Japan was also associated with the high density housing in urban areas, where customers had positive attitudes towards factory-made products developed by manufacturers who were increasing their efforts to satisfy consumer preferences (Gann, 1996). In 1994, panel and modular housing systems were widely adopted in

the Japanese housing industry and accounted for over 10% of the total housing output (Gann, 1996).

Currently, modular construction systems are predominately used in the building sectors in Japan, notably in the residential sector (Gibb, 2001). In 2015, prefabricated single-family housing accounted for $16 Billion US dollars in the Japanese construction market (Manufactured Housing Institute, 2015). Modular construction systems combine different levels of factory and site-based activities. The major prefabricated structural systems include: timber-frames, 2×4 wood frame, factory-made light-gauge welded panels, module steel-frame systems and prefabricated reinforced concrete systems. Among them, 50%-80% of manufactured houses were using steel-framing systems (Gibb, 2001).

Utilisation of Modular Construction Systems in Germany

Modular construction systems have been utilised in Germany for about 70-80 years. In the late 1920s and early 1930s, the first industrially produced home was made as a symbol of modernism and progress (Gibb, 2001). In 1947, an exhibition of eighteen (18) prefabricated houses was held in Stuttgart-Zuffenhuasen by an American construction company, six of them still exist today (Venables, et al, 2004).

In the 1950s and 1960s, the German timber industry and home builders heavily invested in the use of modular construction systems, notably in the residential sector. In 2014, over 23,000 light framed prefabricated homes were completed in Germany, equivalent to 13% of the new residential construction volume for that year. In Eastern Germany, the use of modular construction systems was around 20% (Gibb, 2001).

Currently, modular construction systems have been widely adopted in Germany. These systems are most commonly used in the construction of new detached housing. There are more than 100 manufacturers in Germany with capacities ranging from 50 to 3,000 units annually. The majority of the firms are small family owned. However, similar to the Japanese construction industry, the offsite construction market has been dominated by five large firms. They are Massa, Elk-Bien-Zenker, Kampa, WeberHaus and Schworehaus. Each of them produces 1,000

to 3,000 homes per year and together account for more than half of the market (Venables, et al, 2004).

Some of the German modular manufacturers have extended their operations to other European countries. In 2002, exports of modular homes accounted for 5% of the total German housing industry business. Major export markets included the UK, Switzerland and Austria. Modular homes were also exported to other European countries, and also to Russian and Japan (Venables, et al, 2004).

In Germany, modular construction systems have been used in building construction with a variety of building materials. Timber-based modular construction systems take the form of post–beam construction, and structural insulated panels (SIP), or a combination of both. External finishes normally consist of rendering or cladding. The specifications for the timber construction in Germany set higher standards than those in the UK, with greater concern for the final quality of the finished product. Post-and-beam systems are aimed at the upper end of the housing market and application is still very limited. Concrete and masonry systems are used for building panels and roofing elements. In addition, modular concrete housing and automated production of concrete panels for walls and basements are also utilised in the German construction industry (Barlow, 2004).

Utilisation of Modular Construction Systems in Asia

In Asia, modular construction technologies are not as widely utilised as they are in the western countries. Singapore along with several other developed countries in Asia have developed effective methods for modular construction, especially in using precast reinforced concrete technology to construct multi-story buildings.

Singapore relies heavily on imported labour for its construction industry. The Housing Development Board has developed two basic approaches to solve the shortage of skilled labour; the fully prefabricated reinforced concrete building system and the semi-precast reinforced concrete building system. The board learned from European experience of the importance of quality control of the panel connections and on-site workmanship. They emphasised the need for careful pre-project planning beginning with conceptual design (Gibb, 1999).

In Housing Development Board's semi-precast reinforced concrete system, the main building components, such as beams and columns are all made cast-in-place. All other reinforce concrete components are pre-cast in factories, including staircases, parapets, internal non-load-bearing partition walls. It also developed two different fully precast reinforced concrete systems: precast column-beam-slab system and post-tensioned flat plate floor system. Precast reinforced concrete column and beams are connected together using bolts and anchors. Post-tensioned reinforced concrete flat plate floor systems are comprised of three story precast columns with onsite concrete flat slab with no supporting beams.

The board also developed a volumetric bathroom unit based on a European system. The unit is fully furnished in the factory and is comprised of a fibre-glass or concrete base with lightweight framing for the walls and ceiling. This keeps the weight to a minimum making for easy installation and on-site handling (Gann, 1993).

According to Singapore's experience, the standardization of building components is the key to successful utilisation of modular construction systems. This standardization greatly reduces the number of modules needed to precast the concrete components and thus speed up the erection work.

In Korea, the leading construction company in the field of modular construction is Daewoo Corp, which developed a multi-room modular construction system used for multi-story buildings. Daewoo Construction typically has a prefabricating facility set up on the project site. Because the preassembly is completed onsite, the construction company does not have to deal with the transportation issues. All of the precast concrete modules are manufactured onsite and then lifted into position by a crane at the rate of one floor per d ay. Daewoo states that their system is three times faster than conventional methods because all the factory-built panelised walls incorporate all of the mechanical and electrical systems. Like most other Asian countries, Korea's large population provides a great opportunity for using modular construction systems which have been widely adopted in constructing high-rise buildings that exceeded fifteen floors (Gibb, 2005)

Utilisation of Modular Construction Systems in other European countries

Most European countries have used modular construction systems in various forms for many years, and each of them developed a system that fits their own culture and construction technology. In the Netherlands, most homes are built by a hybrid method of concrete shells and a few exceptions of timber frames. The main applications of modular construction systems in the Netherlands were for roof and wall panels. The method is called rationalised fast-tracking housing systems. This method utilises steel tunnel formworks with cast-in-place concrete to complete a building with 50 units or more, due to the economical scale (Gibb, 2001).

In the Netherlands, the structural walls of buildings are prefabricated and insulated, using timber cavity inner leaves incorporating windows and doors. The inner leaves of cavity walls are prefabricated timber-framed construction, consisting of timber panels, a plasterboard inner skin, insulation, vapour barriers, damp-roof courses, windows, and door frames (either PVC or timber framed). Smooth-faced gypsum blocks are used in the building for non-load-bearing internal walls, which provide layout design flexibility, and better sound and fire resistance. Roofs are prefabricated with hinged timber elements incorporating roof-lights and vents. The prefabricated timber hinged roof elements are designed to sit on wall plates on the eaves and gable walls (Waskett, 2001).

Compared to conventional construction technology in the Netherlands, modular construction approaches reduce construction time from 21 months to 12 months, with 33% more usable floor area. They also reduce the building cost up to 17%. Most dominate contractors are taking advantage of these methods and materials. It has been successfully used in the industry for more than 25 years (Waskett, 2001).

2.3 Utilisation of Modular Construction Systems in South Africa

Modular construction in the construction industry is evolutionary, not revolutionary, based on successful and unsuccessful experiences (Smith, 2011). In 1790, simple timber-framed shelters were shipped from England to Australian settlements in New South Wales as hospitals, storehouses and cottages. Years later, a similar system was erected in Eastern Cape Province of SA; these structures were simple and shed-like, with timber frames, clad either with weatherboarding or

board-and-batten siding. Although these structures were not extensively prefabricated, they represented a significant reduction in labour and time compared to onsite methods then.

In comparison with the US and UK or Asia, SA has a limited history of modular construction. Locally grown timber construction tends to be of comparatively poor quality. Together with limited availability and expense, this has made masonry construction a first preference. Major investment in the education of the industry in the use of this new technology will be necessary. This task should not be underestimated, as conservatism resists change, especially when there is the perception that current building methods are as good as anyone needs.

One of the main priorities of the multi-ethnic democratic government that followed the apartheid era was housing for the people. As explained before, modular construction in many countries has been to produce system-built high-density, high rise developments. But in SA, the concept of personal space and being in direct contact with the land is paramount. Most people want their own plot of land with their own dwelling. As a result, the high-density approach that is often associated with modular construction is inappropriate. The challenge for SA is to find a solution that can benefit from modular construction and yet meet the needs of the people (Gibb, 2001).

In SA modular construction has however been used at a smaller scale in the form of toilets, temporal site offices and existing building extensions but not at a large scale in the form of hospitals or apartments. Buildings may be extended easily using modular units which are self-supporting vertically, but which are supported laterally by the existing structure. Modular units were used successfully in the building process when building the new Greenpoint Stadium in Cape Town. It was mainly used for the facilities and non-load bearing walls within the stadium (Lombaard, 2011).

Prefabrication can be accomplished in virtually any material. Today there are more choices of materials than ever before. With the advent of nano materials and composites, the traditions of concrete and steel may begin to seem historic. However these materials are still high performers for their cost and the reality is

that the use of alternative structural materials outside of these two seem unlikely in the near or long-term future, especially in SA (Smith, 2010).

Materials for structures are generally steel and concrete because they are readily affordable and available. Labour crews have been established to handle these materials and their associated systems. Tools, machines, and factories are well established to develop and manipulate steel and concrete and design standards exist for both steel and concrete. In SA these include the National Building Regulations, the South African Standard SANS 10100-1 (2000) for concrete and the SANS 10162-1 (2005) for steel.

According to SASFA, the development of the modular home building industry in SA started in 2006. To date, 31 companies in South Africa have installed modular homes made of light steel frame manufacturing facilities. They have a combined manufacturing capacity of 53-million linear metres of light steel frame sections, and can process some 48 t/y of high-strength galvanised steel sheet a year, based on-one shift operation, five days a week. Expressed differently, the manufacturers have sufficient profiling capacity to produce light steel trusses covering 1,8 million square meters of floor area, as well as complete buildings (wall frames and trusses) for a total of 2,1 million square meters. Some 51% of the local industry's capacity is based in Gauteng province, but could be moved to other provinces.

In SA some engineers have the opinion that the level of quality of construction in any method is the reason why modular construction is not the preferred method of construction. Lombaard (2011), in response, set out to test this statement by investigating the following three issues:

- Specification of element quality in the SA Standard – This seems to be adequate.
- Specifying details regarding quality on construction drawings – This seems to be satisfactory as determined by a small survey.
- Quality control or quality management of construction work – This seems inadequate in general.

Lombaard (2011) further explored these points, in conjunction with a pair of field studies, and overall it was found that non-compliance with building regulations, i.e. SANS, was the prevalent problem in the SA industry.

SA is a developing country with an unemployment rate of about 24.9% (Statistics South Africa, 2016), therefore improvement of living conditions of the poor through job creation among others is, or should be, a priority of government. While conventional building processes have proven to have the ability to create a variety of opportunities for the unemployed in local communities through bricklaying, material provision, subcontracting of services, modular construction systems are not there yet. These systems are often high tech, requiring extensive training and the use of specialist contractors. At present, contractors employed by the Department of Transport and Public Works through traditional means are required to have 50% of their unskilled labour be members of the local community (Willemse, 2011).

2.4 Conclusion

Utilisation of modular construction is a necessary evolutionary step to bring to the forefront modern building construction market so that the construction industry can prosper in SA. Although many opportunities for modular construction exist in the construction market, many barriers also exist. In addition to the systems barriers discussed above the general public has negative preconceptions regarding modular construction that may slow down the large scale adoption of these methods in SA. It is important to look at examples of past modular construction projects and identify the successful elements and failed portions of the projects. Applying the lessons learned from past designs will improve the chance of success for future designs.

Several studies over the past 10 years (those done by Akinboade and Mkowena, Lu Na, Lawson and Carl T. Haas) have identified the amount of pre-planning, project coordination, transportation restrictions, and procurement/scope of work concerns as the primary limitations of modular construction. Collecting the opinions of professional architects, engineers, quantity surveyors, project managers, modular construction systems manufacturers/suppliers and construction industry major

client through both interviews and surveys, these studies predominantly considered the cost effectiveness or business model alterations that could improve the efficiency of onsite construction. This study focused on the interview-based research which seeks to take a more focused perspective in investigating the application of modular construction in SA. This paper examined the extent of modular construction systems utilisation by large firms and their strategies with regard to their current and future use of the systems.

CHAPTER 3 - RESEARCH DESIGN AND METHODS

This chapter explains the research design and methodology of the study. It comprises the objectives of the research, its approach and design, instruments used, the reliability of the research, and the ethical aspect of performing a feasibility study. Saunders et al., (2016) states "Research design is a master plan specifying the methods and procedures for collecting and analyzing the needed information." There is an important link between the research problem and the research design.

In order to answer how the research was answered a clear methodology was used referred to as a "research onion" as shown below in Figure 3.1. It presented a clear framework for the most suitable methods and strategies to address the research. It promoted the knowledge to answer the research questions. After deciding a suitable philosophy other elements were selected from the layer which assisted in answering the research. Each element in a different layer was discussed below in order to get an idea why these elements were selected while conducting the research.

There were three main research questions:

- What range of modular construction systems are available on the market in SA?
- Why are modular construction systems under-utilised by clients of the construction industry in SA?
- What steps should be taken to increase the utilisation of modular construction systems by clients of the construction industry in SA?

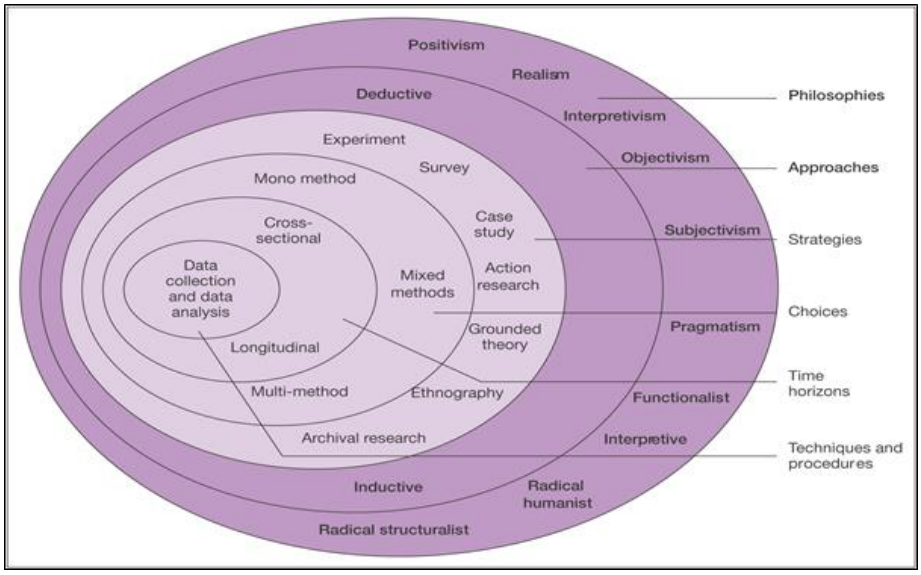


Figure 3.1: Framework used to develop the research design and methodology (adopted from Saunders et al., 2016)

