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THE COSTS OF TRADITIONAL CONSTRUCTION METHODS AGAINST MODULAR CONSTRUCTION METHODS IN SOUTH AFRICA; THE PERCEPTION OF CONSTRUCTION PROFESSIONALS

BY

ASHLEY MIRLNÉ DE JAGER

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Supervisor:

Mr. Mochelo Lefoka

ABSTRACT

This study aims to gain insight into how construction professionals in South Africa perceive the cost of construction with regards to modular construction methods versus traditional construction methods. This study aims to compare the benefits and drawbacks of modular construction versus traditional construction methods. Modular construction involves building certain elements of the structure in a factory setting before transporting them to the construction site for assembly, while traditional construction involves building all the elements of a structure on-site. The research focuses on factors such as cost, time efficiency, quality control, and environmental impact. The study finds that construction professionals perceive modular construction leads to cost savings and improved quality control more than that of traditional construction projects. Overall, the choice between modular and traditional construction should be based on the specific needs and goals of the project and the client's specifications as per contract data. The findings of this study revealed that modular construction is perceived to be more affordable and faster to complete than traditional construction methods. The cost and duration of different stages during construction are the main factors that create cost variances. More construction professionals have experience with traditional construction projects in comparison to modular construction projects. However, modular construction produces less waste, is considered safer, and uses less labour during the construction process. Based on the findings in the study, it can be concluded that modular construction is a cost-effective and efficient method of construction that can save time and money compared to traditional construction methods. However, it is important to note that certain factors can create cost variances between the two methods, such as the cost and duration of different stages during construction. These factors are directly connected to the cost and time spent within the various stages of construction. The findings from the study revealed that during the various stages of construction; site preparation, foundations and excavations, ground floor construction, superstructure work, roof construction, external and internal finishes, and site handover, it was found that construction professionals perceive traditional construction methods to be more costly and take more time to complete in comparison to modular construction methods. Overall, the choice of construction method should be based on the specific needs and goals of the project, as well as the trade-offs between cost, time efficiency, quality, safety, and

environmental impact. To gather data for this study, 91 participants participated and complete an online survey. Google Forms, a widely recognized web-based survey platform, was employed to administer the questionnaire. The survey itself consisted of a series of questions designed to assess participants' understanding and attitudes towards the topic of interest. Upon completion, the collected responses were automatically stored in a centralized database for further analysis. To analyse the collected data, the mean item score method was employed. This approach involves calculating the average score for each survey item, providing a comprehensive overview of participants' responses. The study employed a positivist philosophy, adhering to the belief that knowledge can be derived from objective observation and measurement. To achieve this, the research adopted a deductive approach, whereby hypotheses were formulated based on existing theories and then tested using empirical data. A mono-method approach was implemented, relying solely on quantitative data collection and analysis. This quantitative approach involved collecting numerical data and analysing it using statistical methods. The study was limited to a specific time horizon, providing a record of the hypothesis under investigation.

PLAGIARISM DECLARATION

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December 2023

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ACRONYMS

PWC - PricewaterhouseCoopers

cidb - Construction Industry Development Board

BER - Building Cost Index - the Bureau for Economic Research

CAGR - Compound annual growth rate

BIM - Building information modelling

AECOM - American multinational infrastructure consulting firm

STATSSA - Statistics South Africa

SANS - South African National Standards

ASAQS - Association of South African Quantity Surveyors

CHAPTER 1: INTRODUCTON

1.1 BACKGROUND OF THE STUDY

This thesis examines the concepts of modular construction methods and traditional construction methods used in South Africa. The purpose of this study is to gain insight into the perception, experience, and knowledge of how construction professionals perceive the costs involved in traditional and modular construction methods, and whether a certain construction method offers superior financial benefit. Further discussions regarding the processes, materials and costs involved with the construction methods will be covered.

People have attempted to change and control the environment in which they live throughout history. In past times, caves and other naturally occurring kinds of shelter were used as primitive houses, offering protection from the outside environment. As civilisation progressed, the nature of human shelters became more refined and complex, progressing from caves and natural forms of shelter to simple artificial enclosures, such as those used by nomadic peoples around the world throughout history (Riley & Cotgrave, 2004).

The development of human-made structures has been influenced by the nature of the climate in specific locations as well as the types of building materials available locally. The ability to transport construction materials over relatively long distances is a relatively new development (Riley & Cotgrave, 2004).

Historically, these components would have been manufactured and assembled on-site. However, vernacular architecture has evolved because of the ability to make components out of locally available building materials. This was due to limitations in the ability to transport materials and manufactured components over short distances. Transporting materials and components over long distances became possible due to advancements in transportation networks and development of technology, particularly during the Industrial Revolution (Riley & Cotgrave, 2004).

These advancements enabled not only the use of non-local materials, but also the production of large components away from site. The ability to mass produce

components in a factory setting prompted a shift in approach to the building process, ushering in industrialised building. The availability of construction materials, the local climate, and the lifestyle of the population have all influenced traditional building types in the past (Riley & Cotgrave, 2004).

The use of traditional labour-intensive building crafts (like stone masonry, decorative leadwork, brickwork arches, and architectural plasterwork) is mostly limited to the construction of unique structures and the refurbishment of buildings. This type of building method is expensive because it takes a lot of time and money to make the different parts for the building. This is done by specialised tradesmen, even if some of the parts are pre-made. However, this process is slow because it takes time to put all the pieces together. To save time and money, people choose alternative methods of construction for projects (Riley & Cotgrave, 2004).

The ability to make components fit specific spaces ensured accuracy across buildings in traditional construction. This ability in the production of building elements has been greatly reduced, as many components are manufactured away from the site. The industrialised manufacturing of components dictates a greater emphasis on component size accuracy to ensure that mismatches are kept to a minimum on-site. Standardized building dimensions are common even for small-scale post-traditional construction that utilises factory-produced building materials and components (Riley & Cotgrave, 2004).

Choosing the incorrect construction method is one of the top five areas of loss in productivity. The selection of a correct construction method allows the professional team to make informed decisions on how to improve construction performance. Quantity Surveyors, along with the construction team, experience difficulties in managing information and knowledge about different methods and projects, which causes a barrier for these professionals to perform optimally (Ferrada, et al., 2013).

This research aims to provide an overview for construction and property specialists about the costs associated with traditional and alternative construction methods to make better informed decisions with regards to methods of construction.

1.1.1 The factors that influence cost in construction.

There are several factors that affect the cost of a construction project, starting off with materials; the cost of materials can vary depending on the type and quality of materials used, as well as the location of the project. The cost of materials can also be affected by changes in the market, such as fluctuations in the prices of raw materials (Holm, 2008).

The second factor is labour; the cost of labour can vary depending on factors such as the skill level of the workers, the size of the workforce, and the location of the project. Unforeseen labour shortages or unexpected delays can cause cost overruns. Thirdly, we have the cost factor regarding equipment; the cost of equipment can vary depending on the type and size of the equipment needed, as well as the duration of the project. Renting equipment can be more expensive than purchasing it. The final cost factor is permits; the cost of permits can vary depending on the location and type of project. These costs can include building permits, zoning permits, and inspection fees (Hilson, 2015).

Financing plays a large role in the final cost of construction; the cost of financing can vary depending on the type of financing used, such as a traditional bank loan or crowdfunding. The interest rate and the duration of the loan can also affect the cost. Design changes impact construction costs, depending on the complexity of the changes and the stage of the project. Design changes can also cause delays and disrupt the schedule, which can increase the overall cost of the project. The timeframe of a project directly impacts the cost as projects with a longer duration can have more costs associated with it such as labour, equipment, and materials. And finally, the site conditions such as the quality of the soil, the presence of underground utilities, and the need for excavation or grading work can have an impact on the overall cost of a project (Holm, 2008).

It is important to consider all these factors when estimating the cost of a construction project and to monitor them closely throughout the construction process to minimize any cost overruns.

1.1.2 Research reasoning

The urgency of implementing alternative construction methods such as modular construction is increasing in many countries, including South Africa. With the population growing and the demand for housing, commercial and industrial buildings rising, the construction industry is facing increasing pressure to deliver projects faster, cheaper, and with a smaller environmental impact (Al-Hussein & Islam, 2018). Traditional construction methods are no longer able to meet these demands, and alternative methods are needed to keep up with the fast pace of development. Additionally, the shortage of skilled labour and the need to reduce labour costs, make alternative construction methods more attractive. Furthermore, with the need to improve energy efficiency and reduce carbon footprint, alternative construction methods like modular construction have been proven to have a positive impact in these areas. For these reasons, it is becoming increasingly urgent to implement alternative construction methods to meet the demands of the construction industry and to address the challenges of sustainability, cost, and labour shortage (Loulakis, 2011).

Therefore, the research focusses on the factors that influence construction costs and to evaluate how construction professionals perceive the affordability of the two various methods: modular construction versus traditional construction methods.

1.2 RESEARCH ASSUMPTIONS:

The research success will be dependent on the knowledge of construction professionals with regards to the two specific construction methods, namely traditional construction methods and modular methods, and their associated costs. The success of the paper will also be impacted by the amount of exposure that South African construction professionals have with regards to modular and traditional construction projects, the implementation thereof and historical costings available.

Furthermore, the success of the research will be influenced by the personal experiences and beliefs of individual construction professionals regarding previous encounters when having dealt with modular and traditional construction projects that

could have been financially successful or unsuccessful. The success of the paper will be dependent on the participation of the participants and their ability and willingness to partake in the study. Lastly, the success of the research will depend on the consistency of construction costs concerning traditional and modular construction methods throughout various provinces in South Africa.

1.3 PROBLEM STATEMENT

The perception of cost is a critical factor that influences the selection of construction methods.

The cost of construction in South Africa is increasing annually, closing the gap for investors, homeowners, and development companies to make profit or create fast, effective, and affordable construction projects. Therefore, the study towards alternative construction methods is at the forefront to create new opportunities for more affordable and effective methods of construction.

South Africa's construction industry uses traditional methods more often than alternative methods even though alternative methods could provide more cost savings. According to a Journal posted by Koen and Rust (2011), the construction industry of South Africa is notorious for low levels of innovation and investments should be made towards construction ideas to review the current state of South Africa's construction industry, as well as the developments that will shape the future of construction.

The South African construction industry may be lacking in certain aspects due to the limited utilization of modular construction and considering these potential shortcomings, the South African construction industry may benefit from exploring the implementation of modular construction techniques (Anthony, et al., 2013). By adopting these methods, the industry can increase efficiency, reduce environmental impact, and potentially improve project outcomes while keeping costs in check.

1.4 RESEARCH QUESTION

The research question addressed by this study:

According to Quantity Surveyors in South Africa, which method of construction – traditional or modular – is perceived as the more affordable method?

1.5 HYPOTHESIS

The perception among Quantity Surveyors in South Africa is that modular construction is a more cost-effective method compared to traditional construction methods.

1.6 OBJECTIVES

The objectives of the study are as follow:

a) To determine the cost difference between modular construction methods and traditional construction methods.
b) To determine whether modular construction or traditional construction is perceived as the most cost-effective construction method according to Quantity Surveyors in South Africa.
c) To determine whether modular construction has more advantages than traditional construction methods?

1.7 PURPOSE OF THIS STUDY

The purpose of the study is to determine how Quantity Surveyors in South Africa perceive what the most cost-effective construction method is with regards to traditional construction in relation to modular construction methods, to ultimately inform construction professionals of the benefits and cost-saving advantages of implementing either one the methods and create awareness regarding the cost and time associated with traditional methods against modular construction methods.

1.8 SIGNIFICANCE OF THIS STUDY

The research study has the potential to provide evidence that modular construction can be a cost-effective method of building, making it more accessible to a wider range of clients, particularly in the affordable housing sector. Additionally, this research can help to dispel the perception that modular construction is more expensive than traditional construction methods, which can make it more attractive to developers and builders who are looking to reduce costs. Furthermore, the study can provide valuable information for the construction industry, policymakers, and stakeholders on the potential cost savings that can be achieved by using modular construction and can help to inform decisions about the use and promotion of modular construction. Finally, this research can also help to support the shift towards more sustainable and efficient construction methods, which is becoming increasingly important due to the pressing need to reduce carbon footprint and improve energy efficiency.

1.9 RESEARCH REPORT STRUCTURE

In **Chapter 1**, the research topic is briefly outlined, and the research problem, main question, objectives, and hypotheses are briefly stated. The goal of the study is defined. The chapter also includes a discussion on the significance of the study.

Chapter 2 conducts a critical review of literature on the South African construction industry with regards to modular and traditional construction methods, an overview of the use of modular construction methods in South Africa and internationally is provided. Furthermore, an overview of the major role players in modular construction within South Africa is reviewed, whereafter the construction costs involved with modular and traditional construction is discussed as well as the influence on making decisions regarding which construction method should be implemented.

Chapter 3 describes the research approach and design used for data collection, analysis, and hypothesis testing.

Chapter 4 presents the analysis and interpretation of the collected data, along with a discussion of the results in relation to the literature review.

Chapter 5 concludes the study and offers recommendations for construction professionals and future research. The chapter includes a list of references and appropriate appendices.

CHAPTER 2: SOUTH AFRICAN CONSTRUCTION INDUSTRY

2.1 INTRODUCTION

This chapter aims to provide a detailed overview of the available research and literature pertaining to topics dealing with the South African Construction Industry as a vital sector of the economy, contributing significantly to job creation, economic growth, and development. Furthermore, this chapter discusses how the industry is facing various challenges, including high construction costs. A large focus is placed on the importance of understanding the various construction methods available, and the costs associated with each method. Deeper literature discussions include topics such as traditional construction which involves building structures using bricks, mortar, and other conventional materials. This chapter then goes into modular construction as an alternative method that involves building structures using prefabricated and standardized components.

The South African Construction industry faced different challenges in 2016 with constant pressure on lower revenue, margins and decreasing profits. The construction industry of South Africa is a large contributor towards the employment growth of the country. Seven out of the nine well-known construction companies in South Africa have agreed to enter into agreement with the Government to improve transformation within the industry to move it into the right direction (PricewaterhouseCoopers, 2016).

The construction industry in South Africa is a vital part of our economy and its contribution to economic growth cannot be underestimated ((cidb), 2011). The challenges that arise within this field require new solutions or technologies which are becoming increasingly common across all industries, but certain companies may find themselves at odds when dealing with specific regulations related specifically toward building activity (Ofori, 2007). The construction industry in South Africa is characterised by high costs and low productivity; this, together with an ever-changing political landscape that has seen new regulations introduced monthly for years now and will likely continue doing so, means it's difficult to get anything done. The access people have at present is not enough when you consider all factors such as availability

of materials; especially those related to environmentally friendly building practices which seem very promising but need more investment right now ((cidb), 2011).

Looking back at 2011, the cost of materials can account for up to 60% on construction projects. South Africa relies heavily on imported equipment and materials (Haskell, 2004). With the cost of construction materials rising, many are calling for a review to control these increases. Between October 2000 and 2006, even without considering any other factors like inflation or economic growth, prices for volatile building materials such as steel grew by 100% ((cidb), 2011).

The construction industry of South Africa today, faces several challenges such as the energy crisis, supply chain disruptions, inflation, and a decrease in the total value of building plans passed, it is expected to contract by 1.9% in 2023. Construction material prices have risen significantly, with the average construction materials price index increasing by 12.3% in 2022. The number of construction companies going into liquidation has also increased, with 94 companies doing so in 2022 compared to 71 in 2021 (Global Data, 2023).

The COVID-19 pandemic has caused major disruptions in global supply chains, leading to increased material costs and higher overall construction expenses. Additionally, rising energy costs resulting from factors such as the war in Ukraine have also affected the construction industry. Despite these challenges, the situation has accelerated the adoption of sustainable construction practices worldwide. The impact of climate change on both people and businesses has made sustainability a critical issue. The construction industry, which is a significant consumer of energy and resources, has a major role to play in addressing environmental concerns (King, 2023).

2.1.1 The Modular construction concept

The modular construction concept forms an important part of this study. By understanding the importance of a particular construction method, we need to look further into what the concept entails and the advantages that this method holds. Throughout various literature we can discover the current implementation of modular construction on a national and international level.

Modular construction refers to a method of building structures in which individual modules or sections are constructed in a factory setting before being transported to the construction site for assembly. This method of construction is becoming increasingly popular in many industries, particularly in the field of commercial and residential building construction (Ferdous , et al., 2019).

An integral reason for focussing on the modular construction method throughout this study is due to the several advantages that this method has over traditional construction methods. In an article written by Hoinkova (2021), she discusses the various advantages that modular construction has over traditional construction methods. These advantages include the fast speed at which modular construction projects can be constructed in comparison to traditional buildings, mainly due to the prefabrication process. The cost-effectiveness of modular construction is due to majority of work that takes place in a controlled factory environment, where fewer materials are wasted, and labour costs are distinctively more affordable compared to on-site construction. The quality control of modular construction projects enables better control over the quality of materials and workmanship compared to traditional construction methods. With a large focus on sustainability, modular buildings can be designed and built with eco-friendly materials and methods, reducing the overall environmental impact of construction. The flexibility of modular buildings allows designs and physical structures to be easily expanded, relocated, or modified to meet changing needs. The improved safety of modular construction methods requires less need for on-site workers, reducing the risk of injury and accidents. The consistency that is offered by modular construction enables a high degree of standardization and uniformity, ensuring that each building is of consistent quality. The modular construction method reduced disruptions during the construction process which would usually take place on a traditional construction site.

Understanding the advantages of a certain method allows researchers to further evaluate and study this method and its implementation thereof. In addition to the several advantages, this method offers a large variety of uses within the construction industry, and it is not limited to a specific sector. Loulakis (2011) states that modular construction is used in sectors such as education, healthcare, and even in the construction of temporary or emergency structures. The use of modular construction in these contexts is driven by the need for fast, cost-effective, and flexible solutions.

To provide context towards the flexibility and design limitations of modular construction methods, the following projects that were constructed using modular construction methods are Figure 1, representing a modular hospital constructed by Gaptek (2011), an international construction company.

Figure 1: A hospital constructed by Gaptek (Gaptek, 2011)

Figure 2 below, represents a luxury residential home constructed by HouseZero (2022), in South Africa by utilising modular construction methods.

Figure 2: Residential home designed and constructed in South Africa (HouseZero, 2022)

In Figure 3 is the completed project of administrative offices and counselling rooms at the University of Texas, which consists of a 1300m2 building area and was completed successfully by Ramtech Building Systems (2013) in 65 days.

Figure 3: The construction of a 1300m2 office building (Ramtech Building Systems, 2013)

Ramtech Building Systems (2013), is one of the companies at the forefront of demonstrating the flexibility and possibilities of modular construction. They have successfully completed projects by utilising modular construction methods which include but is not limited to prisons, medical facilities, classrooms, educational labs, storm shelters, auto dealerships, data centres, municipal courthouses, and housing projects.

Modular construction is a very broad term within the construction industry, and within this broad term there are different types of modular construction methods in the construction industry. The first method is called Panelised construction and during this method, the prefabricated wall panels, floor systems, and roof systems are transported to the building site and assembled to form the building envelope (Miles, 2021). The second type is Volumetric construction; this type of modular construction involves building complete rooms or modules in a factory and then assembling them on-site to form the final building (Miles, 2021). The third type is Flat-pack construction which involves flat-packing modular components for transport and then assembling them on-site (Nathan, 2018). Prefabricated steel construction is the fourth type, and this method involves prefabricated steel components that are transported to the building site and assembled to form the structure of the building (Britannica & Editors of Encyclopaedia, 2013). A fifth type is called Container construction, where the method of construction involves repurposing shipping containers as modular building components (Cornachio, 2018).

With all the varying types of modular units comes several design considerations. The two prominent considerations for this method are the transport constraints, as these models are often transported over long distances, which can result in added transportation costs and potential damage to the components during transit. The second consideration is the perception of construction professionals and new clients, where there may be a perception among them that modular construction is not as durable or aesthetically pleasing as traditional construction methods, although this is changing as the technology advances and modular construction becomes more common (Northgate Industries, 2019).