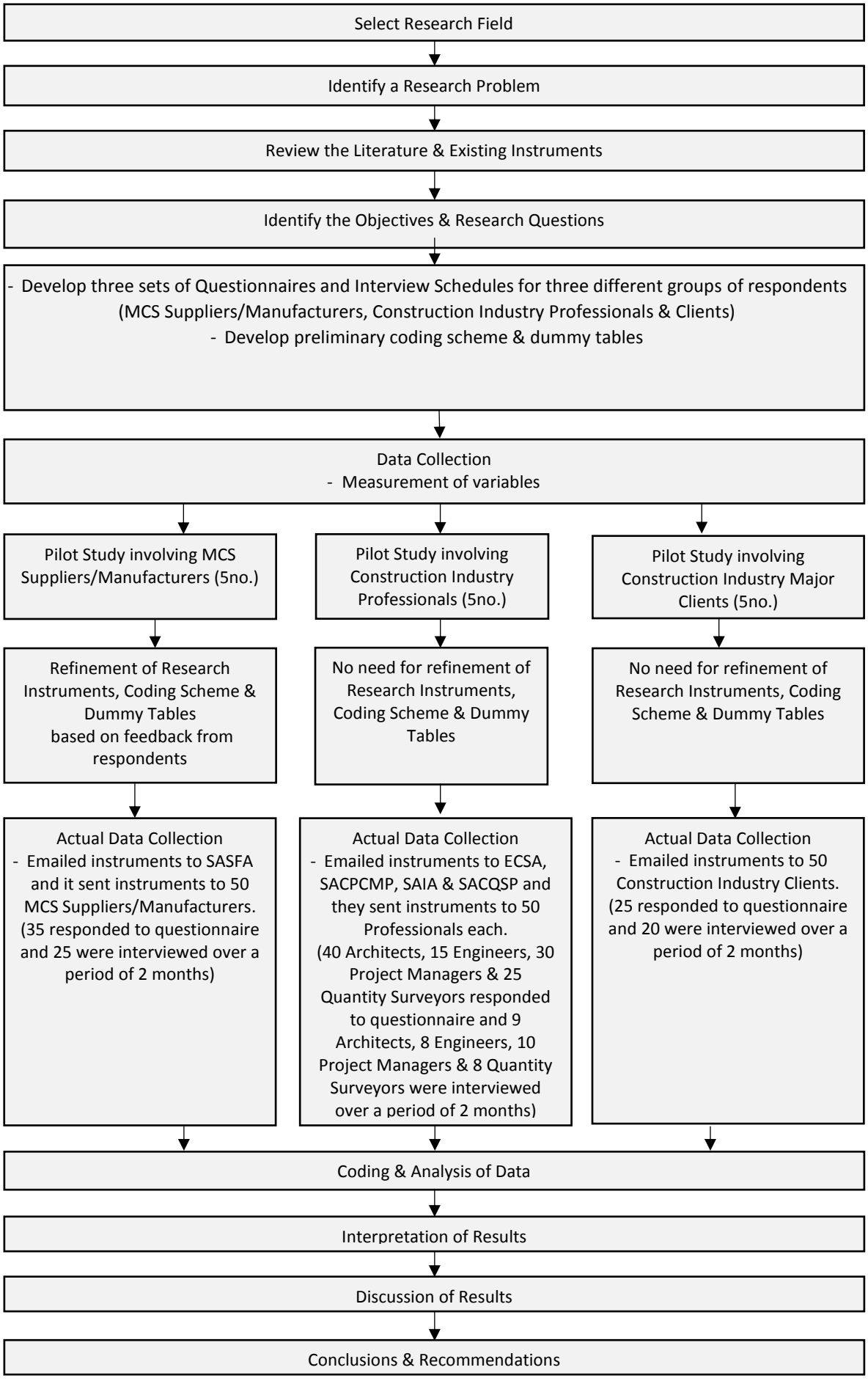


Figure 3.2: Development of the research design and methodology for the study

In essence, the research design and the methods adopted in the study are based on the nature of the research questions and this is illustrated in Figure 3.2 above. The section discusses: the research philosophy, the research approach, the research methodological choice, the research strategy, the research time horizon, in addition to the research techniques and procedures. Thus, the study adopted the pragmatism philosophy which used both inductive and deductive approaches, qualitative and quantitative methodological choices which are mixed methods strategies carried over a cross-sectional time horizon. The methods of data collection and analysis used include semi-structured interviews and surveys which were analysed using content analysis which involves thematic coding which was conducted on transcribed interview data. The development of themes or codes used in the study was developed from literature review as detailed under the content analysis section.

3.1 Research Philosophy

The first layer of the onion is research philosophy. Research philosophy deals with the source, nature and development of knowledge. As part of this research I engaged in knowledge creation when I collected secondary and primary data and engaged in data analysis to answer the research question. In essence, addressing research philosophy in my research involved being aware and formulating my beliefs and assumptions. There were four major ways of thinking about research philosophy: Positivism, Interpretivism, realism and pragmatism. Each contains important differences which influenced the way in which I thought about the research process.

The study considered the principles of good research which include the assumptions about how the world is perceived and how it can be best understood, as underpinned by various schools of thoughts which alluded positivism or post-positivism, interpretivism or constructivism, realism and pragmatism philosophies (Creswell, 2014, Saunders at el. 2016) amongst others. The nature of the inquiry which required the expert opinions or perceptions about modular construction systems utilisation and reasons for under-utilisation, compelled the study to consider both the post-positivism and interpretivism philosophical stances. Interpretivism was developed due to critics over epistemological and ontological stances of the positivism philosophy and it upholds that there is no distinction between the

researcher and the object that is being researched (Krauss, 2005; Cohen and Crabtree, 2006). The post positivism follows an objectivist approach that utilises quantitative methods, while interpretivism uses a subjectivist approach and follows a qualitative research design (Creswell, 2014) and were both useful stances needed by the study.

Other philosophies such as pragmatism and realism among others developed over time as researchers suggested alternatives that were not covered by the two conflicting philosophies or separate from their debates (Creswell, 2014; Biesta, 2010; Melles, 2008). Although interpretivists and positivists differ in epistemological and ontological inferences the two perspectives were considered collectively to address the research problem with necessary measures that nullified their weaknesses to benefit from their strengths (Creswell, 2014). Realism was not central to the study therefore its details are beyond the scope of the study, while pragmatism philosophy is a modern philosophical stance that combines the merits of post-positivism and interpretivism (Creswell, 2014) and is detached from the extremist beliefs and perspectives under positivism or post-positivism and interpretivism or constructivism philosophies (Holden and Lynch, 2004).

Thus, the philosophy allowed the researcher to combine the design methods sequentially to yield better research outcomes with limited bias, improved reliability and validity (Creswell, 2014; Biesta, 2010; Melles, 2008; Holden and Lynch, 2004). Cohen and Crabtree (2006) recognised and recommended the link between qualitative and quantitative methods, which is detached from the paradigm debate between the positivist and the interpretivist. So, the pragmatism philosophy allowed the researcher to use all the possible means to achieve the research objectives which automatically addressed the research questions (Holden and Lynch, 2004; Creswell, 2014).

Mixed methods were used in order to combine the strengths on both qualitative and quantitative research while minimizing the limitations of both approaches and allowed the researcher to group and compute the qualitative data in form of themes or codes to form quantitative measures (Creswell, 2014; Biesta, 2010; Melles, 2008; Holden and Lynch, 2004). Qualitative data was obtained from transcribed

interviews. The themes or codes that were used to extract data from transcripts were developed from literature review (Biesta, 2010). This study used mixed methods research to investigate the utilisation of modular construction systems in SA construction industry, and to examine the causes of under-utilisation of modular construction systems by clients of the construction industry. The study initiated with an exploratory, qualitative phase of interviews with modular construction systems manufacturers/suppliers, construction industry professionals and major clients.

The themes or codes used in qualitative thematic analysis were development through the extensive literature reviews and they went through several testing and improvements which involved detailed scrutiny by other experts in the construction field dealing with modular construction systems as measures to ensure good construct validity (Bell, 2014; Holden and Lynch, 2004). Thus, the study initiated with qualitative data collection followed by qualitative data analysis which was connected to quantitative analysis that enabled the generalisation of the outcome (Creswell, 2014). The research design adopted by the study as supported by the pragmatism philosophical stance was the exploratory sequential mixed methods (Creswell, 2014).

3.2 Research Approach

Two approaches are available, that is, the inductive and deductive research approach. This research uses both inductive and deductive approaches because it is compatible with the research philosophy adopted in the study (Creswell, 2014; Trochim, 2006). Fundamentally, its adoption in the study stems from its connotation to the social construction of knowledge, by creating concepts, themes, or models from the raw data which can be combined with quantitative measures (Holden and Lynch, 2004). Therefore, it facilitated working back and forth between themes and the research database to formulate a comprehensive set of themes (Ketokivi and Mantere, 2010), as discussed in the content analysis section. The qualitative data was sequentially used for quantitative analysis (Creswell, 2014). Succinctly, the research approach precedes the methodological choice discussed in the subsequent section.

3.3 Research Methodology Choice

The study adopted both qualitative and quantitative methodological choices (Saunders et al., 2016), which provided a wider scope for rich data collection; as they focus on the research tools and procedures (Guba and Lincoln, 1994). Hence, more than one data collection methods were used and analysed qualitatively and quantitatively to reinforce the findings, in order to improve the quality of the research results (Polhill et al., 2010). One of the main advantages of mixed methods is its ability to unite exploratory and confirmation research in other words, it allows generation and testing of a theory in the same study (Saunders et al., 2016). Accordingly, the methodological choice connects the research approach and the research strategy.

3.4 Research Strategy

The mixed methods were used as informed by the nature of: the research questions and objectives, the research philosophy, the research approach, the purpose of the study, the extent of existing knowledge, the availability of resources and time, as well as the access to the sources of data and the participants (Creswell, 2014). Predominantly, the mixed-methods combined both qualitative and quantitative methods, in order to address the research questions and the objectives (Creswell, 2014; Biesta, 2010; Melles, 2008; Holden and Lynch, 2004).

The strategy allowed for the triangulation of the data obtained from the interviews and questionnaires; because different data collected from various sources within a study were used to produce the correct meaning (Bell, 2014; Merriam and Tisdell, 2016). Therefore, the adopted strategy overcame the lack of literature in the South African context, which was prompted by the fact that modular construction system is a fairly new building system. Correspondingly, the autonomous use of qualitative and quantitative methods would not have achieved the research objectives, owing to the challenges mentioned above (Creswell, 2014).

In that regard, the option to pursue the subjective insights of modular construction suppliers/manufacturers, construction industry professionals and clients and questionnaires responses analysis (Trochim, 2006; Holden and Lynch, 2004) was the most appropriate to address the questions; as these three groups of participants

were asked for details on modular construction systems utilisation and causes of underutilisation in SA. The questions were adequately answered by mixed methods via the interviews and questionnaires; and these were adopted to generate an understanding of the common causes of under-utilisation and the modular construction systems being utilised by clients in the construction industry (Creswell, 2014; Trochim, 2006; Holden and Lynch, 2004). The sources of the data comprised secondary data (Bell, 2014) obtained from hardcover books, scientific journals, periodicals and websites.

As the research strategy of the "onion ring" lies beneath the research methodological choice, as shown in Figure 3.1, it follows that, the strategy conformed to the preceding three rings (Saunders et al., 2016). It represents the plan taken in answering the research questions or methodological link between the philosophical standpoints, the data collection and the analytical methods used (Saunders et al., 2016). Therefore, the mixed-methods explored the research phenomenon within its context, or a number of actual contexts; since they have the ability to address the "what?" and the "how?" questions, as well as to demonstrate both literal and theoretical replications (Yin, 2009).

3.5 Time Horizon

In coherence with the preceding "onion ring" for the research strategy (mixed method), the cross-sectional time-frame was pertinent to the study (Saunders et al., 2016). Consequently, a cross-sectional perspective was motivated by the instantaneous availability of the data from the experts who had accumulated knowledge over the years and media reports (Creswell, 2014). Interviews were conducted over a short period of time, as well as from the data collected from the questionnaires (Saunders et al., 2016). The period for data collection was done in a maximum period of two months. Longitudinal studies were not used because of time and resource constraints. Finally, the research time horizon "onion ring" encircles the research techniques and procedures.

3.6 Research Design

Research design can be thought of as the logic or master plan of a research that throws light on how the study is to be conducted. It shows how all of the major parts of the research study work together in an attempt to address the research questions. The design of research studies can be divided into three primary approaches, namely a quantitative approach, a qualitative approach or a mixed method approach. The research design for this study is a descriptive and exploratory study that is analysed through mixed methods.

The main determinants for the research design are the degrees of data availability and ambiguity. In areas with great ambiguity and data scarcity the use of explorative research design is appropriate. This type of research provides information for assessing particular phenomena, but is not enough to provide conclusive ground for action. Normally, more detailed surveys are subsequently conducted based on the discoveries from the explorative research. The systems associated with explorative research are: secondary data analysis, pilot studies, in-depth interviews and experience surveys (Zikmund et al., 2013).

Given the exploratory position adopted in this research and the nature of the research question, the mixed study methodology was considered the most appropriate approach to employ because it provides a systematic way to collect data, analyse information, and report the results, thus understand a particular problem or situation in great depth. Further, unlike many other forms of research, the mixed study utilises both qualitative and quantitative methods of data collection or data analysis (Merriam and Tisdell, 2016); therefore, a combination of data collection methods were selected in this study in anticipation of providing a more complete picture.

3.7 Data Collection Methods

The research techniques and procedures comprising the data collection and the analysis methods are situated at the core of the "research onion ring", subsequent to the research time horizon (Saunders et al., 2016). A wide range of data collection tools are available for research. No "one size fits all" solution exists for researchers in general, and those embarking on qualitative research in particular. Amongst the

most common data collection methods, according to Leedy and Ormond (2014), are questionnaires, observations, interviews (structured and unstructured), secondary (literature) review, purposeful and sampling.

For the purposes of this research semi structured questionnaires and interviews were used, which were rich sources of first-hand information (Corbin and Strauss, 2014; Cooper and Schindler, 2013). The secondary data for the analysis was sourced from publications specialising in, amongst others, architecture, project management, operation management, supply chain management and engineering. In addition to that, publications specialising in modular construction analysis, and data and reports from industry associations and organisations were also used.

3.7.1 Questionnaires

Three questionnaires were developed for each sample based on the findings from the comprehensive literature review. The questionnaires were distributed and analysis of this information to develop findings, and extending these to present the suitable solutions to overcome the barriers for utilisation within construction firms in South Africa Construction Industry in terms of innovation will be done using an online tool called Survey Monkey.

The questionnaires were administered using the following links below:

1. Modular Construction Systems Manufacturers/Suppliers
   http://www.surveymonkey.com/r/HYLSK6F
2. Construction Industry Professionals
   http://www.surveymonkey.com/r/HF36JTW
3. Construction Industry Major Clients
   http://www.surveymonkey.com/r/Z5X9TJK

The questionnaires were sent via email to ECSA, SACPCMP, SAIA and SACQSP and they sent the questionnaires to 50 professionals each. Follow up telephone and face to face interviews were then conducted after the surveys had been conducted. The information collected identified the modular construction systems on the market, also obtained the perspectives of MCS suppliers/manufacturers and the observations of their clients feedback in South Africa. It also identified the causes

of under-utilisation of MCS by construction industry clients and their advisors in South Africa and provided recommendations aimed at increasing the utilisation of modular construction systems by construction industry clients in SA.

3.7.2 Interviews

The purpose of interviews was to allow for probing and the clarification of responses for the participants to give their detailed perspectives on modular construction systems utilisation and causes of under-utilisation by clients in the construction industry. Primarily, the interviews involved semi-structured questions to allow the researcher to gather valid and reliable data, thereby making sure that they answered within the confines of the research objectives (Wilkinson and Birmingham, 2003). Semi structured interviews provided flexibility in investigating the views and individual experiences of the participants and, on the other hand, to provide some common basis of comparison of those experiences across the interviewees.

The interviews consisted of three key questions for each group of participants. Data collection and analysis inform or drive each other, with the result that the analysis becomes a higher level synthesis of the information. The iterative cycle is repeated and course design and development checked and revised as the process continues. The researcher's skills and understanding of the subject were pivotal in ensuring that the participants focused their attention on the vital details and on the subject at the emergence of new lines of inquiry during the investigation (Bell, 2014).

In addition, the questions were flexible – to allow the respondents to think and give detailed responses. The questions asked to the three groups of respondents are as listed below.

Modular Construction Systems Manufacturers/Suppliers;

- What types of modular construction systems do you supply to clients in the construction industry: Permanent Modular Construction or Relocatable buildings?
- What are some of the challenges/barriers that cause under utilisation of modular construction systems by construction industry clients?

- What are some of the possible achievable solutions to overcome these barriers?

Construction Industry Professionals;

- Which type of modular construction system have your clients used in their projects: Permanent Modular Construction or Relocatable buildings?
- What are the challenges/barriers that cause your clients to under-utilise modular construction systems in their projects?
- What are some of the possible achievable solutions to help them overcome these barriers?

Construction Industry Major Clients;

- Which type of modular construction system have you used in your projects: Permanent Modular Construction or Relocatable buildings?
- What are the challenges/barriers that cause you to under-utilise modular construction systems in your projects?
- What are some of the possible achievable solutions to help you overcome these barriers?

In this study, the individual interviews that range from 45 minutes to one and half hours long were recorded and transcribed. The semi-structured questions were posed to which participants were required to respond through the telephone. This interview process called for data analysis to occur during the development of the questions and in the interviews themselves. Themes revealed during the literature review influenced the questions asked. The data coding procedures that followed provided direct comparisons of the stakeholders' responses. The contents of research analysis therefore reflected upon the experiences of the participating stakeholders and their reactions to modular projects they had been involved in.