Further research on this construction method will be discussed in Chapter 2 where the process and costs of this method is understood in more detail.

2.1.2 The traditional construction concept

Traditional construction refers to the method of building structures in which all construction work is completed on site. This method of construction is still widely used today, and it involves the use of different tradesmen such as carpenters, masons, electricians, plumbers, and other professionals who work together on site to build a structure (Hilson, 2015).

The construction site is managed by a general contractor who is responsible for coordinating the work of all the different tradesmen and ensuring that the project is completed on time and within budget. Traditional construction offers the flexibility to make changes on site, but the process tends to be slower and more costly in comparison to other construction methods. This method is known to produce more waste and has a greater negative environmental impact. However, traditional construction is still considered the most suitable method for certain types of projects such as complex, large, or unique buildings (Hilson, 2015).

A historic overview of the traditional construction method

Looking back into the history of traditional construction methods, prehistoric humans used materials that were readily available in their environment to build their shelters. These materials included stone, mud, and wood (Riley & Cotgrave, 2004). Prehistoric people developed basic construction techniques to utilize these materials, such as dry stone walling and wattle and daub.

An early traditional construction method known as “dry stone walling” was a technique used to construct walls and other structures using stones without the use of mortar. This technique required skill and precision, as the stones had to be carefully selected and placed to ensure stability. The walls that were constructed by using dry stone walling were durable and weather resistant, making them ideal for use in prehistoric structures (Brooks & Adcock, 1999).

Wattle and daub were techniques used to construct walls using a wooden frame or wattle, covered with a mixture of mud, clay, and other materials, known as daub. This technique was commonly used to construct houses, barns, and other structures. The use of wattle and daub allowed prehistoric people to construct structures quickly and

efficiently, using materials that were easily accessible (Britannica & Encyclopaedia, 2018). Figure 4 below represents the aesthetic look of a building constructed by using wattle and daub.

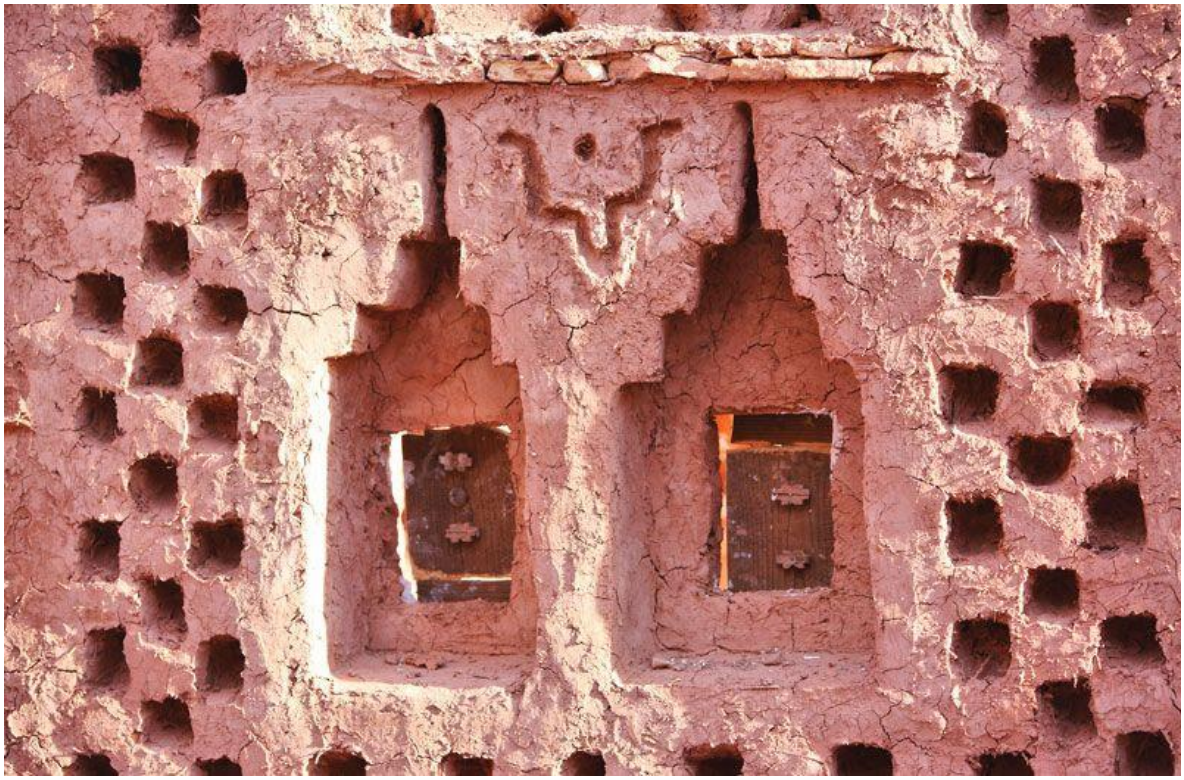

Figure 4: Wattle and daub construction *(Britannica & Encyclopaedia, 2018)*.

Historically, people also utilized wood, bamboo, and straw to construct shelters and other structures. Wood was abundant in many regions, making it a readily available building material (Riley & Cotgrave, 2004). Overall, prehistoric building techniques and materials were shaped by the environment and were the only resources available to prehistoric people. These techniques and materials were simple and effective, and allowed people to construct durable and functional structures that provided shelter and protection.

A significant influence on the choice of material for historical structures were based on the influence of local climate and geography. The local climate and geography had a significant impact on traditional building techniques. For example, in hot, arid climates, such as the desert regions of the American Southwest, the use of adobe was common due to its ability to regulate temperature and resist moisture. In regions with abundant

clay, cob buildings were popular as it was a low-cost and easily accessible building material (Riley & Cotgrave, 2004).

Throughout centuries, the technology of traditional construction methods has evolved from the earliest primitive structures to the more modern traditional construction we know today.

Figure 5: Brick and mortar house *(Clay Brick Association, n.d.)*

The building illustrated in Figure 5 represents the traditional construction method that has been used for centuries to build homes, buildings, and other structures. The method involves laying individual bricks in mortar to form the walls of a building. The mortar provides a strong and durable bond between the bricks, holding them together and creating a solid structure. Bricks are made from clay and are moulded into specific shapes and sizes for use in construction. They are baked in a kiln to produce a hard and durable material that can withstand the test of time. The bricks can be made from a variety of materials, including clay, concrete, and other materials, and can be used in a variety of colours, textures, and finishes (Smith & Smith, 2009).

Brick and mortar construction is a traditional building method that provides benefits such as durability, strength, and energy efficiency. Bricks offer good insulation and allow for flexible design options, but also require specialized skills and equipment, as well as a higher cost compared to other traditional methods (Glen Gery, 2020).

Traditional building methods offer a range of benefits, including sustainability, energy efficiency, cultural heritage, cost-effectiveness, durability, comfort, and flexibility. These methods provide a proven and effective way to construct homes and other structures that are well-suited to the environment and the needs of local communities (Ryan, 2011).

Chapter 2 will discuss the materials and costs associated with the traditional construction method to provide further insight into the concept and processes of this method.

2.2 THE USE OF MODULAR CONSTRUCTION METHODS WITHIN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY AND INTERNATIONALLY

The use of modular construction projects in South Africa has grown in recent years due to the benefits it offers such as cost-efficiency, faster construction times, and improved quality control. Modular construction projects in South Africa are mainly used in the residential, commercial, and industrial sectors. The residential sector has been a major user of modular construction, particularly for low-cost housing projects. Prefabricated housing units can be mass-produced in a factory setting and then transported to the building site, which helps to reduce the construction time and cost. In the commercial and industrial sectors, modular construction is mainly used for office buildings, retail spaces, and warehouses. The use of modular construction in these sectors provides faster construction times and improved quality control. These benefits are achieved by prefabricating large parts of the building off-site, reducing the need for skilled labour on-site (Cartwright, 2011). Despite the benefits, modular construction projects in South Africa face some challenges such as shortage of skilled labour, lack of standardization, and limited access to financing. The government and private sector are working together to address these challenges by training and educating the workforce, encouraging standardization, and making financing more accessible to modular construction projects (Holm, 2008).

According to a report published by Mordor Intelligence (2021), the prefabricated buildings industry in South Africa is expected to see significant growth in the coming years, with a projected CAGR of over 5%. The increasing demand for building

construction, as well as government investments in various sectors, is driving this growth. Building information modelling (BIM) is also seen as a potential opportunity for the industry in the future. However, technical issues such as weak joints and poor thermal insulation may hinder market growth. The high cost of logistics involved in prefabricated building construction is also expected to be a challenge. The demand for prefabricated hospital and patient bed facilities has risen during the pandemic due to the short completion time.

In comparison to other countries, South Africa's modular construction industry is still in its early stages of development, but it is growing rapidly as more developers, contractors, and builders adopt this method. The use of modular construction is becoming more widespread in South Africa as the industry responds to the increasing demand for affordable, high-quality housing solutions.

On a global level, modular construction is widely used in countries such as Australia, the United States, the United Kingdom, and Japan. These countries have matured modular construction industries that have been able to deliver large-scale, high-quality projects for a wide range of applications, including commercial buildings, hotels, schools, and hospitals (Ramtech Building Systems, 2013). The modular construction industry in South Africa faces some challenges, such as a lack of skilled workers, limited access to financing, and a need for improved standardization and quality control (Loulakis, 2011). However, the industry is working to address these challenges and to promote the benefits of modular construction, including improved speed and efficiency, greater design flexibility, and reduced waste.

In conclusion, while the modular construction industry in South Africa is still in its early stages of development, it has the potential to grow and to offer significant benefits to the construction sector and the broader economy.

International market value of modular construction

Infrastructure investment needs are growing globally, particularly in developing economies such as India, Japan, Indonesia, Nigeria, Mexico, and China. The world is expected to spend around USD 78 trillion on building infrastructure between 2014 and 2025, driven by increased urbanization and population growth. As a result, people are expected to spend more on housing and businesses. Modular construction is becoming increasingly popular due to its benefits, such as improved stability, faster

construction, greater flexibility, reduced waste, and less need for labour. This has attracted many new professionals and companies to enter the modular construction market, seeking to take advantage of its growth potential (Straits Research, 2022).

A comprehensive report compiled by Straits Research (2022), states that the modular construction market is divided into three regions: North America, Europe, and Asia-Pacific. North America holds a significant market share of USD 28 billion in 2021, expected to reach USD 53 billion by 2030 at a CAGR of 7%. Europe, known as the industrial hub of the world, holds the second largest market share valued at USD 33 billion in 2021 and projected to reach USD 49 billion by 2030 at a CAGR of 6%. Asia-Pacific is the leading region with a market value of USD 67 billion in 2021 and expected to reach USD 139 billion by 2030 at a CAGR of 8%, due to the presence of major emerging economies like India and China.

2.2.1 The major role players in Modular Construction within South Africa

The South African prefabricated buildings market is diverse, with a mix of international and domestic companies competing. These companies are using advanced technologies to lower production costs and minimize risks. However, the market can be challenging for new entrants due to high capital requirements and fast-paced technological advancements. Some companies in the market specialize in providing fully customized wooden prefab structures. The market is expected to grow in the coming years due to increased investments in prefab construction and upcoming major projects in the country. Key players in the market include Karmod Prefabricated Building Technologies, Kwikspace Modular Buildings Ltd., Cube Modular, Fabricated Steel Manufacturing, and Concretex (Mordor Intelligence, 2021).

Figure 6: Major Players in Modular Construction (Mordor Intelligence, 2021)

2.3 CONSTRUCTION COSTS IN SOUTH AFRICA

According to an online article written by (Tabalia & Apindi, 2022), building a home in South Africa is an exciting process, but it's not without its challenges. What you're faced with are different costs depending on the size of the building and how much work needs to be done before getting started. Costs included are price of land; if you do not already own land in your ideal location then it is best to purchase as much of the property before building. You should also consider this cost when making decisions about investing money into any project that requires long-term investments such as buying an apartment complex. The first thing people spend their funds on after deciding where they want live and how much they can afford per month leaves them with two options: purchasing real estate or starting a business because both have benefits depending upon what type of person wants something different from either option (Tabalia & Apindi, 2022). Professional fees: The total cost of building a home is not cheap, but it does not have to break your bank. You will be required to pay an architect for designing the house and other professionals who specialize in different fields such as quantity surveying or structural engineering depending on what type of building you choose when starting construction. The price can vary greatly based upon

which service requires more expertise so make sure that any contractor working with them has at least some knowledge about these matters before hiring him/her (Tabalia & Apindi, 2022). Council planning approval costs, municipal rates and taxes, electrical, sewerage and water connection charges, service costs, the actual cost of building, and with some projects, even NHBRC fees (Tabalia & Apindi, 2022).

Construction expenses can vary depending on the size of a project, desired finishing touches and current market prices for various construction items. Building a home in South Africa is not an easy task. The construction index determines how much everything costs, and you will have to spend more money if your building material arrives at the wrong time or does not match what was promised by suppliers. The content should include various items that can be used for residential purposes including steel beams, bricks/mortar mix (such as cement), and wood shingles - all depending on where this person lives geographically within SA (The Cat Rental Store, n.d.).

The construction index is a factor that determines how much money you will make in your region. The Construction Material Price Indices, also known as CMPI for short helps predict whether there'll be an increase/decrease of various items such as materials and labour within certain areas based on their current prices (Statistics South Africa (Stats SA), 2010).

If you want to build your dream home, the costs will vary depending on the type of land and how many extras are included. For example, cupboards can cost between R10 000 - R20 000 per meter; lights might be another extra as well at around 10% above installation fees for electricians or plumbers alone; kitchen & bathroom fittings make up an additional expense. The miscellaneous expenses that you should include in your home budget when building it, include travel and accommodation costs for remote sites as well administrative fees to plan out the project. You will also need money set aside just so that there are no surprises during construction (Tabalia & Apindi, 2022).

According to the annual Property and Construction Cost Guide from AECOM, they summarise the traditional residential construction costs of housing in the following categories (AECOM, 2020):

Private dwellings:	Rate per m2 (excl VAT)
Economic	R 5 900.00
Standard	R 7 300.00
Middle-class	R 8 800.00
Luxury	R 12 300.00
Exclusive	R 19 500.00
Super Luxury	R 28 500.00 – R 59 000.00

Source: (AECOM, 2020)

2.4 TRADITIONAL CONSTRUCTION AND MODULAR CONSTRUCTION

The construction industry is endlessly versatile. From bridges and buildings to sidewalks, there's no limit on how you can use this grey material in your project. Peckenham talks about how concrete construction has many negative effects. One such effect is that it releases tons of carbon dioxide into our atmosphere every year - which contributes greatly to South Africa's calamity. Alternatives like straw bales, grasscrete, rammed earth, hempcrete, bamboo, recycle plastic, wood, mycelium, prefabricated components, modular units, container homes and many more are suggested and used specially to subsidise traditional construction materials to combat high construction costs (Peckenham, 2016).

The global alternative construction market is fuelled by an increasing number and variety in materials used for building projects worldwide. There are many ways that researchers can pursue new strategies when it comes down creativity with what they do best - there's no capped limits on innovation.

In today's world, people are always looking for ways to be more efficient and save money. In the construction world, some people think that the only way to do things is by using modern methods. However, sometimes traditional methods can lead to better results than those achieved with modern construction processes. Traditional construction is the way that houses and other structures have been built for a long period of time. People in the United States call this "brick-and-mortar." Some people call it "stick-by-stick." This means that they put the walls up one at a time. There are

many different materials that can be used in traditional construction. Concrete is often used for the foundation or for load-bearing walls because it is very strong and durable (Lacoma, 2017).

Traditional construction is when each step of the project is done on site. This means that each individual step needs to be completed before the next one can start (Reds10, 2015). With traditional construction techniques, you can choose the architect who will help make your dreams a reality. The architect then has the freedom to be creative and make your dreams come true. For modular homes, the components are made in a factory and put together quickly on site. When traditional construction techniques are used, it often results in a stronger and higher quality home. The disadvantage of using traditional methods of construction is that it takes longer. It can be more complicated to build a house this way, and you might need to hire skilled designers and builders. This can add significant costs to the project; materials and labour are more expensive (Lacoma, 2017).

Moladi technology is an example of a modular construction method used by the South African Housing and Infrastructure Fund, it is cheaper than traditional building methods. This technology uses plastic instead of brick (South African Housing & Infrastructure Fund, 2020). A good example of alternative construction was researched by a student, Haselau, where he found that Builders Trade Depot supply high quality modular timber homes. These homes come in two sizes: 41m2 and 53m2. The homes come with everything you need, including the walls, ceilings, cornices and skirting, floor and wall tiles, plumbing and electrical fittings, windows and doors. The kitchen and bedroom units are also included (Haselau, 2013). This method supports skills development, and it also helps improve productivity and the quality of work. It also sets high standards for homeowners.

2.5 CONSTRUCTION METHODS AND THEIR COSTS

2.5.1 METHOD A: Traditional construction process

According to an article written by The Brick Industry Association, brick homes are a lot more affordable than we may think. They have many benefits, like being more cost competitive. Brick homes do not need a lot of exterior maintenance and their colour will never fade. Brick homes have a higher resale value and lower insurance premiums. Brick homes save energy, and it will last for hundreds of years and is the safest wall cladding for any home (The Brick Industry Association, 2020).

It is estimated that the average total construction cost of a clay brick-sided home is cheaper than stone, stucco, wood, and fiber cement. People often try to copy the look of brick, but it is not as good as the real thing. Genuine clay brick is the best type of wall cladding because it offers many advantages. Brick is a good investment. It lasts a long time and does not need to be fixed. Brick also saves energy, which means it is cheaper to run and the house will be worth more when you sell it. Brick is the best material for an exterior wall on a home. It does not burn and it can withstand a lot of damage, where fiber cement and vinyl provide three times less the protection of brick walls (The Brick Industry Association, 2020).

According to STATSSA, the average cost per square meter for residential projects in the Western Cape smaller than 80m2 as of March 2021 was R 5 798.00 per m2 (Department of Statistics South Africa, 2021). The following headings discuss the details and methods of traditional construction to get a better understanding of the timelines and systems involved with the specified method of construction.

Step 1: Preparation of the site

The site should be clean, without debris, vegetation or any other organic or building materials. This process duration is dependent on the size and condition of the site. The typical duration for site preparation is between 1 – 2 months according to Pro Crew Software (Pro Crew Software, 2020). In this research paper we will adopt a site

that has never been constructed before and, therefore, only has municipal connections and natural vegetation.

The preparation stages of a site as stated by Pro Crew Software consists of the following (Pro Crew Software, 2020):

The first step is site clearing, clearing the site is the first step in preparing the land to build on. The entire site must be graded and cleared. This means that all buildings, trees, and underground infrastructure must be removed. If these things are not removed, they could interfere with building on the site and slow down or stop the construction process. It is very important that this task is done correctly so that the project can continue smoothly.

Thereafter, site surveying occurs. A surveyor is responsible for surveying a specified land, erf or site and making sure that the area supports the specified project. The process of surveying land is important, but it might not be an option depending on zoning and permitting processes. Besides, surveying is how contractors figure out how to build something that looks like what they've planned.

After site surveying is completed, soil tests are conducted. The soil's main composition will tell you how well it absorbs water and how strong it is. The site engineer must make sure that all necessary soil testing procedures are done before starting any construction work.

Following the soil tests, the site plan design is developed. This plan illustrates the movement, allocation and positioning of different construction materials, plants, access ways and access to the site. This is required to ensure the team, materials, machinery, and temporary structures are placed with precision to ensure efficiency and accuracy on site.

Lastly, the site investigation is conducted. Geotechnical site investigation is when someone looks at the rocks, soil, and groundwater around a proposed site. They do this to figure out what kind of foundation a structure should have.

Step 2: Excavations and foundations

The process of excavating and pouring foundation can start once the site has been fully prepared. The excavations and foundations can take up to 1 – 2 months as it includes excavation and digging (up to 2 weeks) and curing of concrete (up to 28 days).

Step 2 consists of excavating trenches for continuous foundation as per the structural drawings compiled by a qualified engineer (Zavala, et al., 2004), and preparation of the trenches by compacting and leveling the bottoms and sides and treating the ground with the required soil insecticide. A general rule is that foundations for external masonry walls should not be less than 300mm below the finished ground level (Swift, 2011).

Thereafter, the placement of the previously assembled reinforcing members inside the trench is to receive the concrete mixture (Zavala, et al., 2004).

Step 3: Foundation brickwork

The correct preparation of brickwork on top of your foundation footing is important to avoid unnecessary ingress of groundwater into the physical structure. The process of bricklaying is labour intensive and requires specific bricklaying skills. The process can take up to 3 weeks depending on the size of the project.

This process starts off by wetting the bricks before the layering begins. Wetting the bricks avoids the clay from absorbing any moisture content from the mortar mixture. Mixing of the mortar should have the correct consistency and correct cement to sand to water ratio (Zavala, et al., 2004).

Thereafter, the labour-intensive process starts with the stacking/layering of the bricks in the desired pattern. A brick or mortar trowel is used to lay mortar on top of the brick walls to penetrate the brick holes, the second layer of bricks are then layered on top of the mortar bed and leveled. Every layer of bricks is vertically checked against a lead weight to ensure the walls are being built straight and upright. The research conducted

by Zavala states that bricklayers should not build more than 1.2-meter-high brick walls per day (Zavala, et al., 2004). According to the SANS regulations, brick force is required at every layer in foundation walls as well as every two layers in superstructure walls. External walls are to be cavity walls that are tied with brick ties and filled with concrete up to natural ground level (Swift, 2011).

Step 4: Ground floor construction

The process involved with the construction of the ground floor slabs includes materials and activities such as filling, compaction, soil insecticide, waterproofing membranes, concrete mixture, reinforcing, movement joints and curing agents. The process to construct the ground floor slab can last anywhere up to 1 – 2 months, mainly since the concrete slab should be fully cured and dry which takes up to 28 days alone. The ground floor construction process is explained by Barry to consist of the following (Barry, 1999):

Firstly is the filling and compaction of the soil underneath the concrete slab. This requires specialized filling and compaction that is prescribed by a structural engineer. After the compaction density has been reached, the area is treated with a soil insecticide to prevent any organic growth or life underneath the slab.

Thereafter, a waterproofing membrane is placed over the compacted soil and steel mesh is positioned on top of the membrane. The concrete mixture is thrown to the desired thickness and left to cure to achieve the maximum strength for 28 days. Curing agents are added to the concrete surface and kept moist to minimize possibilities of cracks and incorrect curing.
This is followed by movement and saw-cut joints that are then cut into the slab to allow movement during its lifespan.

Step 5: Superstructure brickwork, Windows, Doors and Exterior finishes

The brickwork in the superstructure is a similar process as the brickwork in the foundations (Zavala, et al., 2004), however, there are several elements of design that have to be incorporated in the brickwork, these include; lintels for door and window

openings, brick force at every 3 – 5 layers of brickwork, roof ties to connect the brickwork to roof trusses, movement joints where concrete members are built up against the brickwork and beamfilling for roof sections (Barry, 1999). The managing director of Dobanti Chartered Surveyors, Tim Doherty, states that it takes a bricklayer an average of 8 hours to lay a cavity wall of 5.5m2. The superstructure brickwork of a 50m2 house that consist of +- 90m2 will take up to 5 - 8 weeks to complete (Doherty, 2016). After the windows and doors have been installed into the exterior walls, the external finishes can now be applied. This process could take two to four weeks to be completed (MCR Safety, 2020).

Step 6: Roof construction

The construction of a roof is dependent on the design of the house. There are several roof designs and coverings, and these include flat roofs, mono pitch, hip roof, asymmetrical pitch and more. The covering of the roof varies from metal sheets, cement tiles, asphalt or thatched roofs. Each design has its own complexities and methodologies (Barry, 1999). The duration of the roof construction varies between 2 – 6 weeks from the start of the manufacturing to the installation (Guido, 2016).

The construction of a roof is a complex item especially with regards to the details of connecting the roof structure to the structural brickwork. The following steps will provide you with the process involved in roof construction:

The roof contractor will receive or design the required roof plan for the project which must conform to all structural requirements from the engineer. Once the structural engineer has signed off on the design, the manufacturing of the roof trusses can begin (Barry, 1999).

Thereafter, the installation and fixing of roof trusses are a dangerous and skilled task which requires contractors to work from heights of 3 meters and higher, therefore, the use of solid formwork, cranes or lifts are required to assist with heavy lifting and placing of the roof members. The safety of roof construction is important and, therefore, this process within the project requires the needed safety, clothing, support and fitness. (SKAT, 1993).

If trusses are used, they need to be assembled on site. The ground must be perfectly level for them to be accurate and look the same. A template should be used to make sure they are all the same size (SKAT, 1993).

After the roof covering has been chosen, the batten layout can be established (SKAT, 1993). The use of metal roof sheeting has become a famous choice amongst designers and clients as it is a low maintenance, easy installation, and aesthetically pleasing building material. The installation of any roof covering involves insulation membranes and moisture vapor membranes to be installed prior to placing the metal roof coverings. Eaves, barge boards, ridge flashings, wall flashings and several roof accessories are required to seal and finish off the roof covering (Barry, 1999).

Step 7: Internal construction and finishes

The internal construction of a project as specified by The Association of South African Quantity Surveyors (ASAQS) includes but is not limited to elements such as internal brick walls, partitions, floor finishes, internal wall finishes, ceiling finishes, fittings and service installations such as plumbing and electrical works (The Association of South African Quantity Surveyors, ASAQS, 1999). The internal finishings and services of a project can only be completed once the project has reached a stage where the building has been completely sealed or closed. Becky Striepe writes in an online article that the internal process does require attention to detail as this is the final step to finish off the work. The duration of this process can take up to anywhere from 4 – 12 weeks depending on the complexity of tiling, joinery items or ceiling designs (Striepe, 2022). In an article written by Jeff Finney, he states that it is highly advised to ensure all subcontractors are well informed of the main contractor's program to avoid unnecessary delays in completing items (Finney, 2017). A look into the process of internal finishing includes:

Chasing or cutting into walls for all electrical and plumbing services needs to be completed prior to internal finishing can start. Once the placement and installation of all first fix plumbing and drainage has been completed the plastering and painting of all internal walls can commence (Hall & Greeno, 2007).

Internal ceilings need to be installed and painted prior to electrical fittings being installed. All internal painting and wet works need to be finalized prior to the floor finish being installed, as it is not wise to still be working with plaster or paint once a beautiful floor has been installed. The final fittings and kitchen installations can then be installed to finalize the internal fit out (MCR Safety, 2020).

The diagram below summarizes the expected construction timeline of a typical masonry house based on the research discussed above.

CONSTRUCTION PROGRAM
50m2 Masonry Home

TASK DESCRIPTION	PLAN START	PLAN END	TYPE
50m2 Construction Masonry House	2022/02/15	2023/01/15	
Preparation of site	2022/02/15	2022/03/15	B
Excavations and Foundations	2022/03/15	2022/04/15	P
Foundation Brickwork	2022/04/15	2022/05/15	R
Groundfloor Construction	2022/05/15	2022/06/15	X
Superstructure	2022/06/15	2022/08/15	O
Roof construction	2022/08/15	2022/10/15	G
Internal Finishes	2022/10/15	2022/12/15	X
Site Cleaning and close out	2022/12/15	2023/01/15	X

Figure 7: Construction Program of 50m2 masonry house (SKAT, 1993)

2.5.2 METHOD B: Modular construction process

Modular construction has been a popular way to build large-scale projects because it offers many advantages and disadvantages. One benefit is that the cost of each piece or module can be lower than traditional methods, which may make them cheaper in total if you add up all your individual purchases over time; however, this also means there are more steps involved with putting together any given structure - especially safety-wise since these components need testing before they're put into place on site (this process usually takes about six months). Modular construction methods can have

several advantages, such as better quality, less labour, lower costs, and shorter construction times (Ferdous , et al., 2019).

The modularization method for construction has two important benefits. First, several activities can be done at the same time. This means that the construction process goes faster. Added to that, severe weather conditions do not have a significant impact on the process or manufacturing which means that the construction process can continue even if it is raining or snowing. Modular construction projects usually take 40% less time than traditional construction projects. This can be very important for projects that need to be completed quickly, such as post-disaster reconstruction. Ramaji and Memari found that the more complex a project is, the less time is saved by modularizing it. This is because there is more need for communication and on-site work (Ramaji & Memari, 2016).

The study done by Cartwright found that when modularization is used, the construction cost of a project can be reduced by 10%-25%. There are several reasons why the construction of homes is cheaper now. The benefits of off-site manufacturing are many, including reduced transportation costs for materials and labour. The lack of vulnerability to weather extremes also makes this option more appealing as there is no risk in having inventory spoil because it's stored somewhere else. Cartwright explains that this method of construction takes up far less time than the standard or traditional method of construction, that is why we experience a reduction in costs (Cartwright, 2011). Working on-site often involves activities that can be dangerous to workers. This has led to many fatalities and non-fatal injuries. Researchers are looking for ways to make it safer. Studies have shown that modularization decreases the number of safety problems for laborers. When modular construction is used, the rate of accidents goes down by 80%. This is a good way to have less injuries on the job site (Penaloza, et al., 2017).

The making of parts and panels for modular construction is conducted, constructed, and compiled by machinery. The people who make the components are good at their job because they have done it many times. Weather has no effect on the materials and components of modular construction. Weather conditions that could harm the materials have no effect on the components. Modular items have the potential to be of higher quality, less expensive, and manufactured in greater quantities in less time

than those made on the job site (Kermanshanci, et al., 2018). Traditional building methods generate a lot of waste, which has always been a burden for construction professionals. Traditional construction produces more waste than modular construction. The waste is easy to dispose of, and the products are easy to reuse and recycle. When their lifecycle is complete, the components may be removed, and they do not cause any dust, greenhouse emissions, or noise on site (Kawecki, 2010).

There are limitations to modular construction, which includes careful planning. O'Connor found that the project planning process of modular construction differs by more than 36% from the project planning of traditional construction. There are many differences between traditional construction and prefabricated construction. The biggest challenge with prefabricated construction is that it often leads to limitations on how much you can build. For example, if the planning process only extends for 8 weeks before starting work, then there's no way your building will be complete by the 16th week. Another problem comes from all of these complex components which have to come together during one single phase in order for everything else around them to not fall apart too quickly - imagine having 50 different pieces being assembled at once while still needing time left over just so they're finished right. You need to plan your project well before you start. This includes having specific designs and details ready. You also need a lot of vehicles to deliver the manufactured parts to the construction site (O'Connor, et al., 2016).

Having large or oversized parts or panels will require special transportation considerations which can create time delays, additional costs, and could require a higher level of skill (Hu, et al., 2019).

The public and some construction experts think modular construction is bad. People need to know about the good things about modular construction to make this change happen. The cost of materials for modular construction is cheaper than traditional construction, but the cost of setting up a fabrication plant is more expensive (Kermanshachi, 2010).

Modular construction refers to producing standardized components of a structure in an off-site factory. This can include anything from single elements that are clipped together using standard connections and interfaces, to more complex systems where multiple elements are brought together. A 2D panelised solution is similar to how

furniture is often packed for shipping. In most cases, the panels are prepared to receive service piping for air conditioning, electricity, and plumbing (Bertram, et al., 2019).

The following section discusses the method and systematic approaches involved with the construction of a 50m2 modular home.

Step 1: Designing

Designing modular projects takes longer than designing traditional projects. This is because designers need to learn how to work with the manufacturing process. Design decisions need to be made at the beginning of the project and it is more difficult and costly to make changes later on. The industry is not familiar with this method of construction. This could potentially save time through automated design, which would shorten the design period. One client identified savings of almost 15 percent in design time through using modular libraries (Bertram, et al., 2019).

Some people think that there is a cost for designing a modular home, but this cost can go down in the future. There are people who do not have a lot of experience with modular homes, and so they need to redesign the house. However, we are getting better at making designs for modular homes that can be used again and again, and tools like digital design will help make this easier (Bertram, et al., 2019).

Step 2: Foundations

Panels and sections are specifically designed with being lightweight for transportation to sites. Having a lighter frame project reduces the size of the foundations and in turn, provides cost reductions (Bertram, et al., 2019).

Step 3: Manufacturing off-site

The process of manufacturing off-site is much faster than the traditional on-site building process. This is because the factory environment is enclosed and controlled, and activities can be coordinated and repeated. The number of shifts also impact how quickly things get done; typically, two eight-hour shifts are used, but three shifts could theoretically be possible if the right labour is found. Manufacturing can take place at the same time as foundation work, unlike in a traditional project where everything happens one step at a time (Bertram, et al., 2019).

The advantage of modular construction is that it allows for parallel construction. This means that while the main part of the construction happens on site, the modules can be built elsewhere. This reduces the amount of time it takes to build the house. Different parts of the house can be worked on at the same time in different places (Modular Building Institute, 2015).

It is difficult to know if the cost of materials will be higher or lower when using off-site manufacturing. However, overall reductions of 5 to 10 percent are possible (Bertram, et al., 2019).

In modular builds, up to 80 percent of the traditional labour activity can be done in a factory. This includes mechanical, electrical, and plumbing work. This reduces the wage bill because these activities can be handled by lower-cost workers. Additionally, the controlled operating environment of a factory can double productivity above what can be achieved with traditional builds. This is even before considering the productivity benefits of establishing simplified, repetitive processes or advanced automation equipment (Bertram, et al., 2019).

Step 4: On-site assembly and construction

With modular construction, the work done on site is much simpler than traditional construction. “You basically put together 3D modules and connect services to the main site connections. Typically, one team of five workers can assemble up to six 3D modules, or 270 square meters of finished floor area, per day. This is much faster and cheaper than traditional construction” (Bertram, et al., 2019).

Modular construction is different because you can build the floors, walls, ceilings, rafters, and roof at the same time. Usually in traditional construction, the walls cannot be set until the floors are in position, and the ceilings and rafters cannot be added until the walls are erected (Modular Building Institute, 2015).

Modular construction has already been shown to reduce the schedule of a project which in turn, lowers the costs of things like security and managing weather-related issues, as well as construction management (Bertram, et al., 2019).

In modular construction, it is very important to coordinate and deliver the modules to the site. This is especially true when there are large 3D units involved. If the regulations for transportation are restrictive, it can cost up to 10 percent more. When builders

consider using 3D modules, they have to make sure that the productivity gains outweigh this cost. They need to weigh things like wage differentials between the manufacturing facility and the product's end destination, as well as how far away each one is (Bertram, et al., 2019).

Step 5: Inspection and finishing off

If you have a factory, it is easier to have quality control. On construction sites, it's harder to control quality because there are so many things that can go wrong. This can cause problems with the schedule. Sometimes, construction sites have problems that are not found until later. It is then harder and more expensive to fix them (Bertram, et al., 2019).

McKinsey Capital Projects & Infrastructure compiled a direct comparison between traditional construction vs modular construction projects based on time, and illustrates how modular construction produces construction speeds of between 20% - 50% faster than traditional construction methods (Bertram, et al., 2019).

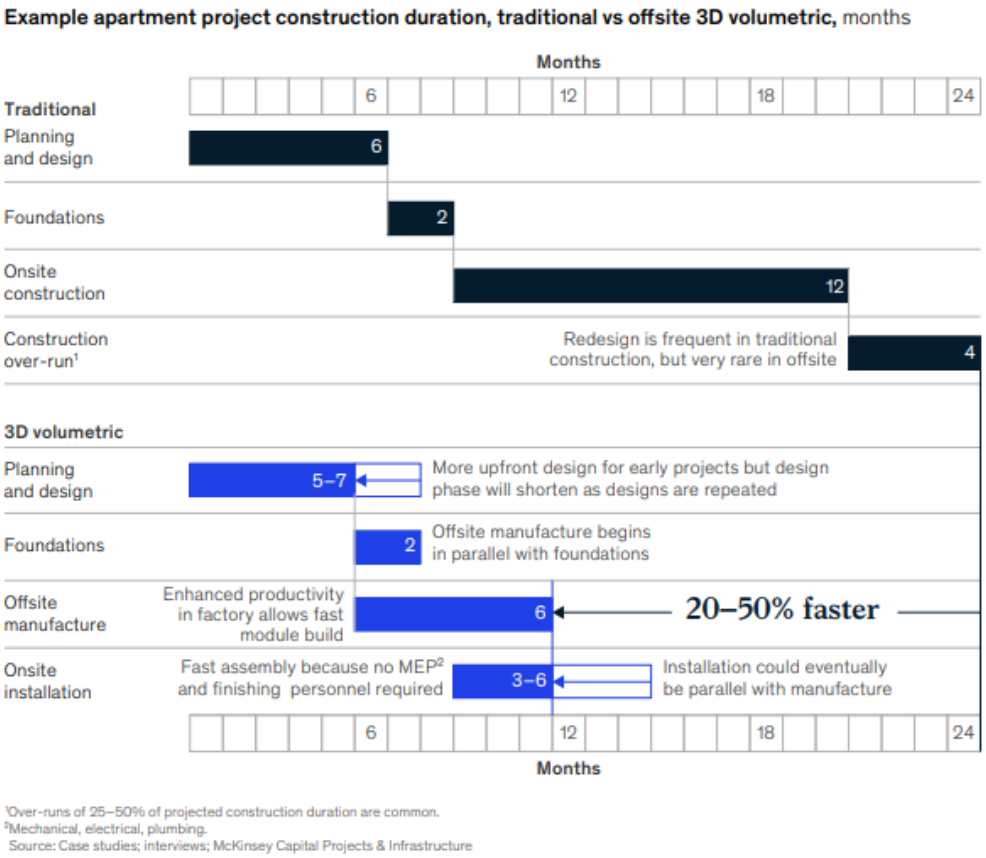

Figure 8: Construction duration of modular construction vs traditional construction (Bertram, et al., 2019)

In other industries, using a manufacturing approach often means lower costs. However, this has not been the case in construction. There is usually a higher price for modular construction. This may change in the future as the construction industry changes its ways and gets better at it. We have found that sometimes there are no cost savings, but sometimes there are savings of up to 20% (Bertram, et al., 2019).

There are many ways to save money when building a house. The first way is to use modular construction. This means that you do not need as many subcontractors, so you save on their fees. You can also save money on labour costs by building the house in parts and assembling it on site. However, this might cost more for materials and increase the cost of logistics. Finally, upfront design costs might be higher for modular projects, but you save money on rework and redesign costs (Bertram, et al., 2019).

The specifications and materials involved in a standard 54m2 modular home is provided below (National & Overseas Modular Construction, n.d.).

Item	Materials
Base plates	1.6mm galvanised base plate
	Foundation bolts
	Reinforced steel
Outer Walls	Steel columns
	9mm fibre cement sheets
	Aluminium cover strips
	12.7mm Gypsum Rhino Partitioning Board
	0.6mm studs
	Gypsum plaster
	50mm Aerolite glass fibre insulation
	Face brick profile panels
Windows	Reinforcing bearer
	Composite windows with 3 – 4mm glass
Roof	Trusses
	Bracing
	Laths
	0.5mm Galvanised Iscor S-Rib Supraspan corrugated iron sheets
	Sisalation
Inner Walls	12.7mm Gypsum Rhino partitioning boards
	Gypsum plaster
	Supawood skirtings

Ceilings	6mm Rhino boards with H-section frame
	Cornices
	50mm Fibre glass insulation
Gutters, Downpipes and Fascias	Square galvanised Gutters and downpipes
	Steel Fascia's
Doors	Six panel Meranti wooden front door
	Semi Solid external door – BC 133
	Flush panel including locks interior door
Interior floor	Vinyl tiles
	Damp proof course
Indoor Plumbing	1800mm built in bathtub
	Handwash basin 560 x 406 on pedestal
	White low-level toilet set
	150 litre electric geyser
	Bathroom accessories
Painting	Internal painting – One coat primer, 1-2 coats high quality interior paint
	External painting - One coat primer, 1-2 coats high quality exterior paint
Built in Cupboards	Red oak supawood veneer boards, including doors and drawers
Electricity	Electrical Wiring
	Electrical connection
Sewerage	Glass fibre reinforced septic tank with 21 meter 100mm pipe
Transport costs	Transporting materials to site
Foundations	250 x 450mm strip footing
	6mm Reinforcing
	220mm foundation wall 240mm high
Groundfloor slab	90mm thick concrete slab

According to the owners of a modular construction company (National & Overseas Modular Construction, n.d.), pricing a 54m2 modular home at R 235 278.50 excluding VAT, this excludes labour, erection, plumbing, cupboards, floor finishes, painting, and electricity, which brings us to a total of R4 357.00 per m2. If we include all the excluded amounts, we reach a total of R 341 910.50 excluding VAT, which amounts to an average of R 6 331.67 per m2 (National & Overseas Modular Construction, n.d.).