3.8 Data Analysis and Interpretation

The analysis guidelines used included embracing the essence of transparency and the methodical approach used in qualitative research, which states that the analysis of the data should be public, in order to enable the readers to have a detailed

perspective on the methods and the procedures involved in arriving at the findings (Yin, 2011). Therefore, all the procedures, coding, extracts from transcripts, identification and computational procedures were included in the study for public scrutiny (Yin, 2011).

For the purpose of the research, the coding was also done for the frequency of occurrence of themes (Creswell, 2014), in order to identify the most popular causes of under-utilisation of Modular Construction Systems by construction industry clients in South Africa. The coding for frequency was adopted, which involves assigning numbers to the coding frames. The procedure involves listing the coding frames on Excel, followed by allocating alphabetic characters to each conceptual category and the use of Excel count functions to compute and assign numbers to each conceptual category.

The figures and analysis details considered the assessment of positive and negative results, the importance of each source; since conceptual analysis is used to quantify the presence and occurrence of a concept that is chosen for examination (Jabareen, 2009), as a result, the figures were expressed as percentages. Furthermore, the literature findings were matched with the findings of the study to reinforce the findings.

3.9 Validity and Reliability

According to Leedy and Ormrod (2014), validity is concerned with the accuracy, meaningfulness and credibility of the research project as a whole. To ensure validity, a research instrument must measure what it is supposed to measure (Gray, 2006). Reliability is defined by Leedy and Ormord (2014) as the extent to which the same study can be replicated and yield the same result. Due to the nature of the study that it depends on perceptions, attitudes and experiences of individuals, the study is not likely to yield the same result when replicated. However, respondents who are knowledgeable and experienced about study objectives were involved in this study in order to improve the dependability of the results.

To enhance the validity and reliability of the survey instruments, a pilot study was conducted using five (5) representatives of each of the three (3) stratums. Feedback

from the pilot-study respondents regarding the content, scope, question structure, and response scales was solicited and used to make improvements to the survey questionnaire. The survey questionnaires was emailed to the randomly selected research subjects and they were required to respond within three days. An open-ended interview questionnaire to facilitate developing research instrument was also administered to two (2) representatives of each of the three (3) stratums. In order to improve the response rate, personalized cover letters addressed directly to the representatives was developed and sent with the questionnaires. The pilot study took place over a period of seven weeks in the months of July and August, 2017.

3.10 Ethical Considerations

The surveys and interview questions were designed to elicit information on the utilisation of modular construction systems in South Africa. The research adhered to the framework and policies of the School of Construction Economics and Management, University of the Witwatersrand Research Ethics Committee. Any data for research publication purposes was treated with anonymity unless permission is granted for it to be used otherwise. In addition, the data obtained was not be used for either commercial purposes or made available to third parties without your express and written consent. By participating in this study, I expressed my consent to use the data for research as stated. The participant acknowledged their right to discontinue participation in this research at any time without reason. A summary of the findings emerging from the study were made available to all participants on request.

3.11 Research Instruments Design

The unit of analysis for this study was a key decision maker in an architectural, engineering, manufacturing or major clients in the industry involved in or familiar with modular construction. The key decision makers were principal architects, engineers, quantity surveyors, project managers, operations executives and one chief executive officers at the modular manufacturers, and a chief operating officer at major client companies in the construction industry.

These key decision makers were chosen based on their potential ability to commit their respective companies to the adoption of modular building as a construction innovation. The sample of participating companies consisted of both privately owned and publically held companies, all of which are located in South Africa.

As mentioned earlier, open-ended and semi-structured face-to-face and telephone interviews were conducted. These were based on a questions seen in Appendix A designed predominantly to facilitate discussion on modular construction methods, trends and causes of utilisation of these methods by clients in the industry, and not at extracting data and statistics.

The survey and interview questions design and pre-testing took over six weeks. During this period the necessary adjustments to the questions were made and the list of the participants was obtained. The next step was to send out the survey and set-up the appointments. The questions were pretested during discussions with my academic supervisor. These discussions contributed not only in improving the survey and interview questions, but in shaping this research.

3.12 Population

The population refers to the total number of objects, groups or people in the context of the study in a given area or time with similar characteristics; while a sample refers to a portion or subset of objects, groups or people within the total population (Saunders et al., 2016). To understand the methods of modular construction systems on the market being utilised and the reasons for their under-utilisation, the most appropriate sources were surveys and interviews (with modular systems manufacturers/suppliers); while the cause of under-utilisation of modular construction systems by construction industry clients were obtained from professional and major built environment clients. Subsequently, the total sample size was 80 interviews participants and 170 survey participants from were used to achieve the research aim.

The professionals dealing with modular construction utilisation included: architects, engineers, project managers and quantity surveyors. The professionals were selected using non-probability self-selection sampling method which also

became a snowballing sampling technique from respondents out of SAIA, SACPCMP, ECSA and SACQSP professional bodies. The same applied for the modular construction system manufacturers/suppliers that responded out of SASFA. The clients were also selected using the snowballing sampling technique from commercial public and private built environment clients found online. I believe that the intention was not to generalise to the entire population but to gain an understanding if there are barriers causing the under-utilisation of Modular Construction Systems in South Africa.

CHAPTER 4 – DATA COLLECTION, ANALYSIS AND RESULTS

This chapter provides a detailed presentation and description of the results obtained from the qualitative data collected via surveys and interviews. In order to cover all the objectives, the chapter comprises sections on results pertaining to objectives 1, 2 and 3, and a summary of the results. The sections on results are divided into the presentation of the results and the analysis of the results. In order to obtain a glimpse of the data-collection instruments used and variables according to objectives, see Table 4.1

Table 4.1: Summary of variables and data collection

Specific Objectives	Variables	Sources of Data and Triangulation	
		Questionnaires	Semi-structured Interviews
1. To identify the modular construction systems on the market in SA.	- Company type (Supplier/ manufacturer) - Professional job title (Architect/ Engineer/ Project Manager/ Quantity Surveyor) - Type of MCS supplied (Permanent /Relocatable MCS) - Type of MCS used (Permanent /Relocatable MCS) - Segment with highest percentage of clients (residential/ commercial/ industrial/ institutional/ other) - Segment with highest percentage of project use (residential/ commercial/ industrial/ institutional/ other)	- 35 survey participants (MCS suppliers/ manufacturers) - 25 survey participants (construction industry major clients) - 110 survey participants (construction industry professionals)	- 25 interviews (MCS suppliers/ manufacturers) - 20 interviews (construction industry major clients) - 35 interviews (construction industry professionals)
2. To identify the causes of under-utilisation of modular construction systems by clients of the construction industry in SA.	- Identify the top 5 reason why clients use MCS (to compensate for the shortage of skilled craft workers/ compensate for weather condition/ reduce design duration/ reduce construction duration/ increase product quality/ reduce overall project cost/ increase overall labour productivity/ compensate for the restricted working space/ reduce environmental impact/ improve project safety performance/ increase their profit margin/ enhance their reputation/ other)	- 35 survey participants (MCS suppliers/ manufacturers) - 25 survey participants (construction industry major clients) - 110 survey participants (construction industry professionals)	- 25 interviews (MCS suppliers/ manufacturers) - 20 interviews (construction industry major clients) - 35 interviews (construction industry professionals)

	- Identify the top 5 reasons that restrain clients using MCS (construction professional advisors did not specify use/ local building regulations restrict use/ lack of skilled assembly craft workers onsite/ use will increase construction cost/ transportation restraints/ limited design options/ inability to make changes onsite/ other)		
3. To provide recommendations aimed at increasing the utilisation of modular construction systems by construction industry clients in SA.	- Provide possible achievable solutions to overcome challenges of under-utilisation by construction industry clients.	- 35 survey participants (MCS suppliers/ manufacturers) - 25 survey participants (construction industry major clients) - 110 survey participants (construction industry professionals)	- 25 interviews (MCS suppliers/ manufacturers) - 20 interviews (construction industry major clients) - 35 interviews (construction industry professionals)

4.1 Survey and interview data characteristics

4.1.1 Survey samples

The online administered survey developed through Survey Monkey was emailed to four hundred (400) construction industry professionals by SAIA, SACPCMP, ECSA and SACQSP professional bodies, fifty (50) MCS manufacturers/suppliers by SASFA and fifty (50) major construction industry clients and one hundred and ten (110) construction industry professionals, thirty-five (35) MCS manufacturers/suppliers and twenty-five (25) major construction industry clients responded within the following eight weeks. Table 4.2 below shows the summary of respondents.

4.1.1.1 Demographic profile of survey respondents

148 participants had responded to the survey by the deadline, and 22 participants responded within the following two weeks. Therefore, a total of 170 (57%) out the 300 participants participated in this research; of which 40 (24%) are architects, 15

(9%) engineers, 30 (18%) project managers, 25 (15%) quantity surveyors, 25 (15%) major construction industry companies and 35 (21%) are MCS manufacturers/suppliers. Table 4.2 presents the summary of the respondents.

Participants	Initial email	Undelivered	Respondent
Architects	50 (17%)	6 (19%)	40 (24%)
Engineers	50 (17%)	4 (13%)	15 (9%)
Project managers	50 (17%)	8 (25%)	30 (18%)
Quantity surveyors	50 (17%)	5 (16%)	25 (15%)
Major clients	50 (17%)	5 (16%)	25 (15%)
Manufacturers/suppliers	50 (17%)	4 (13%)	35 (21%)
Total Respondents	**300**	**32 (10.7%)**	**170 (100%)**

Table 4.2: Summary of survey respondents

4.1.2 Interview data characteristics

Considering the exploratory nature of the study, a qualitative evaluation was done to identify the modular construction systems on the market and causes of under-utilisation of MCS by construction industry clients. The raw data (transcripts from the interviews conducted with the participants telephonic and face to face was analysed using coding to answer the research questions proposed by the current study. The respondents were not taking part in the study on behalf of their firms hence no mention of firms has been referred to in the study. Neither projects nor clients have been mentioned in the study as the study seeks to understand the individuals experience and understanding of the practise.

4.1.2.1 Demographic profile of interview respondents

Table 4.3 shows the summary of interview respondents according to discipline. Out of 300 respondents that were invited to take part, 80 experienced professionals, construction industry major clients and MCS manufacturers/suppliers responded. All the 80 respondents had knowledge of modular construction. Out of the 80 respondents that were interviewed, nine (9) were architect, eight (8) engineers, ten (10) project managers, eight (8) quantity surveyors, twenty (20) engineers, project managers and managing directors from MCS suppliers/manufacturers and twenty-five (25) procurement managers, project managers and engineers from construction industry major clients.

Participants	Initial invites	Declined	Respondents
Architects	50 (17%)	5 (15%)	9 (11%)
Engineers	50 (17%)	7 (21%)	8 (10%)
Project managers	50 (17%)	3 (9%)	10 (13%)
Quantity surveyors	50 (17%)	8 (24%)	8 (10%)
Major clients	50 (17%)	5 (15%)	20 (25%)
Manufacturers/suppliers	50 (17%)	5 (15%)	25 (31%)
Total Respondents	**300**	**33 (27.5%)**	**80 (100%)**

Table 4.3: Summary of interview respondents

4.2 Identification of Modular Construction Systems on SA construction market

4.2.1 Survey respondents analysis

The following is the summary of MCS Manufacturers/Suppliers', Construction Industry Professionals' and Construction Industry Major Clients' survey responses and analysis for the first three questions in the surveys that fulfilled the first objective, that is, to identify the modular construction systems on the market.

4.2.1.1 Survey responses

Modular Construction Systems Manufacturers/Suppliers' responses

Question 1: Please indicate your company name

1) All 35 companies that responded were private limited companies operating in all of South Africa.

Question 2: Please select the types of Modular Construction Systems you supply

Categories	Responses	
	Frequency	Percentage
Permanent Modular Construction systems where components are attached to a permanent foundation	34	97%
Relocatable Modular Construction systems that maintain their mobility to serve temporary functions	32	91%
Total Respondents: 35		

Table 4.4: The respondents' type of Modular Construction Systems supply

Question 3: Please select the segment with your highest percentage of clients in the construction industry

Categories	Responses	Percentage
Residential	5	14%
Commercial	9	32%
Industrial	8	22%
Institutional	4	11%
Other; Mining industry and Government departments	9	32%
Total Respondents: 35		

Table 4.5: The respondents' highest percentages of clients using Modular Construction Systems

Construction Industry Professionals' responses

Question 1: Please indicate your job title

Categories	Responses	Percentage
Architect	40	36%
Engineer	15	14%
Project Manager	30	27%
Quantity Surveyor	25	23%
Total Respondents: 110		

Table 4.6: Construction Industry Professionals' responses on job title

Question 2: Please select the types of modular construction systems you have used in clients' previous projects.

Categories	Responses	
	Frequency	Percentage
Permanent Modular Construction systems where components are attached to a permanent foundation	65	59%
Relocatable Modular Construction systems that maintain their mobility to serve temporary functions	102	93%
Total Respondents: 110		

Table 4.7: The respondents' type of Modular Construction Systems used

Question 3: Please select the segment with your highest percentage of projects that clients use Modular Construction Systems.

Categories	Responses	Percentage
Residential	13	12%
Commercial	41	37%
Industrial	30	27%
Institutional	24	22%
Other; Mining industry	6	5%
Total Respondents: 110		

Table 4.8: The respondents' highest percentages of projects using Modular Construction Systems

Construction Industry Major Clients' responses

Question 1: Please indicate your company name

1) Clients that range from government departments, private limited, public and state owned companies in SA responded to the survey.

Question 2: Please select the types of modular construction systems you have used in previous projects.

Categories	Responses	
	Frequency	Percentage
Permanent Modular Construction systems where components are attached to a permanent foundation	17	68%
Relocatable Modular Construction systems that maintain their mobility to serve temporary functions	24	96%
Total Respondents: 25		

Table 4.9: The respondents' type of Modular Construction Systems used

Question 3: Please select the segment with your highest percentage of projects that use Modular Construction Systems.

Categories	Responses	Percentage
Residential	3	12%
Commercial	9	60%
Industrial	5	20%
Institutional	2	8%
Other; Mining industry	6	24%
Total Respondents: 25		

Table 4.10: The respondents' highest percentages of projects using Modular Construction Systems

4.2.1.2 Survey data analysis

The following is the summary of data analysis for each of the two research questions of the three (3) surveys.

Data analysis for Modular Construction Systems Manufacturers/Suppliers' survey

1) Please select the types of Modular Construction Systems you supply.

Categories	Percentage
Permanent Modular Construction systems where components are attached to a permanent foundation	97%
Relocatable Modular Construction systems that maintain their mobility to serve temporary functions	91%

Table 4.11: Overall percentages of Modular Construction Systems supply

As Table 4.11 shows, Modular Construction Systems manufacturers/suppliers had specified they supplied Permanent Modular Construction systems to 97% and Relocatable Modular Construction systems to 91% of their clients.

2) Please select the segment with your highest percentage of clients in the construction industry.

Categories	Percentage
Residential	14%
Commercial	32%
Industrial	22%
Institutional	11%
Other; Mining industry and Government departments	32%

Table 4.12: Percentages of clients using Modular Construction Systems

Data in Table 4.12 indicates that modular construction system manufacturers/suppliers supplied to 14% of residential, 32% of commercial, 22% of industrial, 11% of institutional and 32% of mining and government department projects of the construction industry clients.

Data analysis for Construction Industry Professionals' survey

1) Please select the types of modular construction systems you have used in clients' previous projects.

Categories	Percentage
Permanent Modular Construction systems where components are attached to a permanent foundation	59%
Relocatable Modular Construction systems that maintain their mobility to serve temporary functions	93%

Table 4.13: Overall percentages of Modular Construction Systems use by Construction Industry Professionals' clients

As Table 4.13 shows, construction industry professionals had specified the use of Permanent Modular Construction systems in 59% and Relocatable Modular Construction systems in 93% of their clients' projects.

2) Please select the segment with your highest percentage of clients' projects that use Modular Construction Systems.

Categories	Percentage
Residential	12%
Commercial	37%
Industrial	27%
Institutional	22%
Other; Mining industry	5%

Table 4.14: Percentages of Modular Construction Systems use in Construction Industry Professionals clients' projects

Data in Table 4.14 indicates that construction industry professionals **i**ncorporated modular construction systems in 12% of residential, 37% of commercial, 27% of industrial, 22% of institutional and 5% of mining clients' projects.

Data analysis for Construction Industry Major Clients' survey

1) Please select the types of modular construction systems you have used in previous projects.

Categories	Percentage
Permanent Modular Construction systems where components are attached to a permanent foundation	68%
Relocatable Modular Construction systems that maintain their mobility to serve temporary functions	96%

Table 4.15: Overall percentages of Modular Construction Systems use by Construction Industry Major Clients

As Table 4.15 shows, construction industry major clients had specified the use of Permanent Modular Construction systems in 68% and Relocatable Modular Construction systems in 96% of their projects.

2) Please select the segment with your highest percentage of projects that use Modular Construction Systems.

Categories	Percentage
Residential	12%
Commercial	60%
Industrial	20%
Institutional	8%
Other; Mining industry	24%

Table 4.16: Percentages of Modular Construction Systems use in Construction Industry Major Clients' projects

Data in Table 4.16 indicates that construction industry major clients **i**ncorporated modular construction systems in 12% of residential, 60% of commercial, 20% of industrial, 8% of institutional and 24% of mining projects.

4.2.2 Interview analysis

The following is the summary of MCS Manufacturers/Suppliers', Construction Industry Professionals' and Construction Industry Major Clients' interview responses and analysis for the interview questions that fulfilled the first objective, that is, to identify the modular construction systems on the market.

Modular Construction Systems Manufacturers/Suppliers' responses

1. What types of modular construction systems do you supply to clients in the construction industry: Permanent Modular Construction or Relocatable buildings?

Table 4.17 below indicates responses from respondents on the types of MCS that they have manufactured/supplied. Based on the information provided by respondents it is adequate to conclude that all suppliers/manufacturers have provided their clients with relocatable modular construction systems that maintain their mobility to serve temporary functions and 14 (56%) of the respondents also supplied permanent modular construction systems where components are attached to a permanent foundation.

Categories	Responses
Permanent Modular Construction systems where components are attached to a permanent foundation	14 (56%)
Relocatable Modular Construction systems that maintain their mobility to serve temporary functions	25 (100%)
Total Respondents: 25	

Table 4.17: The respondents' type of Modular Construction Systems supply

Construction Industry Professionals' responses

1. Which type of modular construction system have you used in your clients' projects: Permanent Modular Construction or Relocatable buildings?

Table 4.18 below indicates responses from respondents on the types of MCS that they have used in their previous projects. Based on the information provided by respondents it is adequate to conclude that all construction industry professionals have utilised relocatable modular construction systems that maintain their mobility to serve temporary functions and 18 (51%) of the respondents also utilised permanent modular construction systems where components are attached to a permanent foundation.

Categories	Responses
Permanent Modular Construction systems where components are attached to a permanent foundation	18 (51%)
Relocatable Modular Construction systems that maintain their mobility to serve temporary functions	35 (100%)
Total Respondents: 35	

Table 4.18: The respondents' type of Modular Construction Systems used

Construction Industry Major Clients' responses

1. Which type of modular construction system have you used in your projects: Permanent Modular Construction or Relocatable buildings?

Table 4.19 below indicates responses from respondents on the types of MCS that they have used in their previous projects. Based on the information provided by respondents it is adequate to conclude that majority 16 (80%) construction industry major clients have utilised relocatable modular construction systems that maintain their mobility to serve temporary functions and 8 (40%) of the respondents have utilised permanent modular construction systems where components are attached to a permanent foundation.

Categories	Responses
Permanent Modular Construction systems where components are attached to a permanent foundation	8 (40%)
Relocatable Modular Construction systems that maintain their mobility to serve temporary functions	16 (80%)
Total Respondents: 20	

Table 4.19: The respondents' type of Modular Construction Systems used

4.3 Causes of under-utilisation of Modular Construction Systems by SA construction industry clients

4.3.1 Survey respondents analysis

The following is the summary of MCS Manufacturers/Suppliers', Construction Industry Professionals' and Construction Industry Major Clients' survey responses and analysis for the next two questions in the surveys that fulfilled the second objective, that is, to identify the causes of under-utilisation of MCS by SA construction industry clients.

4.3.1.1 Survey responses

Modular Construction Systems Manufacturers/Suppliers' responses

Question 4: Please choose the top 5 reasons why your clients use Modular Construction Systems.

	Responses	
Categories	**Frequency**	**Percentage**
To compensate for the shortage of skilled craft workers	6	17%
To compensate for weather condition	16	46%
To reduce design duration	11	31%
To reduce construction duration	22	63%
To increase product quality	11	31%
To reduce overall project cost	21	60%
To increase overall labour productivity	12	34%
To compensate for the restricted working space onsite	18	51%
To reduce environmental impact	8	23%
To improve project safety performance	4	11%
To increase their profit margin	3	9%
To enhance their reputation	1	3%
Other; Less capital investment on fixed term projects, minimal waste onsite	1	3%
Total Respondents: 35		

Table 4.20: The top 5 reasons for clients using Modular Construction Systems by Modular Construction Systems Manufacturers/Suppliers' respondents

Question 5: Please choose the top 5 reasons that restrain clients using Modular Construction Systems.

	Responses	
Categories	**Frequency**	**Percentage**
Construction professional advisors did not specify the use of Modular Construction Systems.	13	37%
Local building regulations restrict the use of Modular Construction Systems.	20	57%
Lack of skilled assembly craft workers onsite.	15	43%
Using Modular Construction Systems will increase the construction cost.	22	63%
Transportation restraints	16	46%
Limited design options in using Modular Construction Systems.	19	54%
Inability to make changes onsite by using Modular Construction Systems	17	49%
Other; - Perception of modular construction building systems within South Africa - Lack of financing options, ignorance of the benefits of the building system by the community at large.	5	14%
Total Respondents: 35		

Table 4.21: The top 5 reasons that restrain clients from using Modular Construction Systems by Modular Construction Systems Manufacturers/Suppliers' respondents

Construction Industry Professionals' responses

Question 4: Please choose the top 5 reasons why you use Modular Construction Systems for your projects.

Categories	Frequency	Percentage
Project owners require using modular construction systems	36	33%
To compensate for the shortage of skilled craft workers	45	41%
To compensate for weather condition	56	51%
To reduce construction duration	70	64%
To increase product quality	41	37%
To reduce overall project cost	42	38%
To increase overall labour productivity	28	25%
To compensate for the restricted working space onsite	55	50%
To reduce environmental impact	39	35%
To improve project safety performance	40	36%
To increase their profit margin	30	27%
To enhance their reputation	23	21%
Other; To pilot these projects against conventional buildings	1	1%
Total Respondents: 110		

Table 4.22: The top 5 reasons for using Modular Construction Systems by Construction Industry Professionals' respondents

Question 5: Please choose the top 5 reasons that restrain you from using Modular Construction Systems in your projects.

	Responses	
Categories	**Frequency**	**Percentage**
The project owners did not specify the use of Modular Construction Systems.	43	39%
Local building regulations restrict the use of Modular Construction Systems.	86	78%
Lack of skilled assembly craft workers onsite.	62	56%
Using Modular Construction Systems will increase the construction cost.	74	67%
Transportation restraints	80	73%
Limited design options in using Modular Construction Systems.	72	65%
Inability to make changes onsite by using Modular Construction Systems	83	75%
Other; - High maintenance cost - High design cost associated with the building system - Bad reputation.	14	13%
Total Respondents: 110		

Table 4.23: The top 5 reasons that restrain the use of Modular Construction Systems by Construction Industry Professionals' respondents

Construction Industry Major Clients' responses

Question 4: Please choose the top 5 reasons why you use Modular Construction Systems for your projects.

Categories	Frequency	Percentage
Construction industry professionals advised using modular construction systems	3	12%
To compensate for the shortage of skilled craft workers	7	28%
To compensate for weather condition	21	84%
To reduce construction duration	23	92%
To increase product quality	11	44%
To reduce overall project cost	14	56%
To increase overall labour productivity	4	16%
To compensate for the restricted working space onsite	21	84%
To reduce environmental impact	7	28%
To improve project safety performance	8	32%
To increase their profit margin	3	12%
To enhance their reputation	3	12%
Other	0	0%
Total Respondents: 25		

Table 4.24: The top 5 reasons for using Modular Construction Systems by Construction Industry Major Clients' respondents

Question 5: Please choose the top 5 reasons that restrain you from using Modular Construction Systems in your projects.

	Responses	
Categories	**Frequency**	**Percentage**
Construction professional advisors did not specify the use of Modular Construction Systems.	11	44%
Local building regulations restrict the use of Modular Construction Systems.	18	72%
Lack of skilled assembly craft workers onsite.	11	44%
Using Modular Construction Systems will increase the construction cost.	22	88%
Transportation restraints	17	68%
Limited design options in using Modular Construction Systems.	21	84%
Inability to make changes onsite by using Modular Construction Systems	25	100%
Other	0	0%
Total Respondents: 25		

Table 4.25: The top 5 reasons that restrain the use of Modular Construction Systems by Construction Industry Major Clients' respondents

4.3.1.2 Survey data analysis

The following is the summary of data analysis for each of the two research questions of the three (3) surveys.

Data analysis for Modular Construction Systems Manufacturers/Suppliers' survey

4) Please choose the top 5 reasons why your clients use Modular Construction Systems.

The manufacturers/suppliers identified the following top five (5) motivations for their clients to use MCS in rank order were to 1) reduce the construction duration, 2) reduce the overall project cost, 3) compensate for the restricted working space, 4) compensate for weather condition and 5) increase overall labour productivity. In addition, almost 3% of respondents mentioned other reasons – to reduce capital investment on fixed term projects and to minimise waste onsite.

5) Please choose the top 5 reasons that restrain clients using Modular Construction Systems.

The manufacturers/suppliers identified the following top five (5) challenges for their clients to use MCS in rank order were 1) increased construction cost, 2) local building regulations restrictions, 3) limited design options, 4) inability to make changes onsite and 5) transportation restraints. About 14% of manufacturers/suppliers discussed other reasons included the negative perception and ignorance of the benefits of the building system by the community at large.

Data analysis for Construction Industry Professionals' survey

4) Please choose the top 5 reasons why you use Modular Construction Systems for your projects.

The top five (5) motivations for construction industry professionals' clients to use MCS in rank order were to 1) reduce the construction duration, 2) compensate for the restricted working space onsite, 3) compensate for weather condition, 4) reduce overall project cost and 5) increase product quality. In addition, 1% of the respondents mentioned another reason – to pilot these projects against conventional buildings.

5) Please choose the top 5 reasons that restrain you from using Modular Construction Systems in your projects.

The top five (5) challenges for construction industry professionals' clients to use MCS in rank order were 1) local building regulations restrictions, 2) inability to make changes onsite, 3) transportation restraints, 4) increased construction cost and 5) limited design options. In addition, 13% of the respondents mentioned other reasons – high maintenance cost, high design cost and bad reputation.

Data analysis for Construction Industry Major Clients' survey

4) Please choose the top 5 reasons why you use Modular Construction Systems for your projects.

The top five (5) motivations for construction industry major clients to MCS in rank order were to 1) reduce the construction duration, 2) compensate for the restricted working space onsite, 3) compensate for weather condition, 4) reduce overall project cost and 5) increase product quality.

5) Please choose the top 5 reasons that restrain you from using Modular Construction Systems in your projects.

The top five (5) challenges for construction industry major clients to MCS in rank order were 1) inability to make changes onsite, 2) increased construction cost, 3) limited design options, 4) local building regulations restrictions and 5) transportation restraints.

4.3.2 Interview analysis

The following is the summary of MCS Manufacturers/Suppliers', Construction Industry Professionals' and Construction Industry Major Clients' interview responses and analysis for the interview questions that fulfilled the second objective, that is, to identify the causes of under-utilisation of MCS by SA construction industry clients.

Modular Construction Systems Manufacturers/Suppliers' responses

2. What are some of the challenges/barriers that cause under-utilisation of modular construction systems by construction industry clients?

Figure 4.1 below indicates responses from (25) respondents on the challenges that cause under-utilisation of MCS by clients in the construction industry. The majority of the respondents (23) of the respondents were of the view that transport restraints (size constraints, transportation cost and impact on building structures) and limited design options were the major causes of under-utilisation of MCS by clients in the construction industry.

Of the total number of people who took part in this study, 20 were of the opinion that inability to make changes onsite paused a challenge. Thirteen (13) of the total also had an opinion that local building regulations from accreditation bodies such as Agrement South Africa had restrictions and negative perception/reputation that the community had of MCS caused clients to under-utilise the system. Twelve (12) out of the twenty-five (25) respondents were of the opinion that the lack of financing options by banks/institutions for modular building system in construction also restrained the clients utilising the system.

Eight (8) of the total number of respondents suggested that the system increases cost of the overall project while the other four (4) were of the opinion that construction professional advisors did not specify use of the system hence causing challenges for clients to use the systems.

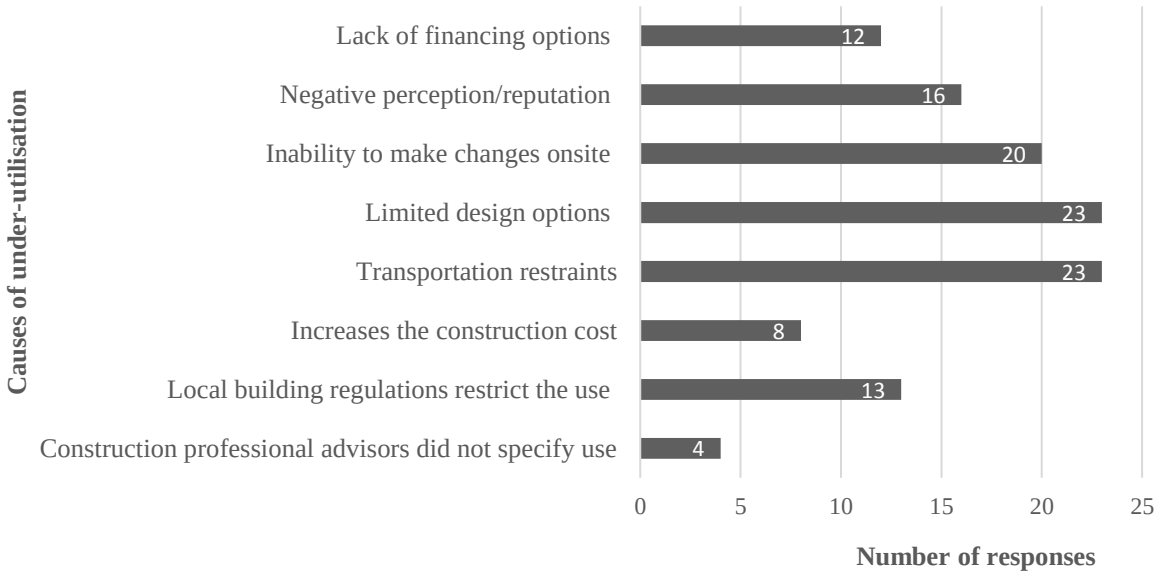


Figure 4.1: Responses on the challenges/barriers that cause under-utilisation of modular construction systems (Modular Construction Systems Manufacturers/Systems)

Construction Industry Professionals' responses

2. What are the challenges/barriers that cause your clients to under-utilise modular construction systems in their projects?

Figure 4.2 below indicates responses from (35) respondents on the challenges that cause under-utilisation of MCS by clients in the construction industry. The majority of the respondents (33) of the respondents were of the view that transport restraints (size constraints, transportation cost and impact on building structures) and limited design options were the major challenges that cause clients to under-utilise modular construction systems in their projects.

Of the total number of people who took part in this study, 32 were of the opinion that local building regulations from accreditation bodies such as Agrement South Africa has restrictions that pause as challenges to clients utilising the system while the other 8 were and also the opinion that the negative perception/reputation that the community has of MCS was also a challenge for its utilisation. Sixteen (16) out of the fifteen (35) respondents were of the opinion that the lack of financing options by banks/institutions for MCS in construction also restrained the clients utilising the system.

Twelve(12) of the total number of respondents suggested that the system increases cost of the overall project while the other seven (7) were of the opinion that project owners not specifying the use of the system cause challenges for clients to use the systems.