2.6 HOW PERCEPTION INFLUENCES DESCISION-MAKING REGARDING CONSTRUCTION METHODS

The selection of construction methods plays a crucial role in the success of a construction project, as it can greatly impact productivity, quality, and cost. This decision is vital for the proper development of a construction project and can significantly affect the productivity and efficiency of the project (Thomas, et al., 1990).

Construction companies struggle with managing and utilizing the information and knowledge associated with their projects. There are often inadequate systems in place for storing and reusing information from previous projects, and knowledge generated on the job is often not shared, leading to its loss. This ultimately impacts decision-making as accurate decisions rely on effectively managing and analysing the information and knowledge available (Cooper, et al., 2005).

In the research article conducted by Ferrada, Serpell and Skibniewski (2013) where they investigate the current practices for selecting construction methods in the local industry, the findings of the case studies indicate that the selection of construction methods is largely based on the prior experience of the professionals involved. It is a process that is complex in nature, heavily reliant on both individual experience and teamwork, and requires a high level of expertise.

This study focusses on the perception of Quantity Surveyors in South Africa regarding cost of two varying construction methods, therefore, it is important to understand the literature behind the influences of decision-making in construction.

An article by Venkatasubramanian (2021), deals with cognitive bias in construction and how it influences decision-making in the construction industry. This is an industry where margins are tight and schedules and budgets can easily be disrupted, it is crucial that decisions are made with as little bias as possible. Artificial intelligence (AI) and machine learning (ML) can be used to improve decision-making and reduce bias. On construction projects, decisions are made constantly, affecting various activities. Traditionally, decisions are made based on past experiences and data from previous projects. However, by incorporating AI and ML, data from various sources can be used to guide decision-making and make recommendations. This ensures that multiple options are considered, and the best course of action is chosen, rather than relying on familiar or comfortable solutions.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter discusses the research methodology chosen and used throughout the research project. Research is a systematic and scientific approach to collecting, analysing, and interpreting data to answer questions or test hypotheses. The goal of research is to increase our understanding of a particular subject or phenomenon, and to contribute new knowledge to a particular field of study.

The goal of the study is to collect data on how construction professionals perceive the costs of modular construction methods against traditional construction methods in South Africa. The construction professionals chosen for this study are Quantity Surveyors in South Africa. The reason for choosing Quantity Surveyors is that they are trained to provide accurate cost estimates, and they are professionals within the construction industry that deal with and calculate construction costs for different projects. Having these professionals participate in the research will assist in the accuracy and market relatedness of the results.

To collect this data, we used empirical research methods, which involve collecting data through a structured survey that involves using a pre-designed questionnaire with closed-ended questions.

Data was collected through an administered online questionnaire. After all the data had been collected, the online platform allowed the researcher to analyse and evaluate the data by using statistical software available on the online platform (Google Forms). The results were interpreted, and conclusions and recommendations were drawn. This research design closely follows the scientific method, which involves conducting experiments to test a hypothesis and answer a research question.

To ensure that the study followed a stringent approach to research methodology, the study makes use of the “research onion”. Figure 9 below depicts a framework of the methods used to assess the study. Each layer represents a following layer that requires identification before moving on to a next or deeper layer.

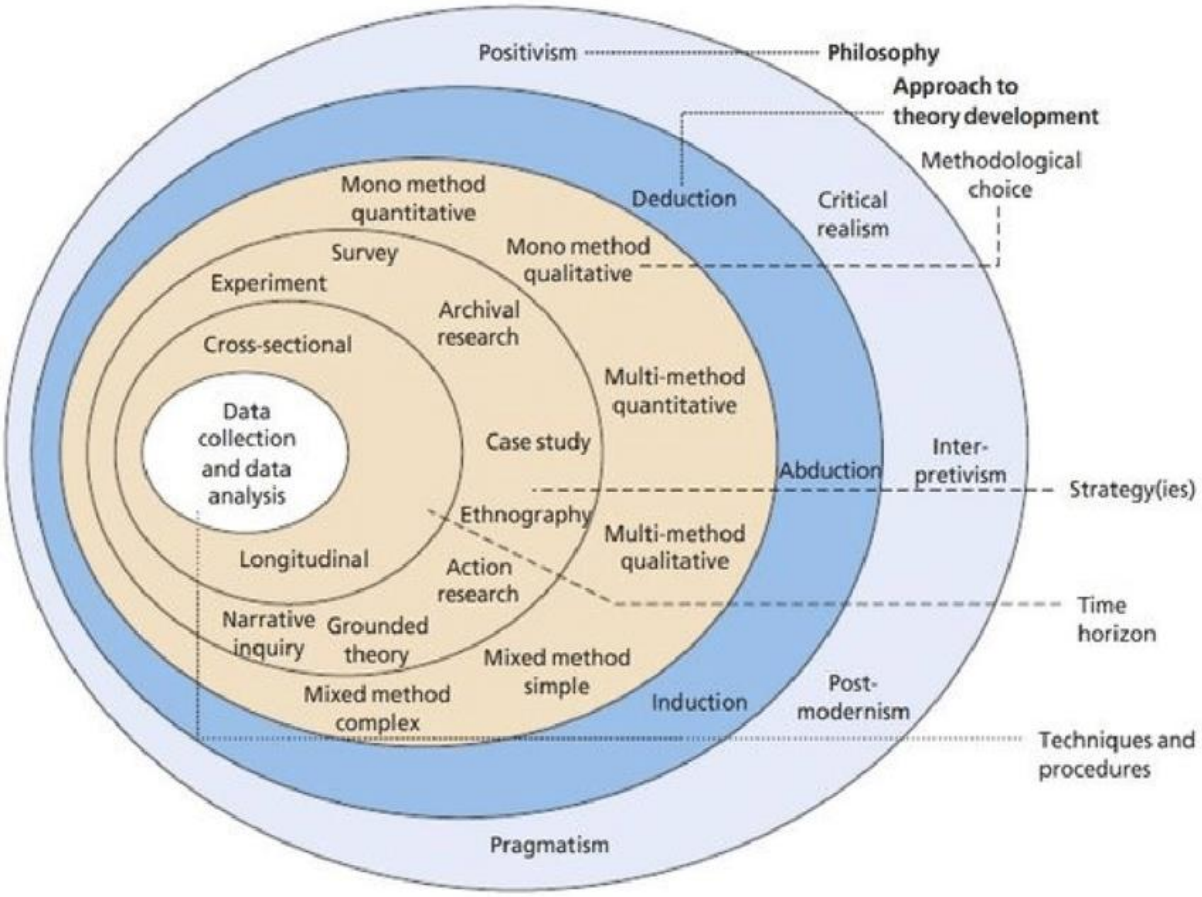

Figure 9: The research design and methodology framework (Sanders et al, 2016)

3.2 RESEARCH PHILOSOPHY AND DESIGN

The first layer of the research onion in figure 9 above represents the philosophy of research. The applicable philosophy towards this research study is called the Positivism Philosophy.

Positivism Philosophy

The study makes use of the positivist approach as a scientific method of inquiry that emphasizes the use of empirical data and quantitative methods to study social phenomena. This approach is based on the idea that social phenomena can be studied in the same way as natural phenomena, using the scientific method of observation, experimentation, and hypothesis testing. The positivist approach assumes that there is an objective reality that can be studied objectively and that social

phenomena can be explained by identifying underlying causes and laws. The positivist approach is often associated with quantitative research methods, such as surveys and experiments, and is often contrasted with interpretive or constructivist approaches, which emphasize the subjective and interpretive nature of social phenomena (Kumar, 2011).

After establishing the first outer layer of the onion, we move to the second outer layer of the onion, which is to determine the approach of the research study. This study makes use of a deductive approach.

Deductive Approach

This approach is adopted where the researcher starts with a theory, whereafter the theory is tested by means of obtaining data. The data is then observed to identify patterns and relationships. This allows the researcher to establish findings and determine whether the hypothesis is true of not (Streefkerk, 2022). The existing theory for this research is that the perception of cost is a critical factor that influences the selection of construction methods.

Thereafter, the researcher can formulate a hypothesis that is based on the theory. The hypothesis for this study is that “Construction professionals perceive modular construction as a more affordable method of construction in comparison to traditional construction methods”.

The deductive approach requires the researcher to collect data to be able to test the hypothesis. This study focusses on obtaining data from construction professionals within the South African construction industry that will be able to provide sufficient and relevant data to create observations and findings. After the data collection has been completed, the data is analysed and presented to the researcher. This data is then used to formulate conclusions and observations to test the hypothesis (Streefkerk, 2022).

The third, fourth and fifth outer layer of the onion focusses on the strategy of the research study. These three layers determine how the research will be conducted. The most applicable method strategy for this study is the mono-method of quantitative survey research.

Mono-Method

The choice of strategy is based on the amount of data types that the researcher will use during the research study and the interpretation techniques used. By using the mono-method, the researcher makes use of only one data type named the quantitative method (Phair & Warren, 2021).

Quantitative approach by using surveys.

This research study makes use of a quantitative research approach which allows the researcher to present a predetermined set of questions to a complete group or sample of individuals through the distribution of online surveys (Blackstone, 2012).

The quantitative approach is also an official and explicitly controlled method in research that results in more exact data that is more closely tied to physical sciences (Mouton & Marais, 1992). The advantage of choosing this research approach is that it's a good technique to collect data from a large group of people, fast. This method is also cost-effective in comparison to other methods such as qualitative methods. Quantitative methods make use of surveys that can be distributed online and sent to a large group of people, where qualitative methods would have to make use of physical interviews with a specific group of participants to collect data (Blackstone, 2012).

The researcher found that by using a quantitative research method, it would provide access to the collection of data in a more cost-effective, flexible, reliable, and generalizable way.

While quantitative research methods have benefits, they also have drawbacks. Surveys can be inflexible as researchers are limited to a single instrument for collecting data, making it challenging to modify questions after sending out the survey. This can lead to confusion and missed opportunities for clarification. Where in-depth interviews during qualitative methods allow for further explanation and the ability to tweak questions for a better understanding of the responses (Blackstone, 2012).

Time Horizons

The sixth and final layer is the time horizon in which the study is aimed to be completed. The most applicable timeframe is the cross-sectional time horizon. This

time horizon is meant for research studies that are aimed to be conducted over a pre-set timeframe. This study aims to obtain data that is currently relevant and not bound to a specific timeframe or range (Creswell, 2005). The researcher aims to collect data from different participants at a single point in time, and the cross sectional approach allows the researcher to do so.

3.3 RESEARCH INSTRUMENT

This study aims to utilise a survey as means of collecting data. This method is chosen where the research study can generalise a population to be able to make changes to behaviours, characteristics, and attributes (Creswell, 2005).

A carefully designed questionnaire is sent to the selected participants. The questionnaire design is used to obtain information regarding demographics, professional experience, and involvement of modular and traditional construction methods. The practical section of the questionnaire aims to obtain relevant data with regards to perceived costs associated with the different construction methods.

The researcher makes use of surveys as a study instrument as they are a cost-effective method of collecting data from many participants quickly and efficiently (Creswell, 2005).

Referring to the location of this study, South Africa is a country that covers 1 221 037 km2, consisting of 9 provinces (Eastern Cape, Free State, Gauteng, Kwazulu-Natal, Limpopo, Mpumalanga, Northwest, Northern Cape and Western Cape). See Figure 10 of the provinces of South Africa below. Therefore, to obtain data from several participants across South Africa requires an effective data collection method.

Figure 10: Provinces of South Africa (Government of South Africa, 2021).

Using surveys as a study instrument provides a standardized approach to data collection, making it easy to analyse the data using statistical methods. Further to the efficient access to different professionals in several locations, the survey method allows the researcher to collect data from a large number of people. This provides the study with a respectable representation of the population. Creswell (2005), also adds that the use of a survey provides anonymity, providing participants with the option to remain anonymous in their feedback, which in turn gives the researcher a higher chance of feedback from the participants.

The researcher did not consider using other forms of study instruments, experiments, observations or tests and assessments as these instruments would not have been sufficient for obtaining the specific data to test the hypothesis. The goal of the

instrument is to obtain specific responses from several participants on a specific subject and evaluating the responses in an analytical evaluation.

3.4 PROCEDURE OF RESEARCH

Step 1: Evaluate theories and hypothesis to base the research study on.

Step 2: Determine the approach of the research study.

Step 3: Determine the strategy of the study on how the data will be collected for the research paper.

Step 4: Determine which research method type/s will be used during the study.

Step 5: Determine in which timeframe this research will take place.

Step 6: Determine the method of data collection and data analysis for the study.

After the steps have been evaluated and determined, the following procedures will be followed:

Step 1: Ensure Ethical clearance is achieved and start to compile the information letter and if required, a letter of consent, and send to each selected participant.

Step 2: Compiling of the questionnaire to include 27 relevant questions to test the objectives of the study.

Step 3: Undergo the selection of 350 Quantity Surveyors within the construction industry of South Africa and obtain permission to forward them the required documentation to take part in the study.

Step 4: Digitally send all questionnaires to willing participants.

Step 5: Analyse the data collected from the questionnaire.

Step 6: Reject or agree with the hypothesis.

3.5 STATISTICAL PROCEDURES

There is a debate among researchers regarding the preferred method of analysing and presenting information. Some believe that graphs are more effective because tables can be distracting, while others argue that tables are better for comparing data. This study uses tables to efficiently present numerical data in a compact format. The tables allowed for comparison of data values among items with shared variables or related items (Sekaran & Bougie, 2009).

3.6 SCOPE LIMITATION OF THE STUDY

The study is limited to the South African construction industry. The focus is mainly on materials, methods and costs associated to modular construction and traditional construction methods. The study is also limited to the perception of Quantity Surveyors in the South African construction industry.

3.7 THE POPULATION AND SAMPLING TECHNIQUES

3.7.1 POPULATION

The selection of participants is an important process of research, and the population needs to be able to provide accurate, effective, and valuable insight to the research study.

To initiate this study, the initial stage is to determine the population of interest, which is the group of participants on whom we want to make specific assumptions. This research utilizes non-probability sampling, a method that involves a deliberate, non-random selection of participants to allow data collection from a chosen group. (McCombes, 2022).

To ensure that the study's research question is answered accurately, a specific group of professionals in the construction industry were targeted to participate in the survey. The study aims to reach a population that has experience and knowledge relating to

the relevant construction costs involved with modular and traditional construction methods and the professionals chosen for this study are Quantity Surveyors.

3.7.1.1 Population determination

According to an annual report conducted by SACQSP, there are 2045 registered Candidate Quantity Surveyors and 2409 registered Professional Quantity Surveyors in South Africa as of 31 March 2021 (SACQSP, 2021). It is important to note that this number only represents registered Candidate and Professional Quantity Surveyors as of 31 March 2021, where several new registrations or de-registrations could have taken place to date.

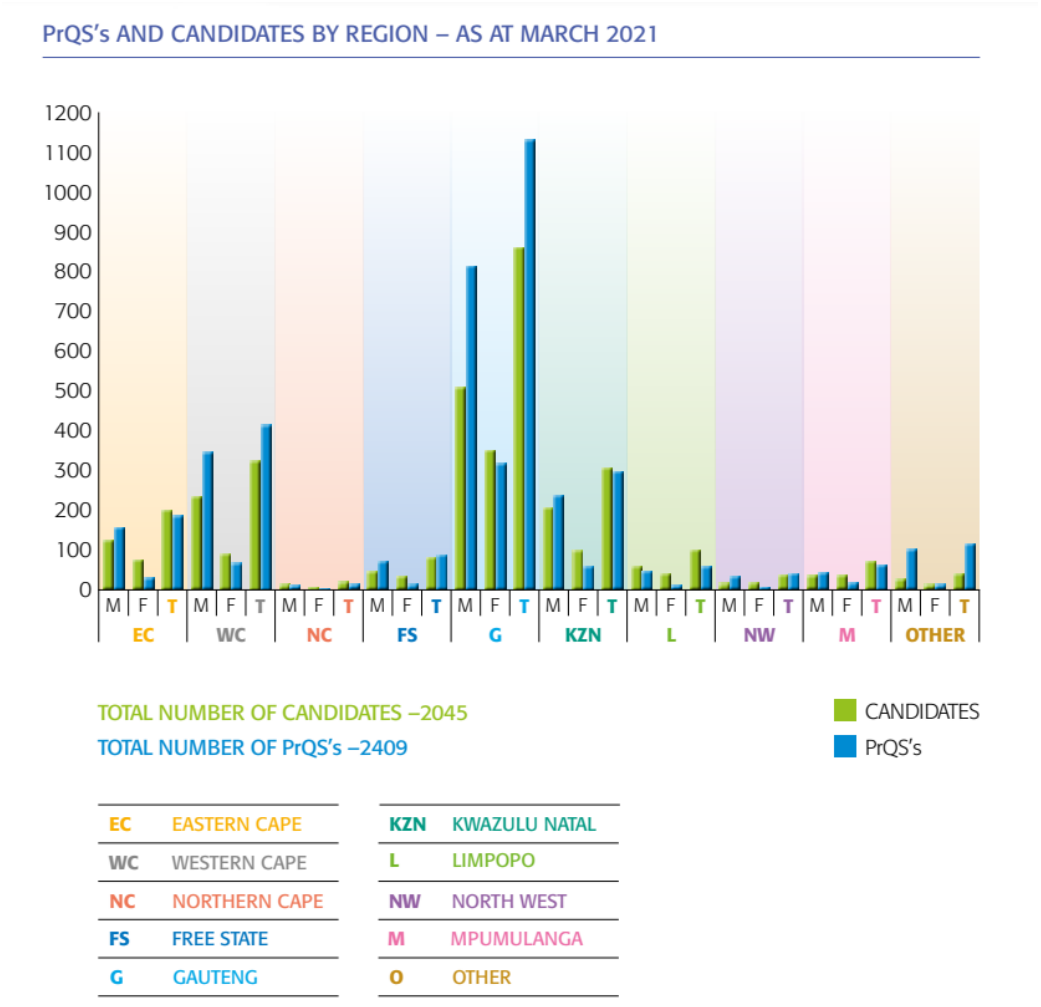

Figure 11: Total Quantity Surveyors in South Africa (SACQSP, 2021).

The total population as of 31 March 2021 is 4 454 registered Quantity Surveyors in South Africa as indicated in Figure 12. Due to the unavailability of the current total

Quantity Surveyors in South Africa in 2023, a linear extrapolation is applied to the available data to predict the possible statistics for 2023.