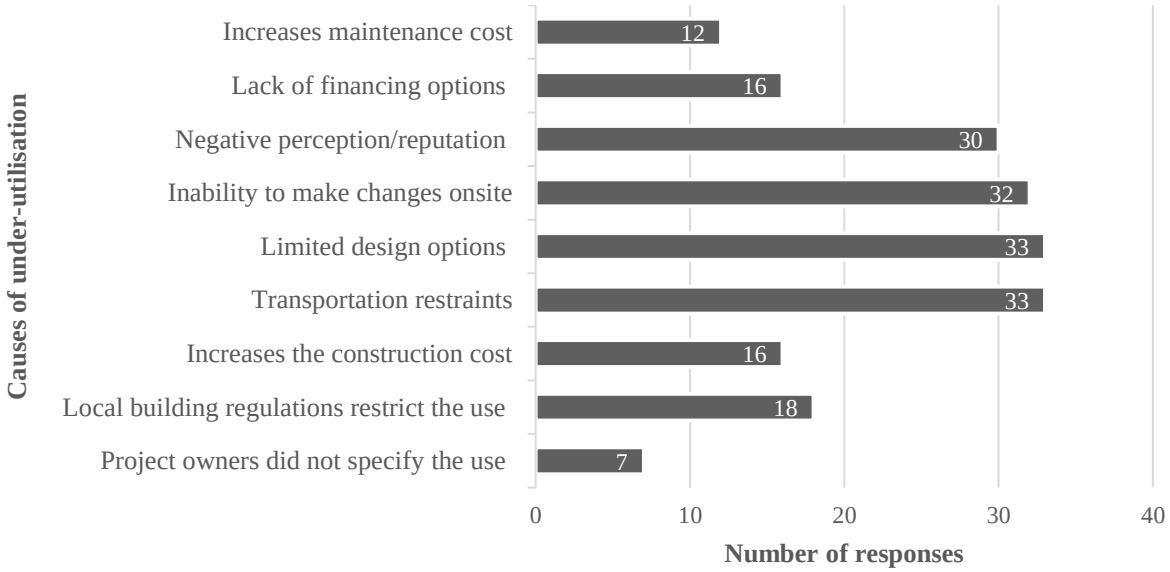


Figure 4.2: Responses on the challenges/barriers that cause under-utilisation of modular construction systems (Construction Industry Professionals)

Construction Industry Major Clients' responses

2. What are the challenges/barriers that cause you to under-utilise modular construction systems in your projects?

Figure 4.3 below indicates responses from (20) respondents on the challenges that cause under-utilisation of MCS by major clients in the construction industry. The majority of the respondents (19) of the respondents were of the view that transport restraints (size constraints, transportation cost and impact on building structures) and limited design options were the major challenges that cause them to under-utilise MCS in their projects.

Of the total number of people who took part in this study, 16 were of the opinion that inability to make changes onsite pause as challenges to clients utilising the system while 13 were of the opinion that the negative perception/reputation that the community has of MCS was also a challenge for its utilisation. Ten (10) out of the

twenty (20) respondents were of the opinion that local building regulations also restrained them utilising the system.

Nine (9) respondents had the opinion that lack of financing options cause challenges for them to use the systems. Seven (7) of the total number of respondents suggested that the system increases cost of construction and maintenance costs while the other four (4) were of the opinion that construction industry professionals not specifying the use of the system cause challenges for them to use the systems.

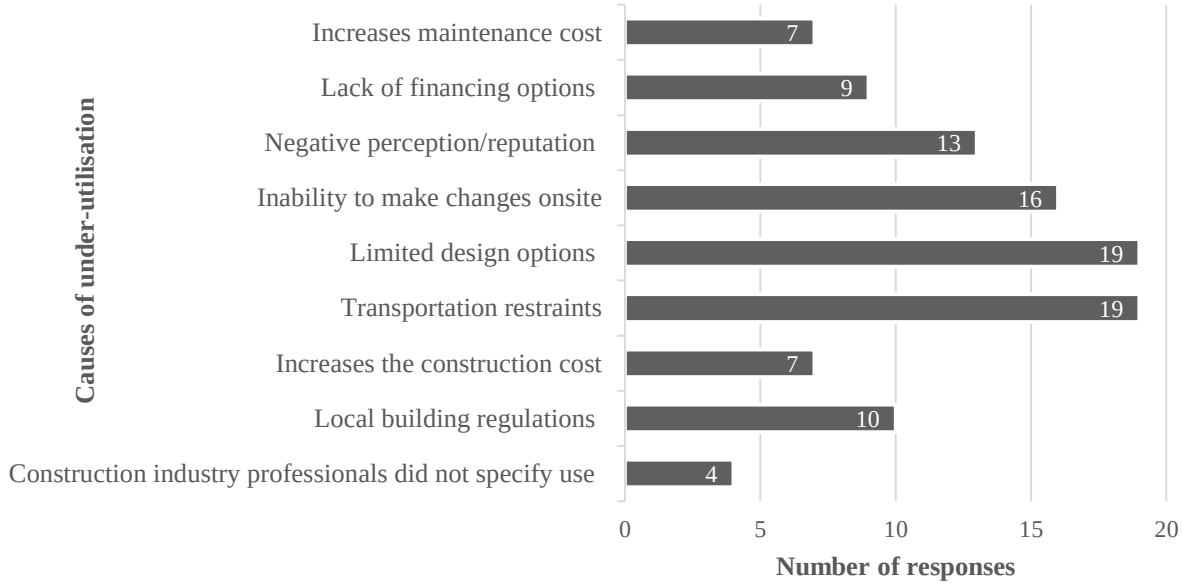


Figure 4.3: Responses on the challenges/barriers that cause under-utilisation of modular construction systems (Construction Industry Major Clients)

4.4 Recommendations by respondents on how to increase utilisation of Modular Construction Systems by construction industry clients in SA

4.4.1 Survey respondents analysis

The following is the summary of MCS Manufacturers/Suppliers', Construction Industry Professionals' and Construction Industry Major Clients' survey responses and analysis for the last questions in the surveys that fulfilled the third objective, that is, to provide recommendations aimed at increasing the utilisation of MCS by construction industry clients in SA.

Modular Construction Systems Manufacturers/Suppliers' responses

Question 6: Please provide possible achievable solutions to overcome these challenges.

Several achievable solutions to overcome these challenges were mentioned by respondents, which include 1) improve transport methods, educate construction professionals and the community on the benefits of the system to improve reputation 2) achieve accreditation with institutions such Agrement South Africa, with this they can overcome many of the building regulations 3) come up with new ideas and concepts allowing for more flexibility in design options 4) interventions with SABS and Municipalities on the regulations and building standards required 5) finance to be made available by banks/institutions for building system in construction.

Construction Industry Professionals' responses

Question 6: What factors would influence you to increase your utilisation of Modular Construction Systems?

Several achievable solutions to overcome these challenges were mentioned by respondents, which include 1) limited maintenance cost 2) significant lower price than conventional buildings 3) good aesthetics 4) good reputation 5) better knowledge on the benefits of using the system

Construction Industry Major Clients' responses

Question 6: What factors would influence you to increase your utilisation of Modular Construction Systems?

Several achievable solutions to overcome these challenges were mentioned by respondents, which include 1) limited maintenance cost 2) significant lower price than conventional buildings 3) good aesthetics 4) good reputation 5) better knowledge on the benefits of using the system.

4.4.2 Interview analysis

The following is the summary of MCS Manufacturers/Suppliers', Construction Industry Professionals' and Construction Industry Major Clients' interview responses and analysis for the interview questions that fulfilled the third objective, that is, to provide recommendations aimed at increasing the utilisation of MCS by construction industry clients in SA.

Modular Construction Systems Manufacturers/Suppliers' responses

3. What are some of the possible achievable solutions to overcome these barriers?

Since MCS suppliers/manufacturers dealt with clients and professionals in the construction industry on a regular basis they were in a better position to give some of the possible solutions to overcome the barriers of the systems' under-utilisation. Table 4.24 below shows a variety of possible achievable solutions to overcome these barriers suggested by respondents.

Respondents indicated that barriers of under can be bridged by coming up with new ideas and concepts to allow for more flexibility in design options and developing construction partners and industry relationships to improve their knowledge of the future demand and thus improve their resources to manufacture additional special elements. Others suggested that providing customised design options would engage customers' preferences. Some respondents suggested investing in developing alternative construction materials to overcome the transportation restraints.

Other respondents suggested developing and providing awareness training of the systems' benefits to manufacturers/suppliers, construction industry professionals and clients to improve reputation. Some were of the opinion that interventions with SABS and Municipalities on the regulations can be made to separate registration, building standards and certification of modular buildings and to bridge the barriers of adherence to Agrement Certification. The table provides the direct quotes of the exact words the respondents used while suggesting the solutions to overcome barriers of MCS under-utilisation by construction industry professionals and clients.

Table 4.26: Suggested solutions by manufacturers/suppliers to overcome barriers of under-utilisation of Modular Construction Systems

Company	Discipline	Solutions to overcome barriers of under-utilisation
A1	Structural Engineering	Respondent A1 said, "come up with new ideas and concepts to allow for more flexibility in design options and improve reputation".
A2, A24	Structural Engineering	Respondents A2 and A24 said, "manufacturers/suppliers can develop construction partners and industry relationships to improve their knowledge of the future demand and thus improve their resources to manufacture additional special elements".
A3	Structural Engineering	Respondent A3 said, "ensure that the clients and whole project team is aware of the advantages of modular construction systems and contractors must experiment with different types of modular construction systems to ensure that they are capable of utilising them".
A4	Structural Engineering	Respondent A4 said, "invest in developing alternative construction materials to overcome the transportation restraints".
A5	Structural Engineering	Respondent A5 said, "develop and provide awareness training of the systems' benefits to manufacturers/suppliers, construction industry professionals and clients to improve reputation".
A6	Structural Engineering	Respondent A6 said, "finance to be made available by banks/institutions for building modular construction systems to increase utilisation by clients".
A7	Structural Engineering	Respondent A7 said, "develop continuing education course to increase the awareness of construction industry professionals' and clients' percentage of the use of the system".
A8	Structural Engineering	Respondent A8 said, "provide customised design options to engage customers' preferences".
A9, A25	Project Management	Respondents A9 and A25 said, "construction and design discipline should work together to develop new and improve existing certification schemes for both manufacturers of modular construction systems and the final product themselves".
A10	Project Management	Respondent A10 said, "new construction funding vehicles can be offered by innovative financial institutions and utilizing novel methods such as independent quantity surveyors to measure and guarantee performance to bridge the lack of finance barriers".
A11	Project Management	Respondent A11 said, "manufacturers/suppliers and construction industry professionals should collaborate on improving product quality, onsite workmanship and engage with the client in pre-project planning during the conceptual design phase to minimize the possibility of onsite changes".

A12	Project Management	Respondent A12 said, “interventions with SABS and Municipalities on the regulations can be made to separate registration, building standards and certification of modular buildings and to bridge the barriers of adherence to Agrement Certification”.
A13	Project Management	Respondent A13 said, “manufactures/suppliers, material suppliers and construction industry professionals should work together to improve the efficiency of material delivery systems to satisfy all design options”.
A14	Project Management	Respondent A14 said, “come up with new ideas and concepts to allow for more flexibility in design options and improve reputation”.
A15	Project Management	Respondent A15 said, “client companies can increase their competence to manage innovation and their will to improve. Therefore their staff’s inability to manage modular construction systems innovations will be bridged”.
A16	Project Management	Respondent A16 said, “invest in developing alternative construction materials to overcome the transportation restraints”.
A17	Project Management	Respondent A17 said, “clients can be provided with incentives by the government to utilize the system more. These incentives can be cost effective construction, labour-intensive construction, greener building method, more sustainable, improved health and safety and improved training”.
A18	Project Management	Respondent A18 said, “interventions on the regulations can be made to separate registration, building standards and certification of modular buildings and to bridge the barriers of adherence to Agrement Certification”.
A19	Project Management	Respondent A19 said, “provide more design options to engage customers’ preferences”.
A20	Managing Director	Respondent A20 said, “invest in developing alternative construction materials to overcome the transportation restraints”.
A21	Managing Director	Respondent A21 said, “finance to be made available by banks/institutions for building modular construction systems to increase utilisation by clients”
A22	Managing Director	Respondent A22 said, “manufactures/suppliers, material suppliers and construction industry professionals should work together to improve the efficiency of material delivery systems to satisfy all design options”.
A23	Managing Director	Respondent A23 said, “clients can be provided with incentives by the government to utilize the system more. These incentives can be cost effective construction, labour-intensive construction, greener building method, more sustainable, improved health and safety and improved training”.

Construction Industry Professionals' responses

3. What are some of the possible achievable solutions to help them overcome these barriers?

Since construction industry professional were in a position to advice clients on the systems to use during construction projects they were in a better position to give some of the possible solutions to overcome the barriers of the systems' under-utilisation. Table 4.26 below shows a variety of possible achievable solutions to overcome these barriers suggested by respondents.

Respondents indicated that barriers can be bridged by coming up with new ideas and concepts to allow for more flexibility in design options, developing construction partners and industry relationships to improve their knowledge of the future demand and thus improve their resources to manufacture additional special elements and providing customised design options to engage customers' preferences. Another respondent suggested investing in developing alternative construction materials to overcome the transportation restraints.

Another respondent suggested developing and providing awareness training of the systems' benefits to construction industry professionals and clients to improve reputation. One was of the opinion that interventions with regulating authorities on the regulations can be made to separate systems' registration. The table provides the direct quotes of the exact words the respondents used while suggesting the solutions to overcome barriers of MCS under-utilisation by construction industry professionals.

Table 4.27: Suggested solutions by construction industry professionals to overcome barriers of under-utilisation of Modular Construction Systems

Company	Discipline	Solutions to overcome barriers of under-utilisation
B1, B16	Architecture	Respondents B1 and B16 said, "come up with new ideas, designs and concepts".
B2, B17	Architecture	Respondents B2 and B17 said, "government to provide incentives to utilize the system more".
B3, B18	Architecture	Respondents B3 and B18 said, "provide customised design options to engage customers' preferences".
B4, B19, B20	Architecture	Respondents B4, B19 and B20 said, "invest in developing alternative construction materials".

B5,B21	Structural Engineering	Respondents B5 and B21 said, "develop and provide awareness training of the systems' benefits to construction industry professionals and clients".
B6, B22, B28	Structural Engineering	Respondents B6, B22 and B28 said, "finance to be made available by banks/institutions for building modular construction systems".
B7,B23	Structural Engineering	Respondents B7 and B23 said, "develop continuing education course for construction industry professionals' and clients' percentage of the use of the system".
B8, B24, B25	Project Management	Respondents B8, B24 and B25 said, "provide customised design options to engage customers' preferences".
B9, B26	Project Management	Respondents B9 and B26 said, "construction and design discipline should work together to develop new and improve existing certification schemes".
B10, B27	Project Management	Respondents B10 and B27 said, "new construction funding vehicles can be offered by innovative financial institutions".
B11, B29	Project Management	Respondents B11 and B29 said, "manufacturers/suppliers and construction industry professionals can collaborate on improving product quality and onsite workmanship".
B12, B35	Project Management	Respondents B12 and B35 said, "interventions with regulating authorities on the regulations can be made to separate systems' registration".
B13, B30	Quantity surveyor	Respondents B13 and B30 said, "manufactures/suppliers, material suppliers and construction industry professionals should work together to improve the efficiency of material delivery systems".
B14, B31, B32	Quantity surveyor	Respondents B14, B31 and B32 said, "engage with the client in pre-project planning during the conceptual design phase to minimize the possibility of onsite changes".
B15, B33, B34	Quantity surveyor	Respondents B15, B33 and B34 said, "construction industry professionals and client companies can increase their competence to manage innovation and their will to improve".

Construction Industry Major Clients' responses

3. What are some of the possible achievable solutions to help you overcome these barriers?

Since construction industry major clients made decisions on which system to utilise during construction projects they were in a better position to give some of the possible solutions to overcome the barriers of the systems' under-utilisation. Table 4.28 below shows a variety of possible achievable solutions to overcome these barriers suggested by respondents.

Respondents indicated that barriers can be bridged by coming up with new ideas and concepts to allow for more flexibility in design options, developing construction partners and industry relationships to improve their knowledge of the future demand and thus improve their resources to manufacture additional special elements and providing customised design options to engage customers' preferences. Another respondent suggested investing in developing alternative construction materials to overcome the transportation restraints.

Another respondent suggested developing and providing awareness training of the systems' benefits to construction industry professionals and clients to improve reputation. The table provides the direct quotes of the exact words the respondents used while suggesting the solutions to overcome barriers of MCS under-utilisation by construction industry professionals.

Table 4.28: Suggested solutions by major clients to overcome barriers of under-utilisation of Modular Construction Systems

Company	Discipline	Solutions to overcome barriers of under-utilisation
C1	Procurement management	Respondent C1 said, "systems suppliers/manufacturers to come up with new ideas, designs and concepts".
C2	Procurement management	Respondent C2 said, "government to provide incentives to utilize the system more".
C3	Procurement management	Respondent C3 said, "provide customised design options to engage customers' preferences".
C5	Structural Engineering	Respondent C5 said, "invest in developing alternative construction materials".
C6	Structural Engineering	Respondent C6 said, "develop and provide awareness training of the systems' benefits to construction industry professionals and clients".
C7	Structural Engineering	Respondent C7 said, "finance to be made available by banks/institutions for building modular construction systems".
C8	Structural Engineering	Respondent C8 said, "develop continuing education course for the community to increase percentage of use of the system".
C9	Project Management	Respondent C9 said, "provide customised design options to engage customers' preferences".

C10	Project Management	Respondent C10 said, “invest in developing alternative construction materials”.
C11, C17	Project Management	Respondents C11and C17 said, “new construction funding vehicles can be offered by innovative financial institutions”.
C12	Project Management	Respondent C12 said, “manufacturers/suppliers and construction industry professionals can collaborate on improving product quality and onsite workmanship”.
C13	Project Management	Respondent C13 said, “develop continuing education course for the community to increase percentage of use of the system”.
C14, C18	Managing Director	Respondents C14 and C18 said, “manufactures/suppliers, material suppliers and construction industry professionals should work together to improve the efficiency of material delivery systems”.
C15, C19	Managing Director	Respondents C15and C19 said, “engage with the client in pre-project planning during the conceptual design phase to minimize the possibility of onsite changes”.
C16, C20	Managing Director	Respondents C16 and C20 said, “construction industry professionals and client companies can increase their competence to manage innovation and their will to improve”.

4.5 Summary of the results

In summary, the conceptual framework was used to produce the figures and tables of results pertaining to the surveys and interviews, which were familiar. Based on the respondents’ experiences working with MCS, all respondents have utilised relocatable modular construction systems that maintain their mobility to serve temporary functions. This reflects that MCS are known in the construction industry. It can therefore be concluded that all of the above recommendations by respondents on bridging the barriers of utilisation would serve to raise the visibility and credibility of the use of MCS by construction industry clients in the S.A. There was a general common understanding of the utilisation of MCS in the construction industry and the causes of under-utilisation by clients in the construction industry.

The following is a summary of the results found from the interviews and surveys in relation to the specific objectives;

To identify the modular construction systems on the market in SA

Conclusively, from the context of the first objective, all three groups of survey and interview respondents specified the highest use of Relocatable Modular Construction systems by construction industry clients. Based on the three groups of survey respondents identified the commercial industry clients as the dominant users of MCS in the construction industry. Conversely institutional clients used the systems the least.

To identify the causes of under-utilisation of modular construction systems by clients of the construction industry in SA.

Concerning the second objective, all three groups of survey and interview respondents specified the top five (5) reasons that motivate construction industry clients to use MCS were to 1) reduce the construction duration, 2) compensate for the restricted working space onsite, 3) compensate for weather condition, 4) reduce overall project cost and 5) increase product quality. In addition, almost 3% of manufacturers/suppliers survey respondents mentioned other reasons – to reduce capital investment on fixed term projects and to minimise waste onsite. Almost 1% of construction industry professionals' survey respondents also mentioned another reason – to pilot these projects against conventional buildings.

The overall results from the three groups of survey and interview respondents also indicated that the top five (5) challenges that restrain construction industry clients from using modular construction systems were 1) inability to make changes onsite; 2) increased construction cost; 3) limited design options; 4) local building regulations restrictions and 5) transportation restraints. About 14% of manufacturers/suppliers respondents discussed other reasons and these included the negative perception and ignorance of the benefits of the building system by the community at large. In addition, 13% of the construction industry professional respondents mentioned high maintenance cost, high design cost and bad reputation as other reasons.

To provide recommendations aimed at increasing the utilisation of modular construction systems by construction industry clients in SA.

With reference to the third objective, all three groups of survey respondents came up with several achievable solutions to overcome challenges of under-utilisation of MCS which include 1) improve transport methods, educate construction professionals and the community on the benefits of the system to improve reputation 2) achieve accreditation with institutions such Agrement South Africa, with this they can overcome many of the building regulations 3) come up with new ideas and concepts allowing for more flexibility in design options 4) interventions with SABS and Municipalities on the regulations and building standards required 5) finance to be made available by banks/institutions for building system in construction.

Based on the results in Figure 4.1, 4.2 and 4.3 it can be observed that majority of the interview respondents were of the view that transport restraints and limited design options are the major causes of MCS under-utilisation by construction industry professionals and clients. It was found that the main solutions that the three groups of respondents suggested to overcome barriers of MCS under-utilisation by construction industry professionals and clients included 1) invest in developing new ideas, concepts and alternative construction materials; 2) develop and provide awareness training of the benefits and methods of utilisation; 3) construction industry professionals and systems suppliers/manufacturers should work together to develop new and improve existing Agrement certification schemes; 4) collaboration of manufacturers/suppliers and construction industry professionals in pre-project planning during the conceptual design phase; 5) finance to be made available by banks/institutions and 6) government to provide incentives for clients to utilise the system more. Conclusively, the succeeding chapter discusses the implications of the study findings in the context of the literature in Chapter 2.

CHAPTER 5 - DISCUSSION OF RESULTS

5.1 Introduction

This chapter discusses the results of the study. In these discussions, reference will be made to the literature review with the intention of drawing comparisons between the results of this study and the associated available literature. The chapter on the discussion of results ends with a conclusion.

5.2 Discussion of the Results

5.2.1 Utilisation of Modular Construction Systems

The results of the study indicate that modular construction systems is not widely used by the stakeholders in the SA construction industry. The majority of the construction industry professionals' and clients' respondents had utilised relocatable modular construction systems more than permanent modular construction systems in their projects. The manufacturers/suppliers respondents pointed out that they had supplied more of the relocatable modular construction systems than the permanent modular construction for their clients. The suppliers/manufacturers supplied the Commercial segment with their systems the most and supplied institutional industry the least. The construction industry professionals and clients respondents had utilised MCS for Commercial projects the most and the least in Residential projects. These results correspond with findings by Akinboade and Mkowena, (2012) that suggest that the South African market is fragmented, resistant to change, labour intensive and wary of new processes.

5.2.2 Causes of under-utilisation of Modular Construction Systems by construction industry clients

The construction industry professionals and clients gave various barriers that cause under-utilisation of MCS for their projects. These barriers range from the following:

The project owners not specifying and construction industry professionals not advising on the use: Schoenborn (2012) states that there is a lack of knowledge of modular systems manufacturing processes among construction industry professionals and clients. Very few respondents that took part in the survey and that were interviewed identified this as a barrier to using modular systems. The construction industry professional and clients interviewed had some knowledge of modular construction systems available on the market and the advantages and disadvantages that come with utilising the system. Construction industry professionals were more familiar with a lengthened design development stage that associated with conventional construction but were not familiar with the process of modular construction and this caused the barrier professionals advising on the use.

Local building regulations restrict the use: Lombaard (2011) states that the existing building code, bylaws, and operational standards are systemically more conducive to conventional construction practices not modular construction. Some respondent agreed to this. Fewer construction industry professionals interviewed identified it as a major barrier to utilisation of MCS, however it was ranked second by the survey respondents. Respondents did not necessarily have issues with the system, that is, there are no rules that make it illegal to build modular, but modular construction is outside the current building tradition within which inspectors, regulators and owners operate. Respondents also pointed out secondary regulations that affect the modular construction industry. Transportation regulations can greatly affect the cost, design and timing of a project, especially when companies are operating across several jurisdictions that may have different rules between them. There are also regulatory bodies such as warranties, SANS, SABS and Agrement South Africa. All of these affect modular, and most problems arise due to the fact that modular construction differs from standard procedures, and while not being prohibited, it often does not fit the standards and regulations in the same way as traditional methods.

Lack of skilled assembly craft workers onsite: Haas et al. (2000) suggests that very few construction industry professionals have the disciple to execute the additional up-front planning and connectivity reviews required by modular construction. Most survey respondents agreed with this. Lack of skilled assembly craft workers onsite, while not as severe a barrier to modular construction as construction industry professionals unfamiliar with designing for modular construction, nevertheless rank second from last by the survey respondents. Ultimately, most participants felt that utilizing professionals with expertise in modular construction can significantly reduce this barrier. As stated by one respondent, "*If you're working with skilled assembly craft workers onsite who understand and assemble modular systems, there will be few, if any issues with the construction timeframes.*"

Transportation restraints: the associated challenges posed by varying transport regulations across multiple jurisdictions, and the resulting limitations these regulations impose upon the modular design process, is identified by Lu (2007) and Lawson et al., (2014) as one of the barriers to the broader utilisation of modular construction. Survey respondents confirmed this, ranking it third on the list of barriers; however, during interviews this barrier was rated one of the highest. Within jurisdictions with wide roads and a familiarity with modular products, such as highways and freeways, transportation regulations were accommodative of oversized modular loads. Survey respondents highlighted the narrower roads and more restrictive transportation rules, which restrict the maximum design width of modular units within residential areas. The cost of transportation was also noted by some respondents as a limiting factor, making modular construction inflating prices and eroding its competitive advantage when the individual modular units had to be transported over distances greater than 700 km from the manufacturing plant.

Inability to make changes onsite: De La Torre et al., (1994) and CII (2015) state that modular buildings, require a well-defined scope early the project planning stages. Both the survey and interview respondents confirmed this and ranked the inability to make changes onsite second of the list of identified barriers to the utilisation of modular systems. Respondents were of the idea that inability to make

changes onsite during construction decreases the use of modular construction systems. Modular construction increases the interdependency of construction activities, thus, changes in a design can disrupt a wide variety of inter-related activities. Once the design has been approved and the other interdependent activities are undertaken, the design must not change.

Negative perception/reputation: Kobet (2008) theorized that a long association with trailer-type mobile homes has tainted modular construction with the stigma of poor building quality and limited its broader utilisation. The survey results agreed to this and ranked the perception of poor quality at the bottom of the list of identified barriers to the broader utilisation of modular construction, tied with financing and construction industry professionals who are unfamiliar with utilisation of modular construction systems. However, the severity of the perceived barrier is ranked fourth in the interviews, behind inability to make design changes onsite, transport restraint and limited design options. Interestingly, despite the relatively low ranking of this barrier among the challenges presented by respondents in the interviews, the words "*poor-quality*" were repeatedly used by respondents in the answers given for a variety of the potential challenges. Many of them identified this idea as being rooted in the historically poor quality of construction jobsite shacks which are produced using a manufacturing process.

Lack of financing options: challenges in securing traditional financing for modular construction projects, identified as a barrier by Schoenborn (2012), were confirmed by survey respondents who denoted that financing was an impediment to the utilisation of modular construction. Several phrases, including "*reluctance to lend for a modular project*," and "*alternative financing*," were identified as commonly used in the survey respondent's answers to discuss challenges in securing construction financing. This is because traditional construction financing is based on monetary draws secured by a structure that is attached to a specific piece of property, which can have a lien placed on title. This financial structure does not work with a factory-manufactured building, constructed off-site and transported to a property only when complete.

Increases construction and maintenance costs: Schoenborn (2012) and De La Torre et al., (1994) identified increased cost as a barrier of utilising modular construction. Construction industry professional respondents identified it as one of the lower barriers of using the system during the interviews and survey. They stated that the additional man-hours required for design and engineering of a modular construction project increase the design and engineering cost by approximately 15%. The additional design and engineering cost can reduce the savings achieved in the erection activity. As stated by one respondent, *"because of the effort needed to evaluate and select vendors, fabricators, and fabrication shops, and to administer contracts, the cost associated with procurement increases by 20% in modular construction projects"*. The costs of the fabrication and transportation activities also increases due to the specialized transportation methods used and the module insurance. Cost increases also arise from the need for additional material and high initial costs compounded with a lack of awareness among clients of the potential long-term financial advantages.

Limited design options: Respondents stated that due to lack of knowledge of the system by construction professionals working onsite, they are unable to make design adjustment to the systems when the clients request for alternative designs. Many construction professionals have had a bad experience with inferior modular products and are, therefore, hesitant to work with modular systems again. Those who are intrigued by the possibilities of modular construction may have limited avenues to learn about the systems.

The barriers to MCS utilisation given above vary from project to project depending on unique circumstances each project faces. The period to resolve these also differs from project to project. There is no time frame that can be given to address each of the above as there are always unique circumstances surrounding each challenge.

5.2.3 Recommendations on how to increase utilisation of Modular Construction Systems by construction industry clients in SA

In order to increase utilisation of MCS, various methods can be employed by the stakeholders in the construction industry. According to the results of the study, the mechanisms that can be employed by each of the stakeholders participating in the

construction industry differ depending on their knowledge of the system and their capacity to influence change. Some of the strategies were suggested by the respondents that can be employed to overcome the barriers of MCS are as follows:

Develop new ideas, concepts and alternative construction materials: Modular construction systems manufacturers/suppliers' and construction industry professionals' interview respondents suggested manufacturers and suppliers should invest more in research and development of customised designs and alternative materials. Musa (2014) confirms this idea and also suggested that it would be very helpful to provide customised design options to engage customers' preferences by using 3D CAD, 4D CAD and Building Information Modeling (BIM) technologies. Respondents gave examples of design software packages that include Autodesk's Revit and Bentley Architecture from Bentley Systems.

Develop training programmes for the benefits and methods of utilisation:
Akinboade and Mkowena (2012), Lu (2007) and Lawson et al., (2014) suggested that manufacturers/suppliers must develop and provide awareness training to construction industry professionals and clients in the use of MCS. Respondents indicated that lack of knowledge MCS is a significant barrier. Therefore, the construction and design disciplines such as Construction Industry Development Board (CIDB), South African Institute of Civil Engineering (SAICE) and the Engineering Council of South Africa (ECSA) should work with mature manufactures/suppliers to develop continuing education course to increase the awareness of construction industry professionals' and clients' percentage of the use of modular construction systems.

Improve existing certification schemes and regulations:
Akinboade and Mkowena (2012) identified developing new and improve existing MCS certification schemes as a solution to overcome under-utilisation. Respondents were in agreement with this idea and they suggested that construction and design discipline should work together to develop new and improve existing Agrement certification schemes for MCS manufacturers/suppliers of modular construction systems. It is a must that MCS designed adhere to all national or international quality standards and codes (SABS or ISO). Therefore the MCS would

have to meet specified structural, compositional, size and other characteristics in area to be certified.

Collaboration of stakeholders in pre-project planning:

Generalova et al., (2016) suggested that manufacturers/suppliers and professionals should collaborate with each other on pre-project planning during the conceptual design phase. This idea was confirmed by respondents interviewed when they suggested that MCS manufacturers/suppliers and construction industry professionals should collaborate on improving product quality, onsite workmanship, and engage with the client in pre-project planning during the conceptual design phase to minimise the possibility of onsite changes.

Finance to be made available by banks/institutions:

Yoon et al., (2015) and Lawson et al., (2014) suggested that financial institutions and banks should make available funding for clients utilising MCS as a solution. Respondents interviewed were in agreement with this idea. They further stated that financial institutions and banks are reluctant to lend to clients that are building using MCS. This is because traditional construction financing is based on monetary draws secured by a structure that is attached to a specific piece of property, which can have a lien placed on title. This financial structure does not work with a modular factory-manufactured building, constructed off-site and transported to a property only when complete. To overcome this challenge in securing construction financing one respondent stated that, *"new construction funding vehicles should be offered by innovative financial institutions, utilizing novel methods such as independent quantity surveyors to measure and guarantee performance"*.

Government to provide incentives for clients:

Zhang (2016) and Akinboade and Mkowena (2012) suggested that governments should provide incentives for clients to utilise MCS. Respondent interviewed agreed to this idea and further suggested that the government of South Africa could encourage manufacturers/suppliers by providing fiscal incentives in the form of tax reliefs on the start-up costs of factories or ring-fencing an element of the existing tax credit scheme for MCS. Respondent also suggested that the construction industry professionals and clients that utilise the system can also be encouraged by

receiving tax relief. They were also of the idea that there could be incentives through the planning system, with public bodies putting conditions on the development of public land to require MCS.