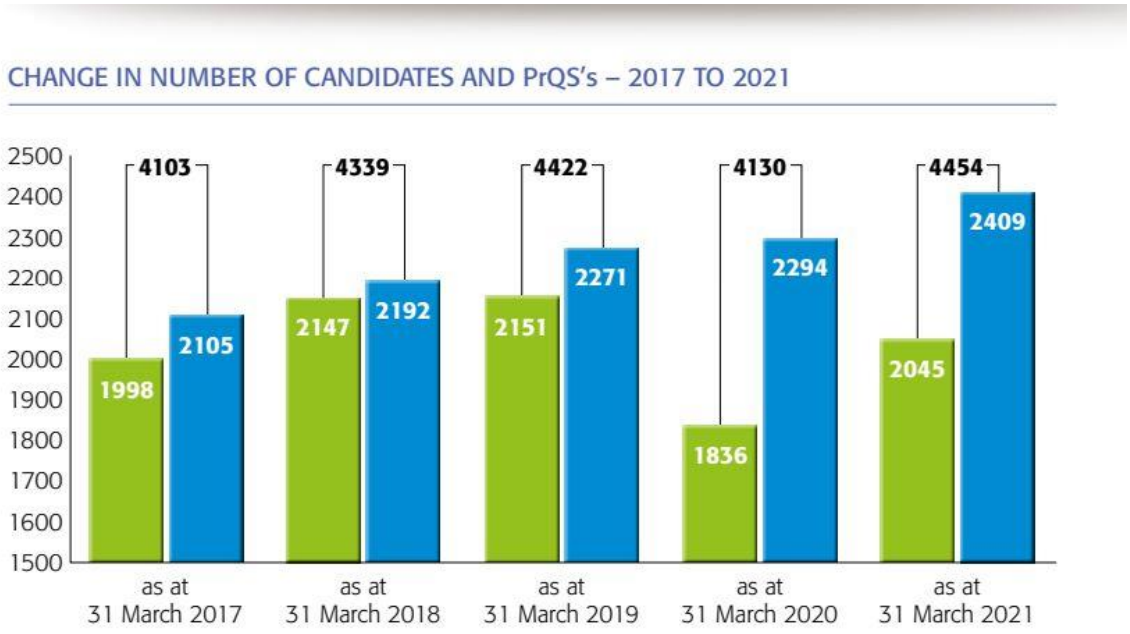

Figure 12: Change in number of Quantity Surveyors from 2017 - 2021 (SACQSP, 2021).

To calculate the growth rate of the abovementioned data, Equation 1 is used.

$$Growth\ rate = 100 \text{ x } \frac{\text{V current} - \text{V previous}}{V\ previous}$$

Equation 1: Growth rate

The results from Equation 1 indicates that the total population of Candidate and Professionally registered Quantity Surveyors is estimated to be 4668 in 2023 as seen in Figure 13. The study will use the prediction of the total population as calculated above as the total for the study.

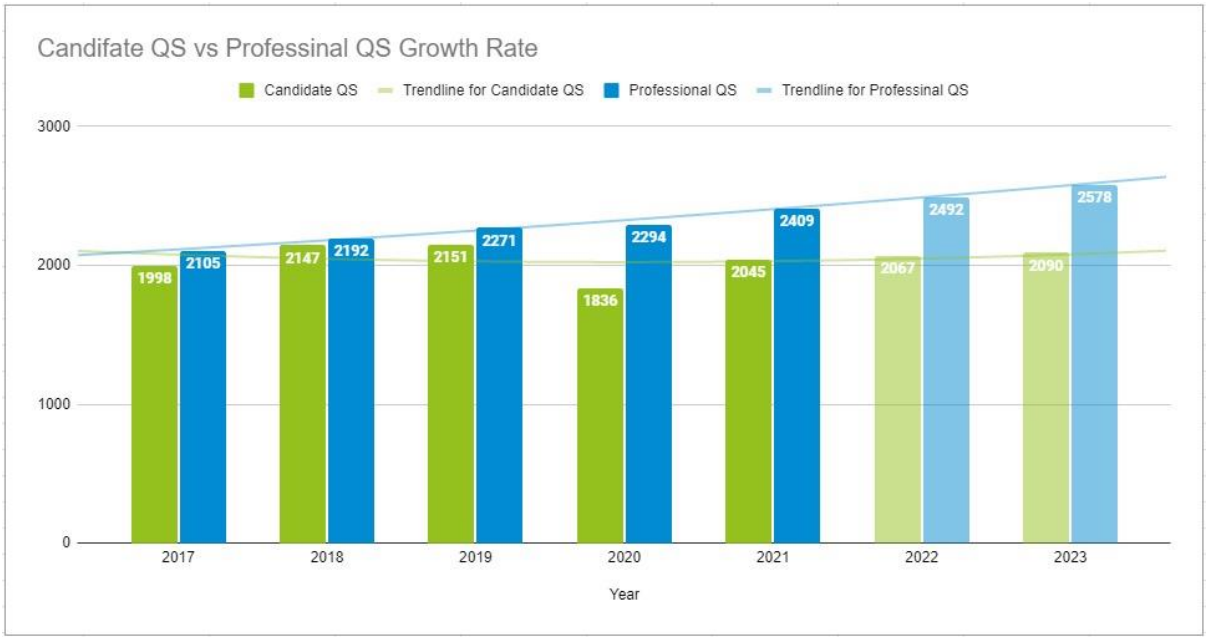

Figure 13: Prediction of total Quantity Surveyors in 2023

3.8 INCLUSION CRITERIA

The inclusion criteria for the study is aimed at construction professionals within the South African construction industry that are currently practicing or working as a Quantity Surveyor.

3.8.1 SAMPLING

3.8.1.1 Sampling method

Homogenous Purposive Sampling

Purposive sampling is a non-probability sampling technique that involves selective, judgmental, or subjective sampling. Researchers exercise their own judgement to choose the participants to be studied. Typically, this method leads to a smaller sample size than probability sampling. (Leard Dissertation, 2015).

According to Leard Disseration (2015), homogenous purposive sampling is based on the similarity or homogeneity with respect to a particular characteristic or criterion of a

group. In this regard, the sample is composed of participants who share similar occupations in the same country (Quantity Surveyors in South Africa). This technique is useful when studying a specific group or subset of the population.

In a journal article written by Sharma (2017), she explains that the advantage of homogeneous purposive sampling is that it can increase the depth of understanding of a particular group. By selecting participants who share a particular characteristic, researchers can gain an in-depth understanding of the experiences and perspectives of that group. Sharma (2017) also mentions the importance of acknowledging that this sampling method may limit the generalizability of findings to the broader population, as the sample is intentionally selected to be homogenous.

3.8.1.2 Sample size for this research study

To calculate the sample size for a study, we will need to consider several factors, including the desired level of accuracy, the margin of error, and the population size. According to an article by Andrade (2020), he states that having a sample size that is too large or too small can result in unscientific, unnecessary, and unethical results, therefore, it's imperative to apply the necessary method towards calculating an accurate sample size.

According to a research article conducted by Couper (2007), they focus on the sample representation related to using web-based surveys. Compared to traditional survey modes, web surveys have several advantages, such as shorter transmitting time, lower delivery costs, more design options, and less data entry time. Despite these benefits, web surveys also face specific challenges, such as the potential loss of participants who lack internet access, and low response rates, which can result in biased results (Couper, 2000; Fricker and Schonlau, 2002; Groves, 1989).

Further to the survey response rates previously discussed, research conducted regarding a meta-analysis of 412 web surveys, found that the average response rate for web surveys was 32.7%, with a median response rate of 34% (Daikeler, et al., 2020).

Manfreda (2008) suggests that in built environment research, a response rate of 30% is considered adequate for the study. This means that if, for example, 100 individuals were invited to participate in the study, a response rate of 30% would mean that 30 individuals completed the questionnaire or survey.

Since the statistic regarding the population is based on an annual report by the South African Council of the Quantity Surveying Profession, the margin of error of 5% is applied due to the statistic only being as of 21 March 2021 and the prediction made in Equation 1 to predict the statistics of the population in 2023 does have a possibility of incorrectness. The confidence level applied to this study is stated at 95%.

Determining the sample size by applying the following Equation 2:

$$Sample\ size = \frac{\{z^2 x\ p(1-p)\}/e\text{^}2}{1 + [\frac{(z^2 x\ p(1-p)\}}{e^2\ N}]}$$

Equation 2: Sample size

Where n is the sample size, Z is the standard score for your desired level of confidence (e.g. 1.96 for a 95% confidence level), p is the proportion of the population that has a certain characteristic (if it's unknown, use 0.5), and E is the margin of error (SurveyMonkey, 1999).

The results from Equation 2 resulted in a sample size of 356 Quantity Surveyors in South Africa. The participants were contacted through an online platform called LinkedIn. This platform allows the researcher to filter a selected group of people to ask their willingness to participate in the survey. The filter consisted of Quantity Surveyors as their job title, and South Africa as their location of work. Figure 13 below illustrates the filtering procedure to obtain applicable participants for the study.

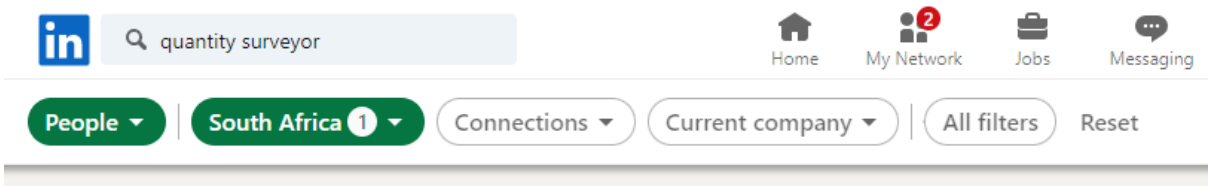

Figure 14: LinkedIn Filtering search for Quantity Surveyors in South Africa

3.9 DATA COLLECTION AND SURVEY ADMINISTRATION

The survey was distributed to 356 Quantity Surveyors between September 2022 and March 2023, using a web survey platform called Google Forms. A total of 91 participants completed the questionnaires at the end of the survey period, resulting in a response rate of 25.56%. While this method had its advantages for the study, it is important to acknowledge that there were also limitations to this method, which should be taken into consideration.

There are benefits of using a web-based survey platform for research, including convenience, where respondents can complete the survey at their own convenience, without the need to be present at a specific location or time. This method is cost-effective and is less expensive than other survey methods, such as mail or telephone surveys. This method allows the study to reach a wider audience, quickly and easily, regardless of their location. The data quality of web-based surveys can include skip patterns, data validation, and other features to improve the quality of the data collected. This method saves time as the data is collected and stored electronically, reducing the time and effort required for data entry and analysis. It provides real-time results, which can help researchers make more informed decisions. This method allows increased response rates in comparison to other methods, as respondents may find them more convenient to complete. Lastly, this method has multi-language support where the support of multiple languages can be adapted, which makes it easy to conduct surveys with non-English speakers (Dillman, et al., 2014).

Even though web-based surveys offer many benefits, there are also some disadvantages that need to be considered. These include non-response bias, technical issues, inaccurate or missing data, limited control over data quality, limited control over survey environment, limited control over participant's attention, and dependency on internet access and technology (Couper, 2000).

3.9.1The questionnaire

The questionnaire consisted of two sections where the first section is a demographics questionnaire, which is aimed at obtaining data of the respondents focusing on personal and professional information. The questions in the first section consisted of province of workplace, participants' profession, number of years' experience within the construction industry, involvement with traditional and modular construction projects and their professional registration. The second section consists of a practical survey to obtain data directly related to the fields of traditional and modular construction with reference to the participants' perception and questions related to construction cost and duration. Refer to Annexure A for the survey.

The research survey makes use of a test format called a dichotomous test. A dichotomous test is a type of measurement that presents participants with only two options to choose from. It is a binary test where the participant must choose one of two options. The most common dichotomous test is called a "Yes/No" test where the participants must choose between two options: "Yes" or "No". Dichotomous tests are often used in research studies and surveys to gather data quickly and easily from many participants.

3.10 DATA ANALYSIS

3.10.1 The Mean Item Score (MIS)

This method is utilised during the data analysis of this research study. This score is a statistical measure used to evaluate the performance of an individual or group on a test or survey. It is calculated by summing the scores on each item (or question) and dividing it by the total number of items. The result is a single score that represents the average performance across all items. The mean item score is often used to evaluate test or survey results because it provides a simple and clear summary of the overall performance (Ebel, 1951). This method was introduced due to the researcher needing to obtain mean scores of specific questions.

3.10.2 Z-Test

The One Sample Proportion Test is a statistical test that is commonly used to estimate the proportion of a population based on a sample. This test is often used in research studies to evaluate whether a proportion in a sample is significantly different from a known or hypothesized proportion. The One Sample Proportion Test is an important tool for researchers who are interested in making inferences about a population based on a sample (Sokal & Rohlf, 2013).

$$Z = (\frac{(\dot{X} - \mu 0)}{s})$$

Equation 3: Z-test formula

The formula represented in Equation 3 above consist of "Ẋ" being the sample average, "μ0" representing the mean and "s" representing the standard deviation. By conducting a one sample proportions test, the researcher states the null hypothesis and alternative hypothesis, states the alpha to illustrate the determination of the significance level, and thereafter, calculates the statistical test. After the previous steps have been conducted, the critical value needs to be determined from the critical value table. Thereafter, the rejection criteria is defined, and results are interpreted (Sokal & Rohlf, 2013).

3.10.3 Validity

According to Creswell (2005), validity refers to the degree to which a research study accurately measures what it aims to measure. Cohen (2007) states that there are several ways to determine the validity of a research study, which includes content validity, criterion-related validity, construct validity, convergent and discriminant validity, internal validity, and external validity. Validity is a complex concept and requires multiple lines of evidence, it's an ongoing process that should be conducted throughout the research project.

The study makes us of peer review as a measure of validity (Creswell, 2014). The questionnaire underwent a thorough review process with the guidance of the

supervisor to ensure its structure, clarity, and alignment with the intended measures of the study. This review process involved checking for any ambiguity and evaluating the correlation between the questionnaire and the intended measures. As a result of this process, the questionnaire was deemed to be valid and effectively captures the intended research objectives.

3.10.4 Reliability

Cronbach's alpha is a measure of internal consistency reliability, often used in quantitative research. It assesses the extent to which a set of items or measures in a questionnaire are related to each other, and therefore, provide a reliable measure of the construct being studied.

According to Creswell *(2014)*, the Cronbach's alpha is calculated by measuring the correlation between each item and the total score of the scale or measure. The alpha coefficient ranges from 0 to 1, with higher values indicating greater internal consistency reliability. The Cronbach's alpha coefficient of 0.7 or higher is generally considered acceptable for research purposes.

$$a = \frac{k}{k-1}\left(1 - \frac{\sum v^i}{Vt}\right)$$

Equation 4: Cronbach's Alpha

3.11 ETHICAL CONSIDERATION

When conducting research, it is crucial to consider ethical considerations as the study may have implications for both the participants and the researcher. There are four criteria for ethical conduct in research: teleology, which emphasizes the researcher's moral obligation to treat participants fairly; deontology, which stresses the importance of reciprocal benefits for participants and the wider community; morality, which is

based on the researcher's personal values and the need to report findings honestly; and fairness, which requires the researcher to respect the rights of all participants (Kivunja & Kuyini, 2017).

To ensure that this study is compliant with the ethical standards outlined above, ethics clearance was obtained from the University of Cape Town's Department of Construction Economics and Management (see Annexure C). A detailed cover letter (see Annexure B) was also provided to the participants, outlining the objectives of the study, and informing them of their rights and participation in the research.

Participants are informed that they have the right to withdraw from the survey at any time without any negative consequences. Their personal information will be kept confidential and will not be associated with their responses in any way. The responses will only be analysed in combined format. The research requests sensitive information that could potentially cause harm to the participants if leaked. To ensure the confidentiality and anonymity of their responses, a consent form is provided, which explains these guarantees in detail and must be agreed to before completing the survey. The potential harm that could result from the findings of the study is taken into consideration, and measures are taken to prevent the identification of participants. This includes not including any names, affiliation, or personal information of the respondents in the data reported, and properly citing and referencing the work of other scholars in accordance with the university's policy.

3.12 CONCLUSION

In conclusion, this chapter has outlined the research methodology, ethical considerations, study instruments, and limitations of the study for a quantitative descriptive research project. The research design adopted for this study was quantitative descriptive research, which is suitable for describing the characteristics of a population and identifying patterns in the data. The sampling technique used in this study was the simple random sampling technique, which ensured that the sample was representative of the population under study.

The study instruments used in this research were surveys which were chosen for their ability to accurately measure the variables of interest. Ethical considerations were also considered throughout the research process to ensure that the rights and well-being of the participants were protected.

The data collected in this study was analysed using mean item score and binary logistic regression which allowed for a thorough examination of the relationships between the variables of interest.

Overall, this chapter has provided a comprehensive overview of the research methodology, ethical considerations, study instruments, and limitations of the study for this quantitative descriptive research project. The chosen methodology, sampling technique, and data analysis techniques have ensured that the data collected is valid and reliable, and the results of this research can be used to provide valuable insights into the topic under study.

CHAPTER 4: EMPERICAL STUDY AND FINDINGS

4.1 INTRODUCTION

This chapter expands on the findings obtained throughout the research study, which includes the analysed results that were obtained from the collected data and the discussion of the findings.

Structured online questionnaires were created and distributed to all participants. The questionnaires focused on testing the knowledge, perception and understanding of modular construction and traditional construction methods with regards to costs, processes, and the duration of construction of the two varying methods.

4.2 QUESTIONNAIRE DISTRIBUTION

For this study, all participants were directly contacted where permission was asked regarding if they were willing to participate in the research study, those who participated did so at their own will. The consent forms were distributed via online platform. All the participants were made aware of all limitations, considerations, and purpose of the research before they were invited to participate in the survey. After consent was received, the survey was distributed via a link where all participants could complete the survey on an online form. After the form was submitted by the participant, the researcher was allowed access to the participants' completed survey. The sample of the questionnaire and consent form is attached as Annexure A and Annexure B.

4.3 DATA PRESENTATION AND DISCUSSION OF RESEARCH RESULTS

4.3.1 The sample results

A total of 356 questionnaires were distributed to the participants, where 91 surveys were returned and completed. Out of the 91 surveys that were returned, 91 were completed in full and was considered useable for this study. The return of the 91

surveys represented a 25.56% response rate out of the 356 questionnaires that were sent out.

4.3.2 Demographics

The participants chosen for this study are construction professionals within the South African construction industry. The participants all have a similar job title, however, varying years of experience and place of work. Below are the analyses of the demographic results from the study.

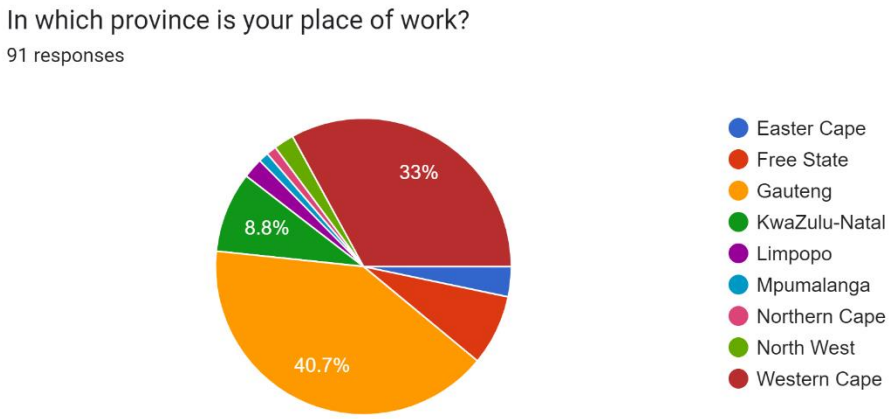

Figure 15: Location of workplace

A total of 91 responses resulted in 40.7% of participants working in Gauteng, 33% working in the Western Cape, 8.8% working in KwaZulu Natal, 7.7% of participants working in the Free State, 3.3% working in the Eastern Cape, 2.2% working in North West and Limpopo respectively, and 1.1% working in the Northern Cape and Mpumalanga respectively.