5.3 Summary of the Chapter

Almost all the results from the study are in conformity with the existing literature. Theory and the results of the study are in agreement on the understanding of the concept of utilisation methods of MCS, the barriers that cause under-utilisation of modular construction systems and the possible achievable solutions to overcome the barriers. However, most respondents experienced challenges in utilising modular construction systems due to limited design options in South Africa were in variance to the existing theory largely as a result of difference in construction professionals' and clients' past experience with MCS and differences in in economic, political and business climates. Variances also exist because research in SA regarding modular construction is new.

CHAPTER 6 - CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

A large body of modern-day construction research has embraced MCS as one of the most effective approaches to overcome industry-wide challenges, such as the shortage of skilled labor, owners' aggressive schedules and inclement weather conditions (Generalova et al., 2016; Kennedy, 2016; CII, 2015; Yoon et al., 2015; Groat and David, 2013; Velamati, 2012). More recently, researchers examined the utilisation of modular construction systems in the residential construction industry, investigated the impact on the construction workforce, and identified the benefits and barriers to the use of these systems (Akinboade and Mkowena, 2012; Velamati, 2012; Evins, 2013; Kamali and Hewage, 2016; Lawson et al., 2014; Schoenborn, 2012).

However, until this present investigation, no studies have examined the MCS on the market and current level of utilisation of these systems in all of the building sectors in South Africa construction industry. None of the previous studies have investigated the motivation and challenges of using these systems in the South Africa construction industry. This study also identified possible achievable solutions to these challenges by systems' suppliers/manufacturers, construction industry professionals and major clients. In addition, this study examined the degree to which these systems were being used by construction industry professionals and major clients.

6.2 Conclusions

6.2.1 Current degree of utilisation of Modular Construction Systems on the market

Modular Construction Systems manufacturers/suppliers had specified the supply of permanent modular construction systems to 96% and relocatable modular construction systems to 88% of their clients in the construction industry. They have supplied these systems to 12% of residential, 28% of commercial, 24% of industrial, 8% of institutional and 28% of mining and government department clients.

Construction industry professionals also specified the use of permanent modular construction systems in 97% and relocatable modular construction systems in 60% of their projects. They have utilised these systems in 11% of residential, 39% of commercial, 28% of industrial, 22% of institutional and 4% of mining projects.

Lastly, construction industry major clients had specified the use of permanent modular construction systems in 68% and relocatable modular construction systems in 96% of their projects. These clients utilised the systems in 12% of residential, 60% of commercial, 20% of industrial, 8% of institutional and 24% of mining projects. There was a difference between construction industry professionals' and major clients' regarding the overall percentage of using these systems, because in this study, the professionals' respondents do not necessarily work for the major clients' respondents.

6.2.2 Causes of under-utilisation of Modular Construction Systems by SA construction industry clients

The study found that the top five (5) reasons that motivate construction industry professionals to use MCS in rank order were to 1) reduce the construction duration, 2) compensate for the restricted working space onsite, 3) compensate for weather condition, 4) reduce overall project cost and 5) increase product quality.

The top five (5) reasons that motivate construction industry major clients to use MCS in rank order were to 1) reduce the construction duration, 2) compensate for the restricted working space onsite, 3) compensate for weather condition, 4) reduce overall project cost and 5) increase product quality.

The top five (5) reason that motivate clients to use MCS according to manufactures/suppliers in rank order were to 1) reduce the construction duration, 2) reduce the overall project cost, 3) compensate for the restricted working space, 4) compensate for weather condition and 5) increase overall labour productivity.

This study identified that the top five (5) challenges that restrain construction industry professionals' clients from using modular construction systems in rank order were: 1) local building regulations restrictions; 2) inability to make changes

onsite; 3) transportation restraints; 4) increased construction cost and 5) limited design options.

The top five (5) challenges that restrain construction industry major clients from using modular construction systems in rank order were 1) inability to make changes onsite; 2) increased construction cost; 3) limited design options; 4) local building regulations restrictions and 5) transportation restraints.

The top five (5) challenges that restrain their clients from using MCS according to manufactures/suppliers in rank order were 1) increased construction cost; 2) local building regulations restrictions; 3) limited design options; 4) inability to make changes onsite and 5) transportation restraints.

In summary, this study found that modular construction systems have not been widely utilised in the building sector of South Africa construction industry. The clients had incorporated MCS in 12% of residential, 60% of commercial, 20% of industrial, 8% of institutional and 24% of mining projects. The construction industry professionals' clients incorporated modular construction systems in 11% of residential, 39% of commercial, 28% of industrial, 22% of institutional and 4% of mining projects.

6.3 Recommendations

6.3.1 General Recommendations on how to increase utilisation of Modular Construction Systems by construction industry clients in SA

This section presents four major recommendations that, if adopted, may not only increase the utilisation of MCS, but eventually will help improve the construction industry.

1) Modular construction systems manufacturers/suppliers and construction industry professionals should invest more in research and development of customised designs and alternative materials.

Findings from this study indicated that limited design options were one of the most significant barriers to increase the use of MCS. Therefore, it would be very helpful to provide customised design options to engage customers' preferences by using

3D CAD, 4D CAD and Building Information Modeling (BIM) technologies. Some examples of design software packages include Autodesk's Revit and Bentley Architecture from Bentley Systems. Each customised design should include a variety of choices of materials, fittings and furnishings. In addition, manufactures, material suppliers and construction industry professionals should work together to improve the efficiency of material delivery systems to satisfy all design options.

Furthermore, modular construction systems manufacturers/suppliers, construction industry professionals and research institutions should also invest in developing alternative construction materials to overcome the transportation restraints on the use of modular construction systems.

2) Develop and provide awareness training to construction industry professionals and clients in the use of modular construction systems.

The findings from this study indicate that lack of knowledge of modular construction systems is a significant barrier. Therefore, the construction and design disciplines such as Construction Industry Development Board (CIDB), South African Institute of Civil Engineering (SAICE) and the Engineering Council of South Africa (ECSA) should work with mature manufactures/suppliers to develop continuing education course to increase the awareness of construction industry professionals' and clients' percentage of the use of modular construction systems.

As part of the course development, case studies would have to be undertaken to compare the use of MCS with conventional ones in terms of project schedule, cost, quality and safety. The actual course development should be done by a team of individuals experienced in the use of MCS in the design and construction process along with one or more people experienced in curriculum development.

3) Develop new and improve existing modular construction certification schemes.

Construction and design discipline should work together to develop new and improve existing Agrement certification schemes for manufacturers/suppliers of MCS. It is a must that MCS designed adhere to all national or international quality standards and codes (SABS or ISO). Therefore the MCS would have to meet specified structural, compositional, size and other characteristics in area to be

certified. As for the new certification program, the same issues are described above would pertain to the development and improvement of MCS certification program.

4) Modular construction systems manufacturers/suppliers and construction industry professionals collaborate with each other on pre-project planning.

Compared to conventional construction, one of the most significant disadvantages of the using MCS is the inability to make changes onsite, which was also identified as one of the top five restraints by construction industry professionals and clients in this study. To overcome this challenge, I recommend that the MCS manufacturers/suppliers and construction industry professionals should collaborate on improving product quality, onsite workmanship, and engage with the client in pre-project planning during the conceptual design phase to minimise the possibility of onsite changes.

5) Financial institutions and banks to make available funding for clients utilising modular construction systems.

Financial institutions and banks are reluctant to lend to clients that are building using MCS. This is because traditional construction financing is based on monetary draws secured by a structure that is attached to a specific piece of property, which can have a lien placed on title. This financial structure does not work with a modular factory-manufactured building, constructed off-site and transported to a property only when complete. To overcome this challenge in securing construction financing, I recommend new construction funding vehicles to be offered by innovative financial institutions, utilizing novel methods such as independent quantity surveyors to measure and guarantee performance.

6) Government to provide incentives for construction industry professionals and clients to utilise modular construction systems.

The government of South Africa could have a role to play in encouraging manufacturers/suppliers of modular construction systems by providing fiscal incentives in the form of tax reliefs on the start-up costs of factories or ring-fencing an element of the existing tax credit scheme for MCS. The construction industry professionals and clients that utilise the system can also be encouraged by receiving tax relief. There could also be incentives through the planning system, with public

bodies putting conditions on the development of public land to require MCS. The government could go even further and play a direct role by commissioning modular construction buildings through the Department of Local Government and Housing, Department of Human Settlement, Department of Public Works or other government authorities.

6.3.2 Recommendations for Future Research

The following recommendations are proposed for further research on the use of MCS based on the finding from this study;

1) Conduct a study similar to this one but using a larger sample size. Improvements to this study could include increasing the number of MCS manufacturers/suppliers, professionals and clients in the construction industry in South Africa.
2) Conduct one or more studies to examine the cost impact of the use of MCS as compared to conventional construction methods, because both the MCS manufacturers/suppliers and construction industry professionals in this study were not clear about the cost impacts of these systems. It would be very valuable to monitor the actual cost of design, construction for one or several buildings using MCS and to create a database to compare with the similar buildings completed by conventional construction methods.
3) Conduct research on the impact of transportation restraints and costs on modular construction systems in order to find ways to alleviate and accommodate the restraints and decrease costs for the purpose of promoting the use of these systems.
4) It would also be worthwhile to examine the impact of advanced design technologies on modular construction systems, such as 3D CAD, 4D CAD and Building Information Modeling (BIM). It would be extremely valuable to identify how these technologies would increase design options, decrease lead-time for procurement, and decrease the need of onsite construction changes.

All of the above recommended research would serve to increase utilisation of MCS by construction industry professionals and clients in South Africa. It will be only through this and similar research projects that the barriers identified in this project will be alleviated. I believe that based on the findings from the study the increased use of modular construction systems will constantly benefit the entire construction industry.

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APPENDICES

Appendix A - Information Sheet to Modular Construction Systems Manufacturers/Suppliers

University of the Witwatersrand
Faculty of Engineering and the Built Environment
School of Construction Economics and Management
Private Bag x 3
WITS
2050

Project Title: **Investigation of the utilisation of modular construction in South Africa**

Information Sheet:
My name is Rufaro Dupwa and I am currently a full time student studying towards a Master of Science (MSc) Building degree in the School of Construction Economics and Management at the University of the Witwatersrand. I am currently investigating the utilisation of modular construction systems in SA construction industry, and to examining the causes of under-utilisation of modular construction systems by clients of the construction industry.

I am inviting you to be a part of the study through a short online survey and follow up interview. The survey will take no longer than 10 minutes and interview 45minutes of your time. It is an anonymous survey and you will not be personally identified in the final report. Please click link below:
https://www.surveymonkey.com/r/HYLSK6F

The results of the survey will not be linked to any particular individual in the final report. The aim of the survey is to investigate the types of modular construction systems being supplied or manufactured and examine the barriers that cause their under utilisation in the construction industry. The results of the questionnaire will not in any way or form influence or change South Africa modular construction utilisation policy in this regard. The research undertaken is solely for academic purposes and once completed will be available electronically and can be accessed publicly. If you have any questions, concerns, or comments or if you would like a copy of the final report, please feel free to contact me at 702743@students.wits.ac.za or 083 767 7982 or my supervisor Prof. Samuel Laryea on Samuel.Laryea@wits.ac.za

Your participation is greatly appreciated

Rufaro Dupwa

Masters of Science (Building) student

Appendix B - Information Sheet to Construction Industry Professionals

University of the Witwatersrand
Faculty of Engineering and the Built Environment
School of Construction Economics and Management
Private Bag x 3
WITS
2050

Project Title: **Investigation of the utilisation of modular construction in South Africa**

Information Sheet:

My name is Rufaro Dupwa and I am currently a full time student studying towards a Master of Science (MSc) Building degree in the School of Construction Economics and Management at the University of the Witwatersrand. . I am currently investigating the utilisation of modular construction systems in SA construction industry, and to examining the causes of under-utilisation of modular construction systems by clients of the construction industry.

I am inviting you to be a part of the study through a short online survey and follow up interview. The survey will take no longer than 10 minutes and interview 45minutes of your time. It is an anonymous survey and you will not be personally identified in the final report. Please click link below:
https://www.surveymonkey.com/r/HF36JTW

The results of the survey will not be linked to any particular individual in the final report. The aim of the survey is to investigate the types of modular construction systems being utilized and examine the barriers that cause their under utilisation by professionals in the construction industry. The results of the questionnaire will not in any way or form influence or change South Africa modular construction utilisation policy in this regard. The research undertaken is solely for academic purposes and once completed will be available electronically and can be accessed publicly. If you have any questions, concerns, or comments or if you would like a copy of the final report, please feel free to contact me at 702743@students.wits.ac.za or 083 767 7982 or my supervisor Prof. Samuel Laryea on Samuel.Laryea@wits.ac.za

Your participation is greatly appreciated

Rufaro Dupwa
Masters of Science (Building) student

Appendix C - Information Sheet to Construction Industry Major Clients

University of the Witwatersrand
Faculty of Engineering and the Built Environment
School of Construction Economics and Management
Private Bag x 3
WITS
2050

Project Title: **Investigation of the utilisation of modular construction in South Africa**

Information Sheet:

My name is Rufaro Dupwa and I am currently a full time student studying towards a Master of Science (MSc) Building degree in the School of Construction Economics and Management at the University of the Witwatersrand. I am currently investigating the utilisation of modular construction systems in SA construction industry, and to examining the causes of under-utilisation of modular construction systems by clients of the construction industry.

I am inviting you to be a part of the study through a short online survey and follow up interview. The survey will take no longer than 10 minutes and interview 45minutes of your time. It is an anonymous survey and you will not be personally identified in the final report. Please click link below:

https://www.surveymonkey.com/r/Z5X9TJK

The results of the survey will not be linked to any particular individual in the final report. The aim of the survey is to investigate the types of modular construction systems being utilized and examine the barriers that cause their under utilisation by clients in the construction industry. The results of the questionnaire will not in any way or form influence or change South Africa modular construction utilisation policy in this regard. The research undertaken is solely for academic purposes and once completed will be available electronically and can be accessed publicly. If you have any questions, concerns, or comments or if you would like a copy of the final report, please feel free to contact me at 702743@students.wits.ac.za or 083 767 7982 or my supervisor Prof. Samuel Laryea on Samuel.Laryea@wits.ac.za

Your participation is greatly appreciated

Rufaro Dupwa
Masters of Science (Building) student

Appendix D - Consent Form for the Interview

University of the Witwatersrand
Faculty of Engineering and the Built Environment
School of Construction Economics and Management
Private Bag x 3
WITS
2050

Project Title: **Investigation of the utilisation of modular construction in South Africa**

I ……. consent to be interviewed by……..for her study on the utilisation of modular construction systems in SA construction industry, and the causes of under-utilisation of modular construction systems by clients of the construction industry. I understand the following:

- Participating in this interview is voluntary
- That I may refuse to answer certain questions
- I may withdraw to participate in the study anytime
- My responses will remain confidential

Signed by…….

Date…….

Appendix E - Consent Form for Interview Recording

University of the Witwatersrand
Faculty of Engineering and the Built Environment
School of Construction Economics and Management
Private Bag x 3
WITS
2050

Project Title: **Investigation of the utilisation of modular construction in South**

I …….consent to be interviewed by…… for her study on the utilisation of modular construction systems in SA construction industry, and the causes of under-utilisation of modular construction systems by clients of the construction industry.

I understand that:

The tape and transcripts will not be seen or heard by any person other than the researcher

No identifying information will be used in the transcripts or the research report

Signed by…….

Date……..

Appendix F - Research Questionnaire to Modular Construction Systems Manufacturers/Suppliers

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG	**Research questionnaire on Modular Construction Systems utilisation in South Africa – Manufacturers/Suppliers**

OVERVIEW:

Modular construction refers to the applications where building systems or assemblies are manufactured or fabricated away from the building site prior to installation in their final positions.