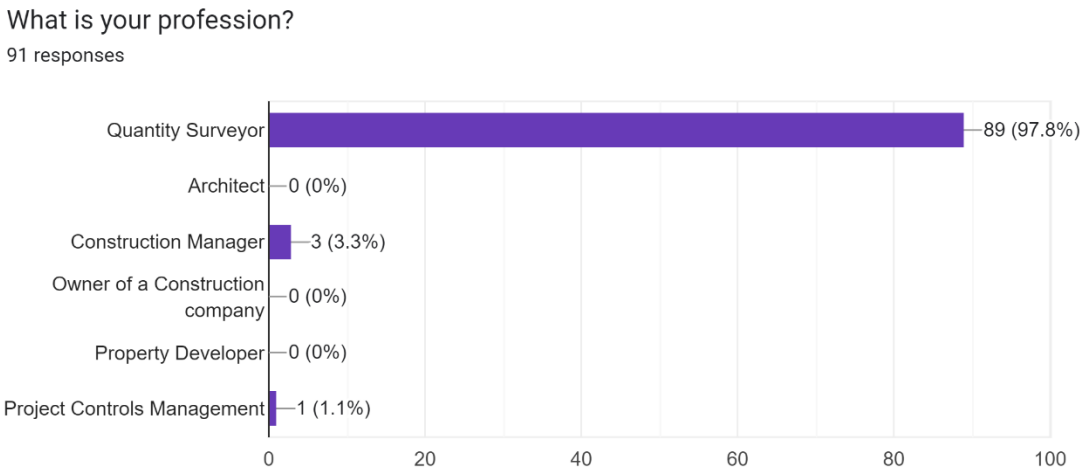

Figure 16: Profession of participants

As seen in Figure 17 above, the respondents' professions consist of 97.8% being Quantity Surveyors as their current job title and 2.2% being Construction and Project control Managers with a Quantity Surveying degree.

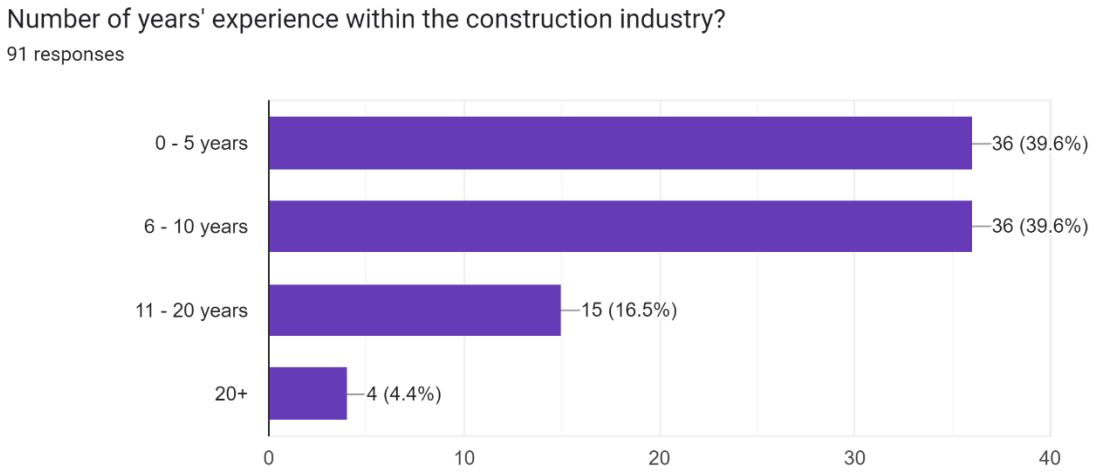

Figure 17: Years of experience within construction industry

The participants' years of experience resulted in 39.6% having between 6 – 10 years and 0-5 years of experience respectively, 16.5% having between 11 – 20 years of experience, and 4.4% having 20 or more years of experience as stipulated in Figure 18 above.

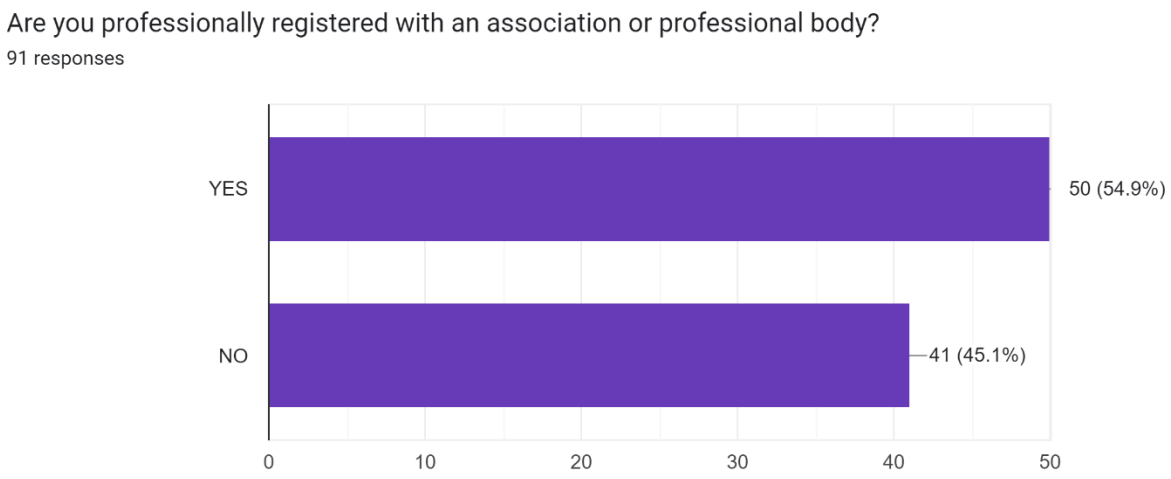

Figure 18: Professional registration status of participants

The results show that 54.9% of the participants are professionally registered with an association of professional body as seen in Figure 19.

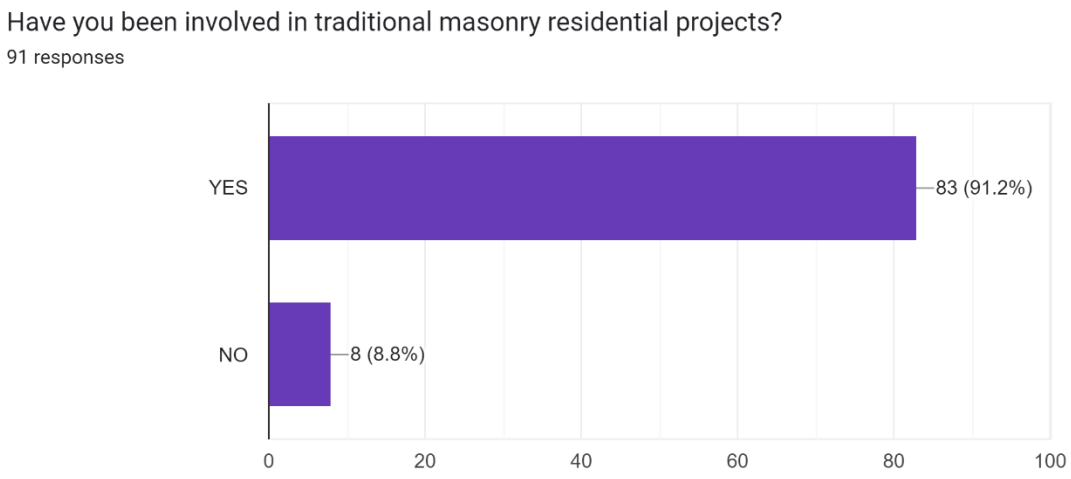

Figure 19: Participants involvement with traditional masonry projects

The results in Figure 20 show that 91.2% of the participants have been involved with traditional construction projects.

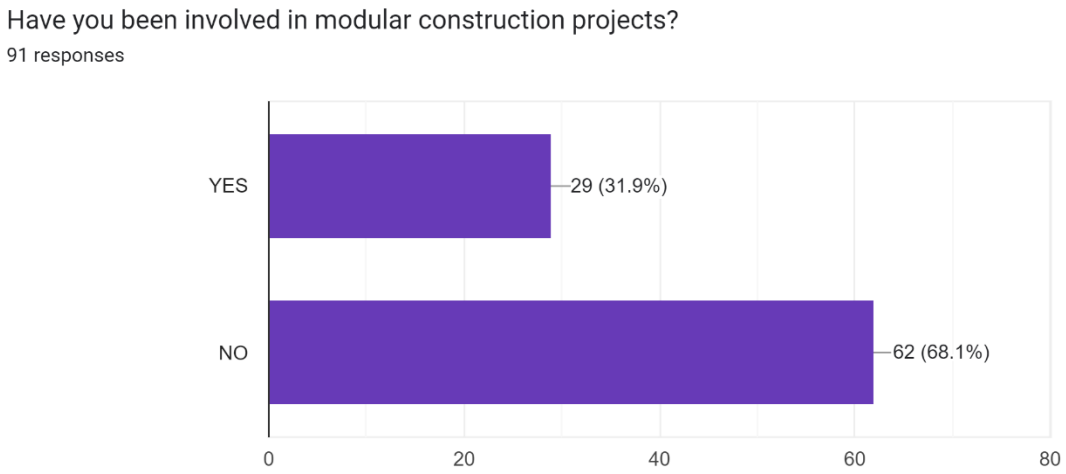

Figure 20: Participants involvement with modular construction projects

The results in Figure 21 state that only 31.9% of the participants have been involved with modular construction projects, and 68.1% of participants have not been involved in modular construction projects.

The following discussions will involve the deeper analysis of the data results obtained from the surveys relating to the research study.

4.4 DATA ANALYSIS

The analysis of the data relating the research study is discussed in this chapter. The questions that were formulated to gather data was designed to gain understanding and evidence for this study. The data that was collected was obtained to find correlations and mutuality between the existing literature and findings from the results. The following tables below will be discussed thoroughly. A total of 91 usable responses were obtained from the survey. The responses are tabled according to their relevance and correlation and is discussed accordingly.

4.4.1 Practical Question 1

The first set of data involved obtaining the understanding and perception of different statements by directly weighing the modular construction method against traditional construction method by using a series of 7 different questions. These questions allow the researcher to obtain results on which construction method is most applicable to the statement questions.

Each question will be discussed in more detail below:

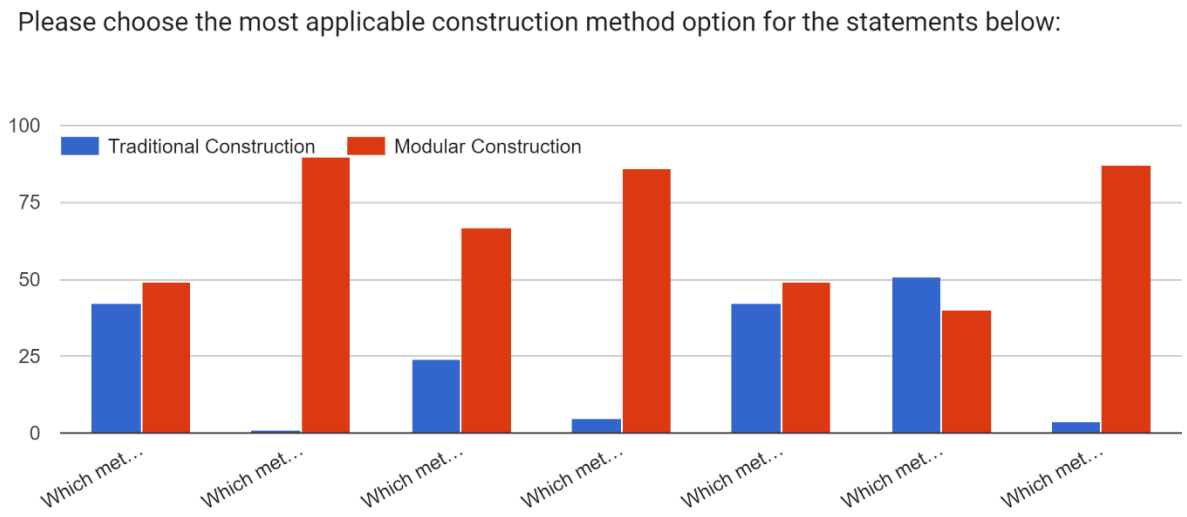

Figure 21: Most applicable construction method

Question 1: Which method of construction do you perceive to be the more affordable construction method?

This question focusses on the direct perception of construction professionals regarding which construction method they perceive as being the more affordable method. The results show that 49 out of the 91 respondents (53.84%) reacted by stating that they perceive modular construction to be the more affordable method compared to traditional construction. This indicated that majority of the respondents perceive that modular construction is the more affordable method.

Question 2: Which method of construction do you perceive takes less time to complete?

This question focusses on the direct perception of construction professionals regarding which construction method they perceive takes less time to complete. The response obtained from the participants resulted in 90 out of 91 participants (98.9%) perceiving that the modular construction method takes less time to complete. Majority of the respondents were in favour of the statement, and it indicates a clear perception that the modular construction method takes less time to complete than the traditional construction method.

Question 3: Which method of construction do you perceive would have the lowest chance of accidents to occur?

This question focusses on the direct perception of construction professionals regarding which construction method they perceive to have the least number of accidents during construction. The results show that 67 out of the 91 participants (73.62%) perceive modular construction to have the lowest chance of accidents occurring during construction. Most participants reacted in favour of modular construction as the safer method.

Question 4: Which method of construction do you perceive will require the least number of people/labourers to construct?

This question focusses on the direct perception of construction professionals regarding which construction method they perceive to require the least number of people/labourers to construct. The results show that 86 participants (94.5%) perceive that the modular construction method will require the least number of people/labourers. The majority of participants agreed that modular construction requires less labour.

Question 5: Which method do you perceive will be of better quality?

This question focusses on the perception of the two varying construction methods with regards to the quality of the build. The results show that 46.15% of participants agree that traditional construction methods provide better quality, where 53.84% of participants perceive that the modular construction method will be of better quality.

Question 6: Which method do you perceive will use the least amount of machinery?

This question focusses on the perception of the two varying construction methods with regards to amount of machinery used during construction. The results show that 56% of participants perceive that traditional construction methods use less machinery, whilst 43.95% agree that modular construction methods use less machinery during construction. Most of the participants perceive that traditional construction use less machinery.

Question 7: Which method of construction produces the lowest amount of waste?

This question focusses on the perception of the two varying construction methods with regards to amount of waste produced during construction. The results show that 95.6% of participants perceive that modular construction produces the lowest amount of waste, in comparison to the 4.39% who agree that traditional construction produces the lowest amount of waste.

The results above will be used to test the hypothesis of the study and will be discussed in the following chapter.

4.4.2 Practical Question 2

The second practical question focused on obtaining data relating to the cost per m2 and duration of construction of the traditional construction method. The questions and results will be discussed in more depth below.

Question 8.1 dealt with the cost per m2 and duration of construction for traditional construction methods. The questions were broken up into 6 stages to obtain the mean cost per square meter and the mean duration of each stage.

Results in Figure 23 represent the cost per square meter for each stage of construction for traditional construction methods.

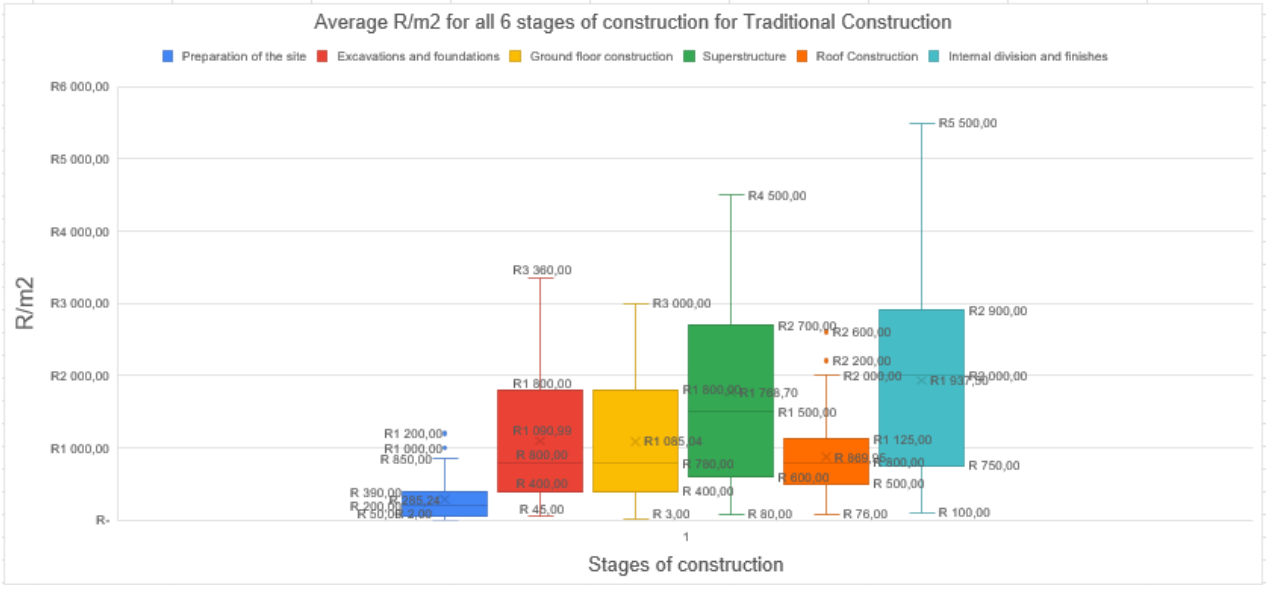

Figure 22: Cost per m2 for the different stages of construction for traditional construction method

The outliers were removed to allow the results to formulate an accurate representation of the data. The boxplots in Figure 23 above consist of 6 categories which starts from preparation of the site, excavations, and foundations, ground floor construction, superstructure, roof construction and internal division. The mean for each category within traditional construction methods resulted in the following: preparing the site costs R 285.24/m2, excavation and foundations cost R 1 090.99/m2, ground floor

construction costs R 1 085.04/m2, superstructure construction costs R 1 768.70/m2, roof construction costs R 869.95/m2, and internal division costs R 1 937.50/m2.

Results in Figure 24 represent the average duration of construction for each stage of construction for traditional construction methods.

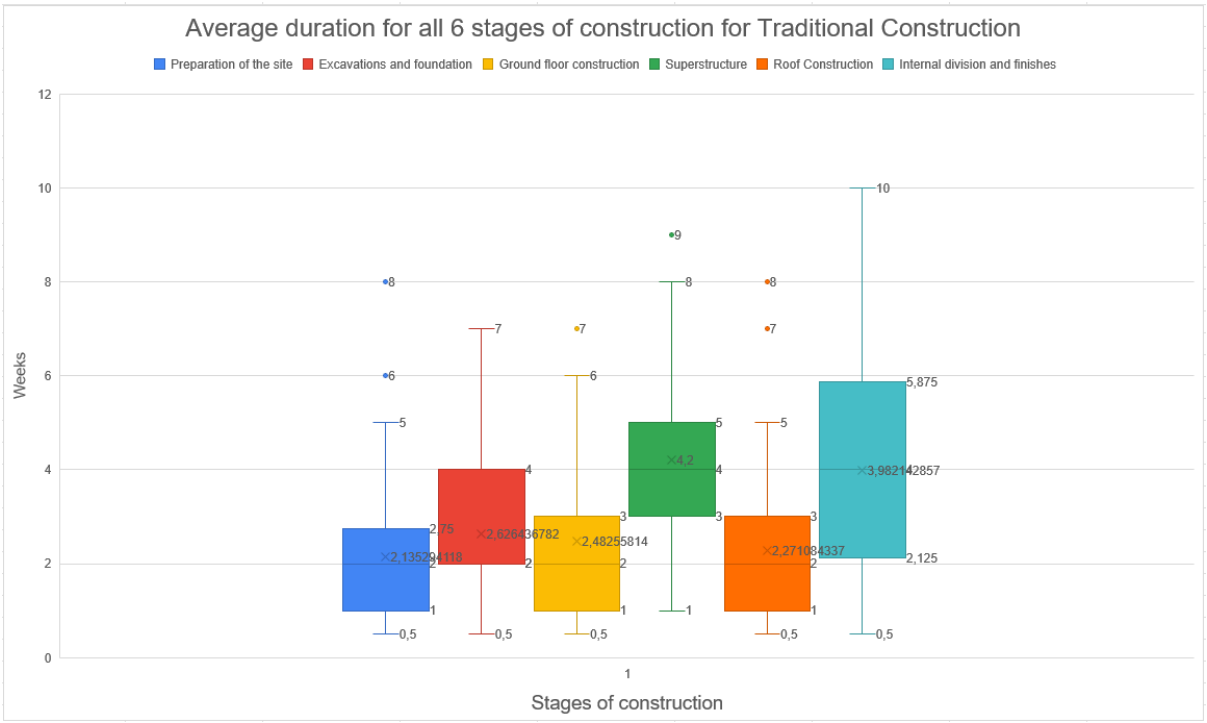

Figure 23: Average duration in weeks for the different stages of construction for traditional construction method

The outliers were removed to allow the results to formulate an accurate representation of the data. The boxplots in Figure 24 above consist of 6 categories which start from preparation of the site, excavations and foundations, ground floor construction, superstructure, roof construction and internal division. The mean for each category within traditional construction methods resulted in the following: preparing the site takes 2.14 weeks, excavation and foundations take 2.63 weeks, ground floor construction takes 2.48 weeks, superstructure construction takes 4.2 weeks, roof construction takes 2.27 weeks, and internal division takes 3.98 weeks.

4.4.3 Practical Question 3

The third practical question focused on obtaining data relating to the cost per m2 and duration of construction of modular construction methods. The questions and results will be discussed in more depth below.

Question 9.1 dealt with the cost per m2 and duration of construction for modular construction methods. The questions were broken up into 6 stages to obtain the mean cost per square meter and the mean duration of each stage.

Results in Figure 25 represent the cost per square meter for each stage of construction for modular construction methods.

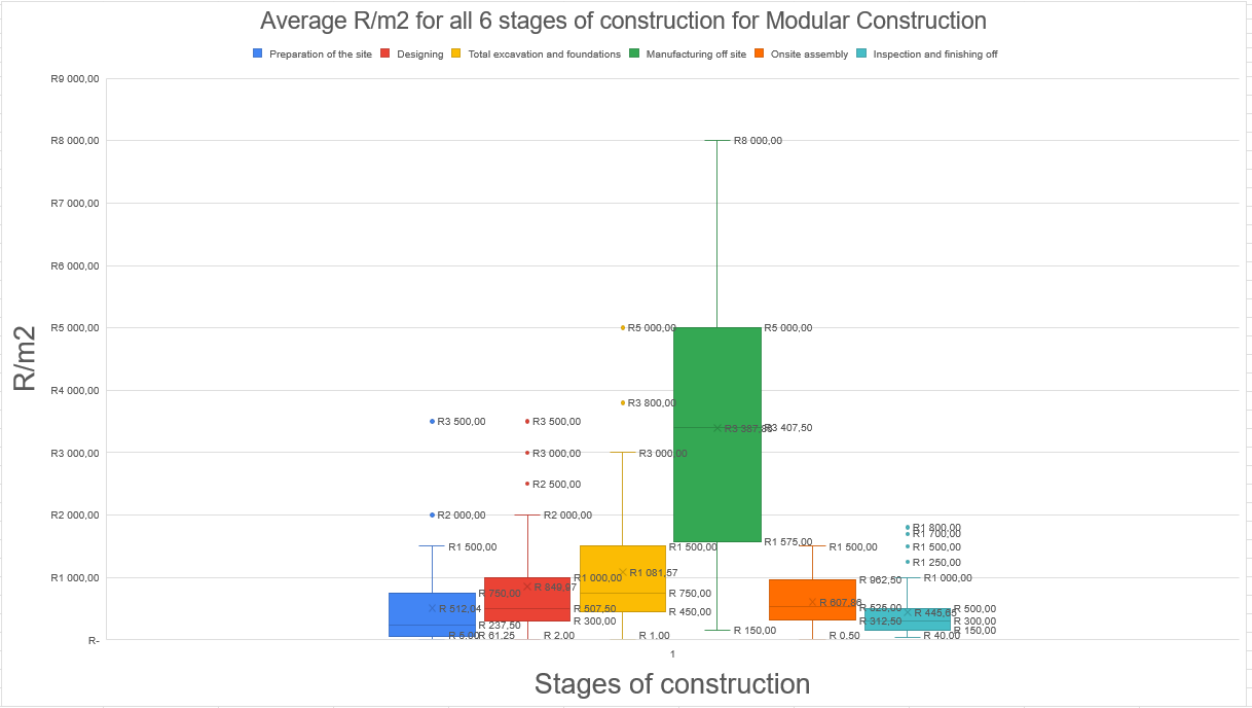

Figure 24: Cost per m2 for the different stages of construction for modular construction method

The major outliers were removed to allow the results to formulate an accurate representation of the data. The boxplots in Figure 25 above consist of 6 categories which start from preparation of the site, designing, excavations and foundations, manufacturing off-site, on-site assembly and inspection and sign off. The mean for each category within modular construction method resulted in the following: preparing

the site costs R 512.04/m2, designing costs R 849.97/m2, excavation and foundations cost R 1 081.57/m2, off-site manufacturing costs R 3 387.86/m2, on-site assembly costs R 607.86/m2, and inspection and sign off cost R 445.65/m2.

Results in Figure 26 represent the duration for each stage of construction for modular construction methods.

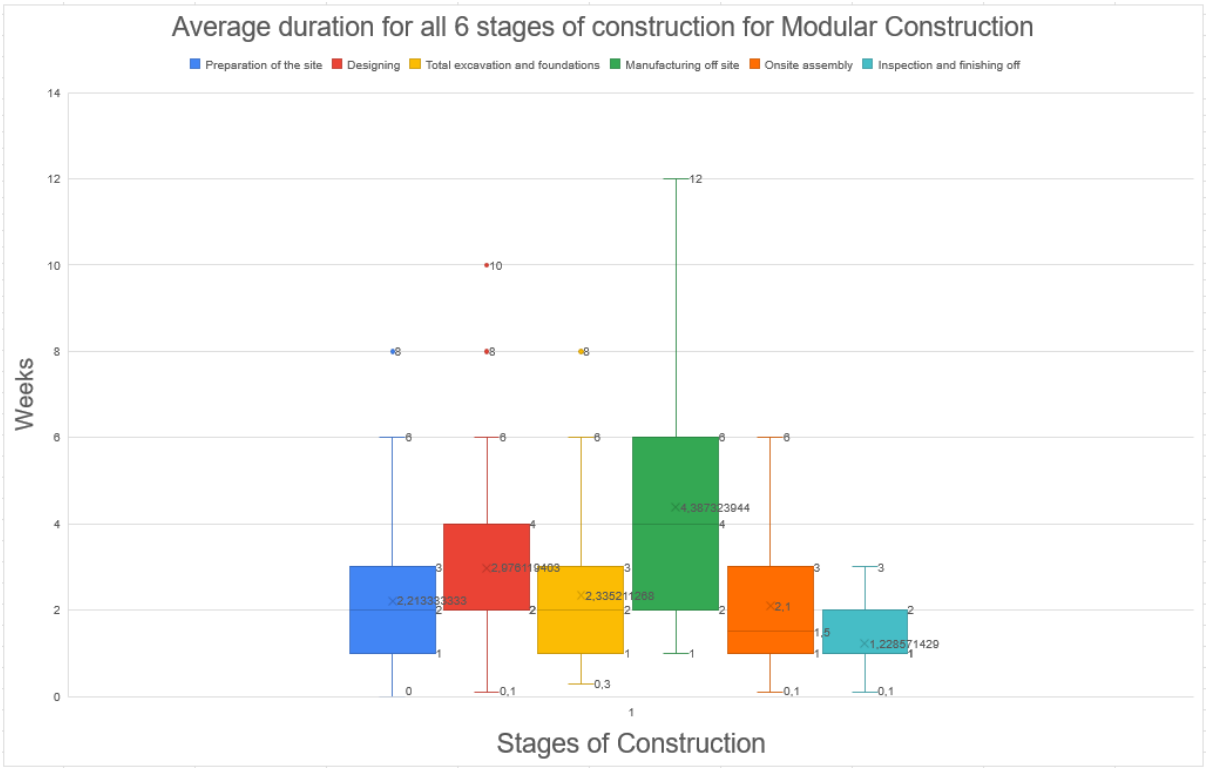

Figure 25: Average duration in weeks for the different stages of construction for modular construction method

The outliers were removed to allow the results to formulate an accurate representation of the data. The boxplots in Figure 26 above consist of 6 categories which start from preparation of the site, designing, excavations and foundations, manufacturing off-site, on-site assembly and inspection and sign off. The mean for each category within modular construction method resulted in the following: preparing the site takes 2.21 weeks, designing takes 2.98 weeks, excavation and foundations take 2.34 weeks, off-site manufacturing takes 4.39 weeks, on-site assembly takes 2.1 weeks, and inspection and sign off takes 1.23 weeks.

Table 1 presents the comparison of the results found in Practical Question 2 and 3 where the cost per m2 is compared between traditional construction and modular construction projects. Based on the data collected, the average cost per m2 of traditional construction methods is R 7 037.42 per m2 and R 6 884.95 per m2 for modular construction methods.

	AVERAGE COST PER M2 (R/m2)										
CONSTRUCTION METHOD:	**Site preparation:**	**Excavations**	**Ground floor construction:**	**Superstructure construction:**	**Roof construction:**	**Internal division and finishes:**	**Designing:**	**Manufacturing off site:**	**On-site**	**Inspection and finishes:**	**TOTAL COST PER M2:**
Traditional Construction	R 285.24	R 1 090.99	R 1 085.04	R 1 768.70	R 869.95	R 1 937.50					**R 7 037.42**
Modular Construction	R 512.04	R 1 081.57					R 849.97	R 3 387.86	R 607.86	R 445.65	**R 6 884.95**
	AVERAGE PROJECT DURATION (in weeks)										
CONSTRUCTION METHOD:	**Site preparation:**	**Excavations and**	**Ground floor construction:**	**Superstructure construction:**	**Roof construction:**	**Internal division and finishes:**	**Designing:**	**Manufacturing off site:**	**On-site**	**Inspection and finishes:**	**TOTAL DURATION (in weeks):**
Traditional Construction	2.14	2.63	2.48	4.2	2.27	3.98					**17.70 weeks**
Modular Construction	2.21	2.34					2.98	4.39	2.1	1.23	**15.25 weeks**

Table 1: Overall cost and duration of traditional and modular construction

4.4.4 Practical Question 4

The fourth set of data involved obtaining the understanding and perception of different statements by directly weighing the modular construction method against the traditional construction method by using a series of 8 stages during construction. These questions allow the researcher to obtain results in which construction method is perceived to have the highest cost at a particular stage within the construction processes.

Each question will be discussed in more detail below:

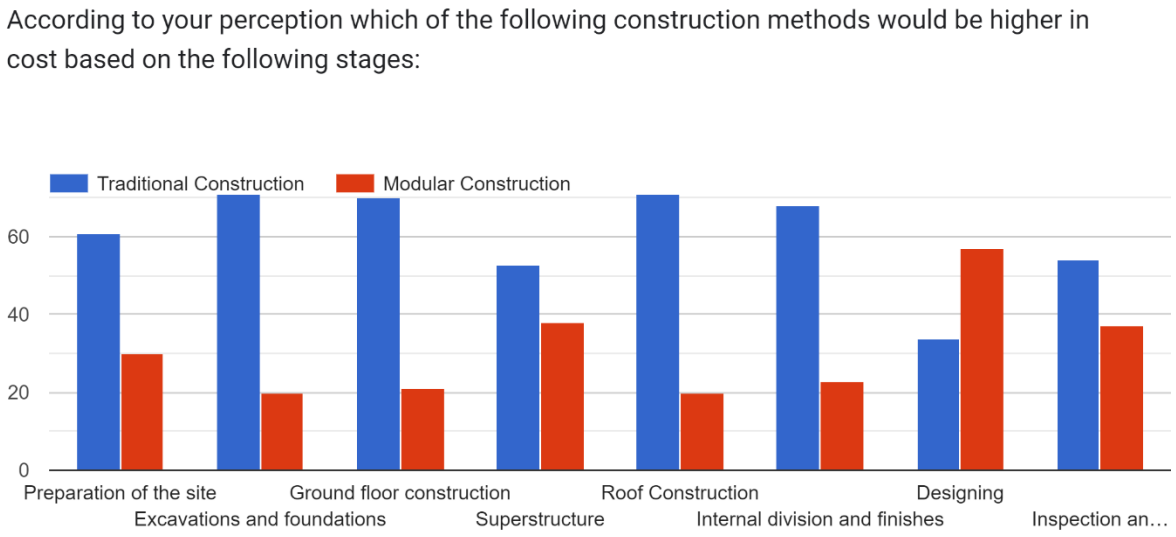

Figure 26: Perception of cost based on construction stages.

10.1 Stage 1: Preparation of site.

This question focusses on the direct perception of construction professionals regarding which construction method they perceive as being higher in cost during the preparation of the site. The results show that 61 out of the 91 respondents (67.03%) reacted by stating that they perceive traditional construction to be higher in cost during this stage.

10.2 Stage 2: Excavations and foundations

This question focusses on the direct perception of construction professionals regarding which construction method they perceive as being higher in cost during excavations and foundation construction. The results show that 71 out of the 91 respondents (78.02%) reacted by stating that they perceive traditional construction to be higher in cost during this stage.

10.3 Stage 3: Ground floor construction

This question focusses on the direct perception of construction professionals regarding which construction method they perceive as being higher in cost during ground floor construction. The results show that 70 out of 91 respondents (76.92%) reacted by stating that they perceive traditional construction to be higher in cost.

10.3 Stage 4: Superstructure

This question focusses on the direct perception of construction professionals regarding which construction method they perceive as being higher in cost during superstructure construction. The results show that 53 out of the 91 respondents (58.24%) reacted by stating that they perceive traditional construction to be higher in cost.

10.5 Stage 5: Roof construction

This question focusses on the direct perception of construction professionals regarding which construction method they perceive as being higher in cost during roof construction. The results show that 71 out of the 91 respondents (78.02%) reacted by stating that they perceive traditional construction to be higher in cost.

10.6 Stage 6: Internal division and finishes

This question focusses on the direct perception of construction professionals regarding which construction method they perceive as being higher in cost during internal division construction and finishes. The results show that 68 out of the 91 respondents (74.73%) reacted by stating that they perceive traditional construction to be higher in cost.

10.7 Stage 7: Designing

This question focusses on the direct perception of construction professionals regarding which construction method they perceive as being higher in cost during the

designing of the project. The results show that 57 out of the 91 respondents (62.64%) reacted by stating that they perceive modular construction to be higher in cost.

10.8 Stage 8: Inspection and signing off.

This question focusses on the direct perception of construction professionals regarding which construction method they perceive as being higher in cost during the inspection and signing off the project. The results show that 54 out of the 91 respondents (59.34%) reacted by stating that they perceive traditional construction to be higher in cost.

4.5 RESEARCH FINIDINGS

Finding 1 – The modular construction method is perceived to be the more affordable construction method in comparison to the traditional construction method.

Based on the results of the survey conducted in Practical Question 1; Question 1, the following finding was evident: Majority of the respondents (53.85%) perceive that modular construction is the more affordable construction method. This indicates that the majority of construction professionals perceive that there is a more affordable method of construction, however, majority of construction projects in South Africa are following the traditional construction method when building residential projects.

The results obtained in Practical Question 2 and 3 based on the average rate per m2 cost of constructing traditional (R 7037.42/m2) and modular projects (R 6884.95/m2) show that it is more expensive to construct a traditional project, thus indicating that the modular construction method is perceived to be the more affordable method.

The findings in Practical Question 4; Question 10, states that construction professionals perceive that traditional construction methods are higher in cost based on 7 out of the 8 stages in construction. Thus, indicating that modular construction is the more affordable method across the majority of construction stages.

Finding 2 – Modular construction projects are perceived to takes less time to complete in comparison to traditional construction projects.

Based on the results found in Practical Question 1; Question 2, the following finding was evident: 98.9% of the respondents perceived that modular construction takes less time to construct in comparison to traditional construction projects. This indicates that the time spent on modular construction is far less than that of a traditional construction method.

By comparing the literature found in the study, we find a direct correlation between the perception of the participants and the statement made by Cartwright, explaining that modular construction takes up far less time than the standard or traditional method of construction, that is why we experience a reduction in costs (Cartwright, 2011).

The results found in Practical Question 2 and 3 based on the duration of construction of modular and traditional construction projects, we see that construction professionals estimated an average 17.70 weeks of construction towards traditional construction projects and 15.25 weeks of construction towards modular construction projects. This finding clearly distinguishes the time differences between the two methods, where modular construction does take less time to complete.

Finding 3 – The main factors that create cost variances between modular construction and tradition construction are the cost and duration of different stages during construction.

Based on the findings in Practical Question 4; Question 10, it was found that construction professionals perceive that traditional construction methods are higher in cost due to several factors. These factors include the time and costs associated with the traditional method when preparing the site, excavations and foundations, ground floor construction, superstructure construction, roof construction, internal division and finishes, inspection and signing off the projects. The only finding where modular construction was being perceived as higher in cost in comparison to traditional construction methods was based on the time and costs of designing the projects.

Finding 4 – More construction professionals have been involved with traditional construction methods than modular construction methods.

The results found in Figure 20 and 21 indicates that 91.2% of the participants have been involved in traditional construction and only 31.9% have been involved with modular construction methods. This finding indicates that the majority of the participants have been involved in the processes, costing and construction of traditional methods and have yet to be part of modular construction projects.

The findings within this study clearly show that the majority of construction professionals perceive modular construction to be more affordable and take less time to construct, however, the minority of the participants have been involved with the abovementioned method.

Finding 5 – Construction professionals perceive that traditional construction is of lower quality in comparison to modular construction projects.

The finding in Figure 22 shows that 53.84% of construction professionals perceive that modular construction is of higher quality in comparison to traditional construction.

Finding 6 – Modular construction produces lower amounts of waste in comparison to traditional methods of construction.

The findings in Figure 22 show that 95.6% of participants agree that modular construction produces less waste than traditional construction methods. This is yet another advantage of the implementation of modular construction.

Traditional building methods generate a lot of waste, which has always been a burden for construction professionals. The waste of modular construction is easy to dispose of, and the products are easy to reuse and recycle. When their lifecycle is complete, the components may be removed, and they do not cause any dust, greenhouse emissions, or noise on site (Kawecki, 2010)

Professionals within the industry are aware of the advantages that modular construction holds with regards to waste, the implementation of these methods is, however, not being visualised.

Finding 7 – Modular construction is the safer method of construction in comparison to traditional construction methods.

The findings in Figure 22 show that 73.62% of construction professionals perceive that modular construction is the safer method to construct a building in comparison to traditional construction methods.

Working on-site often involves activities that can be dangerous to workers. This has led to many fatalities and non-fatal injuries. Researchers are looking for ways to make it safer. Studies have shown that modularization decreases the number of safety problems for laborers. When modular construction is used, the rate of accidents goes down by 80%. This is a good way to have less injuries on the job site (Penaloza, et al., 2017).

Finding 8 – Modular construction uses less labour during construction in comparison to traditional construction methods.

The results from the participants in Figure 22 state that 94.5% of construction professionals perceive that modular construction uses less labour than during traditional construction.

Modular construction methods can have several advantages, such as better quality, less labour, lower costs, and shorter construction times (Ferdous , et al., 2019).

4.6 HYPOTHESIS TESTING

4.6.1 Z-test

4.6.1.1. The perception among Quantity Surveyors in South Africa is that modular construction is a more cost-effective method compared to traditional construction methods.

NULL Hypothesis	ALTERNATIVE Hypothesis
Quantity Surveyors in South Africa do not perceive any difference in cost between modular and traditional construction methods.	Quantity Surveyors in South Africa perceive modular or traditional construction methods to be higher in cost.