COMPANY INFORMATION AND SUPPYING OF MODULAR CONSTRUCTION SYSTEM

1. Company name: _____

2. Please select the types of Modular Construction Systems you supply.

   Permanent Modular Construction systems where components are attached to a permanent foundation ☐

   Relocatable Modular Construction systems that maintain their mobility to serve temporary functions ☐

3. Please select the segment with your highest percentage of clients in the construction industry.

Residential	Commercial	Industrial	Institutional
☐	☐	☐	☐

THE REASONS AND CHALLENGES OF USING MODULAR CONSTRUCTION SYSTEMS

4. Please ***choose the top 5 reasons*** why your clients use Modular Construction Systems.

   A. To compensate for the shortage of skilled craft workers
   B. To compensate for weather condition
   C. To reduce design duration
   D. To reduce construction duration
   E. To increase product quality
   F. To reduce overall project cost
   G. To increase overall labour productivity
   H. To compensate for the restricted working space onsite
   I. To reduce environmental impact
   J. To improve project safety performance

K. To increase their profit margin
L. To enhance their reputation
M. Other (please specify)

5. Please ***choose the top 5 reasons*** that restrain clients using Modular Construction Systems.

A. Construction professional advisors did not specify the use of Modular Construction Systems.
B. Local building regulations restrict the use of Modular Construction Systems.
C. Lack of skilled assembly craft workers onsite.
D. Using Modular Construction Systems will increase the construction cost.
E. Transportation restraints
F. Limited design options in using Modular Construction Systems.
G. Inability to make changes onsite by using Modular Construction Systems
H. Other (please specify)

6. Please provide possible achievable solutions to overcome these challenges.

7. Please provide your contact details if you are willing to participate in a follow-up interview

Email address:

Telephone:

Appendix G - Research Questionnaire to Construction Industry Professionals

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG	**Research questionnaire on Modular Construction Systems utilisation in South Africa – Construction Industry Professionals**

OVERVIEW:

Modular construction refers to the applications where building systems or assemblies are manufactured or fabricated away from the building site prior to installation in their final positions.

COMPANY INFORMATION AND SUPPYING OF MODULAR CONSTRUCTION SYSTEM

1. Please select your job title.

Architect	Engineer	Project Manager	Quantity Surveyor
☐	☐	☐	☐

2. Please select the types of Modular Construction Systems you have used in previous clients' projects.

Permanent Modular Construction systems where components are attached to a permanent foundation	☐
Relocatable Modular Construction systems that maintain their mobility to serve temporary functions	☐

3. Please select the segment with your highest percentage of clients' projects that you used Modular Construction Systems.

Residential	Commercial	Industrial	Institutional
☐	☐	☐	☐

THE REASONS AND CHALLENGES OF USING MODULAR CONSTRUCTION SYSTEMS

4. Please ***choose the top 5 reasons*** why you use Modular Construction Systems for your clients' projects.

A. Project owners require using modular construction systems
B. To compensate for the shortage of skilled craft workers
C. To compensate for weather condition
D. To reduce design duration
E. To reduce construction duration

F. To increase product quality
G. To reduce overall project cost
H. To increase overall labour productivity
I. To compensate for the restricted working space onsite
J. To reduce environmental impact
K. To improve project safety performance
L. To increase their profit margin
M. To enhance their reputation
N. Other (please specify)

5. Please ***choose the top 5 reasons*** that restrain you using Modular Construction Systems for your clients' projects.
A. Project owners did not specify the use of Modular Construction Systems.
B. Local building regulations restrict the use of Modular Construction Systems.
C. Lack of skilled assembly craft workers onsite.
D. Using Modular Construction Systems will increase the construction cost.
E. Transportation restraints
F. Limited design options in using Modular Construction Systems.
G. Inability to make changes onsite by using Modular Construction Systems
H. Other (please specify)

6. What factors would influence you to increase your clients' utilisation of Modular Construction Systems?

7. Please provide your contact details if you are willing to participate in a follow-up interview

Email address:

Telephone:

Appendix H - Research Questionnaire to Construction Industry Major Clients

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG	**Research questionnaire on Modular Construction Systems utilisation in South Africa – Construction Industry Major Clients**

OVERVIEW:

Modular construction refers to the applications where building systems or assemblies are manufactured or fabricated away from the building site prior to installation in their final positions.

COMPANY INFORMATION AND SUPPYING OF MODULAR CONSTRUCTION SYSTEM

1. Company name: ☐

2. Please select the types of Modular Construction Systems you have used in previous projects.

   Permanent Modular Construction systems where components are attached to a permanent foundation ☐

   Relocatable Modular Construction systems that maintain their mobility to serve temporary functions ☐

3. Please select the segment with your highest percentage of projects that you used Modular Construction Systems.

Residential	Commercial	Industrial	Institutional
☐	☐	☐	☐

THE REASONS AND CHALLENGES OF USING MODULAR CONSTRUCTION SYSTEMS

4. Please ***choose the top 5 reasons*** why you use Modular Construction Systems for your projects.

   A. Construction industry professionals advised using modular construction systems
   B. To compensate for the shortage of skilled craft workers
   C. To compensate for weather condition
   D. To reduce design duration
   E. To reduce construction duration
   F. To increase product quality
   G. To reduce overall project cost
   H. To increase overall labour productivity
   I. To compensate for the restricted working space onsite

J. To reduce environmental impact
K. To improve project safety performance
L. To increase their profit margin
M. To enhance their reputation
N. Other (please specify)

5. Please ***choose the top 5 reasons*** that restrain you from using Modular Construction Systems.
   A. Construction industry professionals did not advised the use of Modular Construction Systems.
   B. Local building regulations restrict the use of Modular Construction Systems.
   C. Lack of skilled assembly craft workers onsite.
   D. Using Modular Construction Systems will increase the construction cost.
   E. Transportation restraints
   F. Limited design options in using Modular Construction Systems.
   G. Inability to make changes onsite by using Modular Construction Systems
   H. Other (please specify)

6. What factors would influence you to increase your utilisation of Modular Construction Systems?

7. Please provide your contact details if you are willing to participate in a follow-up interview

   Email address:

   Telephone:

Appendix I - Interview Schedule and Examples of Transcripts for Modular Construction Systems Manufacturers/Suppliers

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG	**Research interview questions on Modular Construction Systems utilisation in South Africa – Manufacturers/Suppliers**

Objective:

The purpose of this interview is to identify the modular construction systems on the market, causes of under-utilisation of modular construction systems by clients of the construction industry and to provide recommendations aimed at increasing the utilisation of modular construction systems by construction industry clients in SA. I would appreciate if you could share you experience/knowledge in this field with me.

Definition:

In this study, the term of modular construction refers to the applications where building systems or assemblies are manufactured or fabricated away from the building site prior to installation in their final positions. They are divided into two categories:

- *Permanent Modular Construction* provides a service comparable to onsite construction where components are attached to a permanent foundation. Components can be integrated into site built projects or stand-alone buildings.
- *Relocatable buildings* maintain their mobility, serving temporary functions for both partial and full building applications usually built on an integrated chassis with detachable wheels, hitch, and axels.

Qualitative Questions – Exploratory Study

1. What types of modular construction systems do you supply to clients in the construction industry: Permanent Modular Construction or Relocatable buildings?
2. What are some of the challenges/barriers that cause under utilisation of modular construction systems by construction industry clients?
3. What are some of the possible achievable solutions to overcome these barriers?

Interview 1

Date: 8 August 2017 @ 2:30p.m.

Interviewee: Structural engineer

1. *What types of modular construction systems do you supply to clients in the construction industry: Permanent Modular Construction or Relocatable buildings?*

We manufacture and supply both permanent modular buildings that are built directly on to concrete and relocatable buildings that are built on a galvanized steel chassis. The modular buildings are available for selling and renting out to schools, clinics, mines, construction and humanitarian sectors. Our modular units measure 1300m² to 9000m².

2. *What are some of the challenges/barriers that cause under utilisation of modular construction systems by construction industry clients?*

Financing can be a problem because financial institutions are unfamiliar with this type of construction method. Ignorance of the benefits of modular buildings by the community and construction industry professionals also causes under utilisation of these systems. This is an extremely sensitive issue in South Africa. Many local authorities has given orders not to use modular construction systems because it is not labour-intensive. Nothing can be as wrong. This system requires just as many if not more labour within the factories. These labourers need to be trained to obtain higher skills levels than on sites.

3. *What are some of the possible achievable solutions to overcome these barriers?*

The only way to overcome these barriers is if new construction funding vehicles are offered by innovative financial institutions, utilizing novel methods such as independent quantity surveyors to measure and guarantee performance. We can also ensure that the clients and whole project team is aware of the advantages of modular construction systems and contractors must experiment with different types of modular construction systems to ensure that they are capable of utilising them.

Interview 2

Date: 10 August 2017 @ 10:30a.m.

Interviewee: Managing Director

1. *What types of modular construction systems do you supply to clients in the construction industry: Permanent Modular Construction or Relocatable buildings?*

We manufacture both permanent modular buildings that are built directly on to concrete and relocatable buildings that are built on a galvanized steel chassis. All buildings are custom designed and built to the client's request, although a number of industry standard applications are available. The buildings are mostly used for accommodation, ablutions, site offices, security, administration and housing projects. Maximum build width is approximately 6 meters, whilst length is not a problem. We also supply container units which are collapsible modular container units. The modular containers can be connected together in any direction or stacked 3 stories high. The container structure is fire resistant, insulated and designed to withstand wind loads of up to 1.5 KN/m² and a magnitude of up to 7.0 seismic intensity.

2. *What are some of the challenges/barriers that cause under utilisation of modular construction systems by construction industry clients?*

Often customers automatically expect modular construction systems to be less expensive and have a faster construction speed when compared to site built buildings. There can be a negative stigma associated with the term "modular" because of examples in history that are built cheap and with low quality. Longer lead-in time is also a barrier to clients using modular construction because its use could delay the beginning of the project on site.

3. *What are some of the possible achievable solutions to overcome these barriers?*

Advertise the benefits modular construction systems of which contrast directly to onsite construction, education of community on the benefits of this build type and finance to be made available by banks/institutions based on provision of certification.

Appendix J - Interview Schedule and Examples of Transcripts for Construction Industry Professionals

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG	**Research interview questions on Modular Construction Systems utilisation in South Africa – Construction Industry Professionals**

Objective:

The purpose of this interview is to identify the modular construction systems on the market, causes of under-utilisation of modular construction systems by clients of the construction industry and to provide recommendations aimed at increasing the utilisation of modular construction systems by construction industry clients in SA. I would appreciate if you could share you experience/knowledge in this field with me.

Definition:

In this study, the term of modular construction refers to the applications where building systems or assemblies are manufactured or fabricated away from the building site prior to installation in their final positions. They are divided into two categories:

- *Permanent Modular Construction* provides a service comparable to onsite construction where components are attached to a permanent foundation. Components can be integrated into site built projects or stand-alone buildings.
- *Relocatable buildings* maintain their mobility, serving temporary functions for both partial and full building applications usually built on an integrated chassis with detachable wheels, hitch, and axels.

Qualitative Questions – Exploratory Study

1. Which type of modular construction system have you used in your projects: Permanent Modular Construction or Relocatable buildings?
2. What are the challenges/barriers that cause your clients to under-utilise modular construction systems in their projects?
3. What are some of the possible achievable solutions to help them overcome these barriers?

Interview 3

Date: 15 August 2017 @ 9:30a.m.

Interviewee: Architect

1. *Which type of modular construction system have you used in your projects: Permanent Modular Construction or Relocatable buildings?*

I have been involved in projects that utilize both permanent and relocatable modular buildings. The modular buildings were for institutional use as school classrooms and for commercial use as offices.

2. *What are the challenges/barriers that cause your clients to under-utilise modular construction systems in their projects?*

Clients are generally not included during the modular construction systems design phase. When construction starts, the clients may find that utilising modular construction systems might be beneficial for them. Unfortunately, if the clients decide on using modular construction systems, the consultant must redesign the structure to incorporate this change - this usually takes additional time resulting in the clients to ignore the use of modular construction systems (for longer contract periods, the new design may not influence the total progress). Many of our clients identify the idea of utilising these systems as being rooted in the historically poor quality of construction jobsite shacks causing under-utilisation.

3. *What are some of the possible achievable solutions to help them overcome these barriers?*

Involve client and construction industry professionals from the start of a project allows them to provide input in the design and alter the design towards modular construction systems. Manufacturers can also come up with new ideas and concepts allowing for more flexibility in design options and improve reputation of the system by advertising the benefits.

Interview 4

Date: 16 August 2017 @ 10:30a.m.

Interviewee: Quantity Surveyor

1. *Which type of modular construction system have you used in your projects: Permanent Modular Construction or Relocatable buildings?*

I have been involved in projects that utilize both permanent and relocatable modular buildings. The relocatable modular buildings were used as side offices and the permanent modular buildings were for institutional use as school classrooms

2. *What are the challenges/barriers that cause your clients to under-utilise modular construction systems in their projects?*

Transportation restraints posed by varying transport regulations across multiple jurisdictions, and the resulting limitations these regulations impose upon the modular design process is as one of the barriers to the utilisation of modular construction. Within jurisdictions with wide roads and a familiarity with modular products, such as highways and freeways, transportation regulations were accommodative of oversized modular loads. The narrower roads and more restrictive transportation rules, which restrict the maximum design width of modular units within residential areas. The cost of transportation is also a limiting factor, making modular construction inflating prices and eroding its competitive advantage when the individual modular units had to be transported over long distances from the manufacturing plant.

3. *What are some of the possible achievable solutions to help them overcome these barriers?*

Manufacturers should invest in developing alternative designs and construction materials that are easier to transport. They can also transport the systems as panels and assemble them onsite to combat the transportation restraints.

Appendix K - Interview Schedule and Examples of Transcripts for Construction Industry Major Clients

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG	**Research interview questions on Modular Construction Systems utilisation in South Africa – Construction Industry Major Clients**

Objective:

The purpose of this interview is to identify the modular construction systems on the market, causes of under-utilisation of modular construction systems by clients of the construction industry and to provide recommendations aimed at increasing the utilisation of modular construction systems by construction industry clients in SA. I would appreciate if you could share you experience/knowledge in this field with me.

Definition:

In this study, the term of modular construction refers to the applications where building systems or assemblies are manufactured or fabricated away from the building site prior to installation in their final positions. They are divided into two categories:

- *Permanent Modular Construction* provides a service comparable to onsite construction where components are attached to a permanent foundation. Components can be integrated into site built projects or stand-alone buildings.
- *Relocatable buildings* maintain their mobility, serving temporary functions for both partial and full building applications usually built on an integrated chassis with detachable wheels, hitch, and axels.

Qualitative Questions – Exploratory Study

1. Which type of modular construction system have you used in your projects: Permanent Modular Construction or Relocatable buildings?
2. What are the challenges/barriers that cause you to under-utilise modular construction systems in your projects?
3. What are some of the possible achievable solutions to help you overcome these barriers?

Interview 5

Date: 18 August 2017 @2:30p.m.

Interviewee: Procurement Manager

1. *Which type of modular construction system have you used in your projects: Permanent Modular Construction or Relocatable buildings?*

Our projects have utilized both permanent and relocatable modular systems. The modular buildings were for commercial use as canteens, offices and site accommodation.

2. *What are the challenges/barriers that cause you to under-utilise modular construction systems in your projects?*

Due to lack of knowledge of the system by construction professionals working onsite, they are unable to make design adjustment to the systems when we request for alternative designs. We have had bad experiences with inferior modular products and we are, therefore, hesitant to work with modular systems again.

3. *What are some of the possible achievable solutions to help you overcome these barriers?*

The manufacturers/suppliers must develop and provide awareness training to construction industry professionals and clients in the use and benefits of using modular construction systems. Come up with new ideas and concepts allowing for more flexibility in design options and improve reputation of the system. Significant lower price than conventional buildings and advice by construction professionals to use the systems.

Interview 6

Date: 24 August 2017 @ 9:00a.m.

Interviewee: Project Manager

1. *Which type of modular construction system have you used in your projects: Permanent Modular Construction or Relocatable buildings?*

We have had projects that utilize both permanent and relocatable modular systems. The modular buildings were for commercial use as homes, locker rooms, diners, ablution facilities and offices.

2. *What are the challenges/barriers that cause you to under-utilise modular construction systems in your projects?*

Financial institutions and banks are reluctant to lend to us when we are building using modular construction systems. This is because traditional construction financing is based on monetary draws secured by a structure that is attached to a specific piece of property, which can have a lien placed on title. This financial structure does not work with a modular factory-manufactured building, constructed off-site and transported to a property only when complete. The building system is also association with trailer-type mobile homes which has tainted modular construction with the stigma of poor building quality and limited its broader utilisation.

3. *What are some of the possible achievable solutions to help you overcome these barriers?*

To overcome the challenge in securing construction financing new construction funding vehicles should be offered by innovative financial institutions, utilizing novel methods. Improved reputation through advertising of benefits of utilising the system and redesigning the systems to improve aesthetics.