Table 2: Null Hypothesis and Alternative Hypothesis

Research Question:	Test:	Decision
According to your perception, will traditional construction methods or modular construction methods be higher in cost based on the following 8 stages involved in construction?	Z-TEST	**REJECT NULL HYPOTHESIS**

Table 3: Z-test result

In table 3 above, a Z-test was conducted to establish whether we reject or accept the Null Hypothesis. Since the p-value in our calculation (6.04e-06) is much smaller than the significance level (0.05), we reject the null hypothesis and conclude that there is sufficient evidence to support the claim that Quantity Surveyors perceive a difference in cost between modular and traditional construction methods. Specifically, the data suggests that Quantity Surveyors perceive traditional construction to be higher in cost than modular construction.

4.6.2 Reliability testing

The researcher makes use of the Cronbach's Alpha to test consistency and reliability of the survey instrument. In this study, there were nine different questions which all tested the participants' answers on whether their answers were reliable and consistent throughout the study. In the questions marked Question 1 to Question 7 as seen in Figure 22, the questions all tested whether the participants perceived if modular construction or traditional construction was perceived as the most affordable method of construction and the results indicated a Cronbach's alpha value of 6.4.

Pallant (2001) notes that a Cronbach's alpha value above 0.6 is considered to indicate good reliability and is an acceptable index of reliability. It is suggested that a Cronbach's alpha value of 0.7 or higher is ideal for most research purposes, but values above 0.6 are still acceptable, particularly for scales or tests that are shorter or have fewer items.

Therefore, the researcher deems the study instrument to be acceptable with a 0.64 Cronbach's Alpha.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter will discuss the empirical study of Chapter 4 and the literature obtained in Chapters 2 to evaluate the objectives of this study. Furthermore, this chapter will consist of the recommendations for future studies or future gaps within research and end off with a conclusion.

5.2 SUMMARY OF FINDINGS

5.2.1 Objective 1: To determine the cost difference between modular construction methods and traditional construction methods.

After analysing the results in chapter 4, the researcher was able to directly establish the costs involved during the stages of modular construction. The results indicated the following costs involved with modular construction includes designing, site preparation, foundations and excavations, manufacturing off-site, on-site assembly and construction, inspection and finishing (Bertram, et al., 2019). The research found in chapter 2 includes the information pertaining to the methodology of traditional construction projects. The literature makes the information known relating to the systematic steps that are involved during this method which includes preparation of the site, excavations and foundations, ground floor construction, superstructure construction, roof construction, internal construction, and finishes. Along with the research information of chapter 2, the researcher was able to obtain the costs associated with each step by means of a quantitative survey. The results obtained in the survey and analysed in chapter 4, brought the following results forward that the two major cost differences between modular construction and traditional construction is the difference in the physical construction processes and difference in time spent on the physical construction project.

5.2.2 Objective 2: To determine whether modular construction has more advantages than tradition construction methods?

The literature research found in chapter 2 discusses the systematic approach of the modular construction method along with the associated costs involved in the elements of the method of construction. Research indicates that modular construction methods have different construction methodologies, advantages, and disadvantages. With the results found and discussed in Chapter 4, it is evident that modular construction has more advantages than traditional construction. The advantage of modular construction is that it takes less time to complete a project, the costs associated with the different construction stages of modular construction is lower than that of traditional construction methods, modular construction produces less waste, it is also the safer method of construction, and modular construction uses less labour during construction in comparison to traditional construction methods.

With the research conducted in chapter 2, it takes 40% less time to complete modular construction projects than traditional construction projects. This can be very important for projects that need to be completed quickly, such as post-disaster reconstruction (Ramaji & Memari, 2016).

5.2.3 Objective 3: To determine whether modular construction or traditional construction is perceived as the most cost-effective construction method according to Quantity Surveyors in South Africa.

In chapter 4, the findings show the costs incurred during the construction phase of modular construction and how each phase/stage has a different timeframe as well as costs associated with each stage. The result of the study indicates that the participants are aware of the costs involved with this method. The research found in the literature study divides the process of construction into different stages and, therefore, the participants were instructed to associate a cost with each stage of construction.

The results indicate that the majority of the respondents (53.84%) perceive that modular construction is the more affordable construction method and based on the

findings in chapter 4, it was found that construction professionals perceive modular construction to be more affordable according to the rand per square meter rates given.

After analysing the findings in chapter 4, the participants result stated that construction professionals perceive that traditional construction methods are higher in cost based on 7 out of the 8 stages in construction in comparison to modular construction methods. Therefore, according to the results in the findings, construction professionals perceive modular construction to be more affordable than traditional construction methods.

5.3 REVISITING HYPOTHESIS

Hypothesis 1: The perception among Quantity Surveyors in South Africa is that modular construction is a more cost-effective method compared to traditional construction methods.

The hypothesis was answered in two ways throughout the research study. The first way was through one sample proportions test, where the study states the null hypothesis and alternative hypothesis, to determine the significance level and thereafter, calculate the statistical test (Sokal & Rohlf, 2013). The Z-test allows the researcher to reject the null hypothesis and conclude that there is sufficient evidence to support the claim that Quantity Surveyors perceive a difference in cost between modular and traditional construction methods. Furthermore, the data suggests that quantity surveyors perceive traditional construction to be higher in cost than modular construction.

The second method of answering the hypothesis is through the quantitative data that was collected and analysed. The findings in Chapter 4 indicate that Quantity Surveyors perceive that modular construction is the more affordable method in comparison to traditional construction methods.

5.4 RECOMMENDATIONS

The following recommendations below are discussed to ensure that construction professionals are made aware of the advantages of implementing modular construction projects, and how the input of the construction professionals can impact cost saving decisions when choosing a construction method. The following recommendations are discussed for better understanding:

5.4.1 Recommendations

To ensure successful modular construction projects, construction professionals need to obtain the necessary knowledge regarding the systematic approaches towards construction, the advantages, and disadvantages of this method. To obtain this information, thorough research should be conducted in the field of modular construction, choosing the correct system, and ensure stringent project planning and management to ensure accurate and timely implementation of the method.

In chapter 4, it is evident that 53.85% of construction professionals perceive that modular construction is more affordable, however, only 31.9% of participants have been involved in modular construction projects. This indicates that there is a slimmer chance for construction professionals to be involved in modular construction projects and they have yet to gain the needed experience to successfully manage, construct or control a project with a modular construction method. In chapter 4, we found that only 53.84% of participants believe that modular construction methods will be of better quality in comparison to traditional construction methods. This is an interesting finding as the majority of construction projects are being constructed by means of traditional construction methods, however, the quality of modular construction is perceived to be of higher quality and more affordable. Furthermore, research should be done on why there is a lack of implementation of modular construction projects.

5.5 LIMITATION OF THE STUDY

This study involved construction industry experts in South Africa, including companies of various sectors and of different sizes. The study focusses on obtaining information from Quantity Surveyors in South Africa to ensure accurate cost data is obtained. These professionals make up only a part of the construction industry of South Africa, and, therefore, limits the study to the perception of only one professional group of service providers in the construction industry. It is important to acknowledge the limitations of the study to avoid any inaccurate assumptions about cost management in construction projects. The limitations of this study are listed below:

1. The response rate of the participants who participated in the study 25.5%. Whilst Manfreda (2008) suggests that in built environment research, a response rate of 30% is considered adequate for the study within the built environment.
2. The study was limited to Quantity Surveyors in South Africa, and no other construction professionals within the South African construction industry.

5.6 CONCLUSION

The research study identified that the most affordable construction method according to the perception of construction professionals, Quantity Surveyors, in South Africa is modular construction methods.

By implementing more affordable construction methods, it will add towards creating more cost-effective, time-effective, and energy-sufficient construction projects. The results found in chapter 4 establish that the cost and time schedule of a project are directly related. When you save time during construction, it lowers the overall cost of the project. The results show that the cost of materials is projected to be lower for modular construction methods in comparison to traditional construction methods due to modular projects taking less time to complete.

Modular construction does come with its own challenges that affect the progress, differently compared to traditional construction. Prefabricated components need to be delivered to the construction site in a specific way so that the project can be completed

on time and within budget. However, this is not always the case with traditional construction methods. Extra costs are likely to be incurred if you want to make changes during your construction projects while using modular construction techniques. This is because there is an initial setup cost, a lack of workers with the necessary skills, and the process is complex. There is also disagreement about modularization, which makes it difficult to use this construction method more broadly.

The perception can influence decision-making regarding the choice of construction methods in several ways. For example, if a particular construction method is perceived to be more efficient or cost-effective, it may be chosen over other methods. Additionally, if a construction method is perceived to be more environmentally friendly or sustainable, it may be chosen to meet certain sustainability goals. Perception can also play a role in how a construction project is perceived by the public, which can affect its overall success and acceptance. Ultimately, the decision regarding which construction method to use will depend on a variety of factors, including cost, feasibility, and the specific goals and requirements of the project.

It remains critical that construction professionals increase their knowledge regarding the cost advantages of modular construction methods to be able to advise their future clients on methods that will save time, money and create efficient construction sites.

Referring to the literature covered in Chapter 2 regarding the influence of cognitive bias on decision-making in the construction industry, the findings in chapter 4 illustrate that most participants perceived modular construction to be more affordable, less time consuming, safer, causes less waste and requires less labourers to construct. This observation states that the professionals are aware of the existing advantages that modular construction has over traditional construction methods.

Decisions regarding which construction method to use are based on past experiences and data from previous projects. The selection of construction methods is largely based on the prior experience of the professionals. These statements open a gap for further research that asks the question; does the weight of “past experiences and data from previous projects” outweigh the option and/or opportunity to choose an alternative construction method, despite their obvious many advantages?

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Annexure A: Original Questionnaire

Demographic Questionnaire

Instructions: Please mark only ONE applicable category with an (X):

1. In which province is your place of work:

a	Eastern Cape	
b	Free State	
c	Gauteng	
d	KwaZulu-Natal	
e	Limpopo	
f	Mpumalanga	
g	Northern Cape	
h	North West	
i	Western Cape	

2. What is your profession:

a	Quantity Surveyor	
b	Architect	
c	Construction manager	
d	Owner of a Construction company	
e	Property Developer	
f	Other	

If other, please specify: _____

3. Number of years' experience within the construction industry

a	0 – 5 years	
b	6 – 10 years	
c	11 – 20 years	
d	20+ years	

4. Have you been involved with traditional residential construction projects?

a	YES	
b	NO	

5. Have you been involved in modular residential construction projects?

a	YES	
b	NO	

6. Are you professionally registered with an association or professional body? If YES, please specify.

a	YES	
b	NO	

Specify Association/Professional Body: _____

Practical Questionnaire

Instructions: Please mark only ONE applicable category with an (X):

Participant guide: Select the most applicable method of construction	**Traditional masonry construction**	**Modular construction**
1. Which method of construction do you perceive to be the more affordable method of construction?		
2. Which method of construction do you perceive takes less time to complete?		
3. Which method of construction do you perceive to have to have the lowest chance of accidents to occur?		
4. Which method do you perceive will require the least number of people/labourers to construct?		
5. Which method do you perceive will be of better quality?		
6. Which method do you perceive will use the least amount of machinery?		
7. Which method do you perceive will produce the lowest amount of waste?		

QUESTION 8: Please only complete this section if you have been involved with traditional construction projects.

8. Answer all questions according to your best knowledge and experience. Only complete the section by providing a rate per square meter and number of weeks.

General information guide to participant:

TRADITIONAL MASONRY CONSTRUCTION – *MASONRY RESIDENTIAL PROJECT of 50m2 (2 Bedroom, 1-bathroom, open plan living and dining-kitchen area). The construction of a traditional residential project includes reinforced strip footings, a solid floor slab, superstructure brickwork including windows and doors, timber roof trusses and metal roof coverings, internal finishes which includes floor tiles, paint to walls and nailed up ceilings, standard light fittings and fixtures, standard plumbing fittings and fixtures.*

8.1 **Preparation of the site**. There are several actions required in preparing the site for construction. This includes, but is not limited to site clearance, site surveying, soil tests, site plan design and site investigation.

8.1.1 What is the **average cost per m2** of preparing a site?

8.1.2 What is **the average duration (in weeks)** of preparing a site?

8.2 **Excavations and foundations**. This includes activities such as excavating trenches, placing foundation and pouring concrete, building foundation brickwork.

8.2.1 What is the **average cost per m2** of foundation construction?

8.2.2 What is **the average duration (in weeks)** of excavations and foundations?

8.3 **Ground floor construction.** This activity generally includes filling and compaction of soil, waterproofing, concrete, and reinforcement for the ground floor slab.

8.3.1 What is the **average cost per m2** of ground floor construction?

8.3.2 What is the **average duration (in weeks)** of ground floor construction?

8.4 **Superstructure.** This includes brickwork, windows and doors and external finishes.

8.4.1 What is the **average cost per m2** of superstructure construction?

8.4.2 What is the **average duration (in weeks)** of superstructure construction?

8.5 **Roof Construction.** This involves timber roof trusses, insulation, and metal roof coverings.

8.5.1 What is the **average cost per m2** for roof construction?

8.5.2 What is the **average duration (in weeks)** for roof construction?

8.6 **Internal division and finishes**. This involves internal plumbing and electrical work and fittings, floor finishes, wall finishes and ceiling finishes, built in cupboards.

8.6.1 What is the **average cost per m2** of internal division construction?

8.6.2 What is **the average duration (in weeks)** for internal division and finishes?

QUESTION 9: Please only complete this section if you have been involved with modular construction projects.

9. Answer all questions according to your best knowledge and experience. Only complete the section by providing a rate per square meter and number of weeks.

General information guide to participant:

MODULAR CONSTRUCTION – *MODULAR RESIDENTIAL PROJECT of 50m2 (2 Bedroom, 1-bathroom, open plan living and dining-kitchen area). The construction of a modular residential project includes reinforced strip footings, structural steel frame, solid floor slab, panelised wall units including windows and doors, timber roof trusses and metal roof coverings, internal finishes which includes floor tiles, paint to walls and nailed up ceilings, standard light fittings and fixtures, standard plumbing fittings and fixtures.*

9.1 **Preparation of the site**. There are several actions require in preparing the site for construction, this includes, but is not limited to site clearance, site surveying, soil tests, site plan design and site investigation.

9.1.1 What is the **average cost per m2** of preparing a site?

9.1.2 What is **the average duration (in weeks)** of preparing a site?

9.2 **Designing.** This includes designing and calculation of sizes of prefabricated items.

9.2.1 What is **the average cost per m2** for designing?

9.2.2 What is the **average duration (in weeks)** of designing a modular unit?

Total excavation and foundations and manufacturing off-site (with expected time-overlap taken into consideration).

9.3 **Excavations and foundations**. This includes activities such as excavating trenches, placing foundation and pouring concrete, building foundation brickwork.

9.3.1 What is the **average cost per m2** of foundation construction?

9.3.2 What is **the average duration (in weeks)** of excavations and foundations?

9.4 **Manufacturing off site.** This includes manufacturing of the entire prefabricated unit and panels in a factory environment.

9.4.1 What is the **average cost per m2** of manufacturing?

9.4.2 What is the **average duration (in weeks)** of manufacturing?

9.5 **On-site assembly**. This includes transportation of the prefabricated unit to site and assembling all items.

9.5.1 What is **the average cost per m2** of on-site assembly?

9.5.2 What is the **average duration (in weeks)** of on-site assembly?

9.6 **Inspection and finishing off.** This includes inspection to ensure assembly and finishes are done according to standard.

9.6.1 What is the **average cost per m2** for inspection and finishing off?

9.6.2 What is the **average duration (in weeks)** for inspection and finishing off?

10. According to your perception which of the following factors would **increase the construction of cost** involved with traditional construction in comparison to modular construction (more than one factor may be chosen):

No	Factors	Applicable (x)
1	**Preparation of the site**. There are several actions require in preparing the site for construction, this includes, but is not limited to site clearance, site surveying, soil tests, site plan design and site investigation	
2	**Excavations and foundations**. This includes activities such as excavating trenches, placing foundation and pouring concrete, building foundation brickwork.	
3	**Ground floor construction.** This activity generally includes filling and compaction of soil, waterproofing, concrete, and reinforcement for the ground floor slab.	
4.	**Superstructure.** This includes brickwork, windows and doors and external finishes.	
5	**Roof Construction.** This involves timber roof trusses, insulation, and metal roof coverings.	
6	**Internal division and finishes**. This involves internal plumbing and electrical work and fittings, floor finishes, wall finishes and ceiling finishes, built in cupboards.	

11. According to your perception, which of the following factors would **increase the cost** involved with modular construction in comparison to traditional construction (more than one factor may be chosen):

No	Factors	Applicable (x)
1	**Preparation of the site.** There are several actions require in preparing the site for construction, this includes, but is not limited to site clearance, site surveying, soil tests, site plan design and site investigation.	
2	**Designing.** This includes designing and calculation of sizes of prefabricated items.	
3	**Excavations and foundations**. This includes activities such as excavating trenches, placing foundation and pouring concrete, building foundation brickwork.	
4	**Manufacturing off site.** This includes manufacturing of the entire prefabricated unit and panels in a factory environment.	
5	**On-site assembly**. This includes transportation of the prefabricated unit to site and assembling all items.	
6	**Inspection and finishing off.** This includes inspection to ensure assembly and finishes are done according to standard.	

Annexure B: Cover Letter and Information Sheet

The perception of construction professionals with regards to construction cost of masonry residential projects versus modular construction residential projects in South Africa.

Good Day Sir/Madam

I, Ashley Butler, am currently enrolled as a Master's of Property Studies student at the University of Cape Town. This is an invitation to participate in the research study that I am conducting regarding *"The perception of construction professionals with regards to construction cost of masonry residential projects versus modular construction residential projects in South Africa".*

The purpose of the study

The purpose of the study is to determine how construction professionals perceive what the most cost-effective construction method is with regards to traditional construction versus modular construction method in South Africa.

What is expected from the participants in the study?

The study will be conducted by utilising a questionnaire which will be distributed electronically to several professionals within the construction industry. These participants are limited to Quantity Surveyors based in South Africa. Hereby you are invited to take part in this study by completing the questionnaire.

Benefits in partaking in the questionnaire

There are no benefits in parting in the questionnaire. This study only aims to determine how construction professionals perceive what the most cost-effective construction method is with regards to traditional construction versus modular construction method in South Africa.

Confidentiality

Every completed questionnaire will be captured on a secure digital platform recommended by the University of Cape Town for research questionnaires – this will

ensure that confidentiality is maintained throughout the study. All participants have the right to freely withdraw or not partake in this study.

If there are any questions regarding this research, you may freely contact myself, Ashley Butler, at cell phone number 073 979 1600 or via email at btlash004@myuct.ac.za. Any ethical queries or enquiries should be made to Mareldia Fagodien at Mareldia.Fagodien@uct.ac.za

Kind regards,

Ashley Butler (Researcher)
btlash004@myuct.ac.za
073 979 1600
Mochelo Lefoka (Supervisor)
mochelo.lefoka@uct.ac.za

Annexure C: Ethics Clearance

Re: MSc Thesis - Ethics approval ERA

Zita Jemaar <zita.jemaar@uct.ac.za>
Wed 2023/07/26 10:41

To:Ashley Butler <BTLASH004@myuct.ac.za>
Cc:Khanyisa Tivaringe <khanyisa.tivaringe@uct.ac.za>;Khaya Salman <khaya.salman@uct.ac.za>;Mochelo Lefoka <mochelo.lefoka@uct.ac.za>;Frank Ametefe <frank.ametefe@uct.ac.za>

Dear Ashley,

Thank you for the email.

Your application has been reviewed. The Dean has agreed to the recommendation that your dissertation be sent for examination, and that no further action is required from you.

Please proceed with the above.

@Khaya please note the ethics matter has been resolved and the student will proceed as required. Thank you.

Kind Regards,
Zita

From: Khanyisa Tivaringe <khanyisa.tivaringe@uct.ac.za>
Sent: Tuesday, July 25, 2023 12:20 PM
To: Zita Jemaar <zita.jemaar@uct.ac.za>
Subject: FW: MSc Thesis - Ethics approval ERA

From: Ashley Butler <BTLASH004@myuct.ac.za>
Sent: Tuesday, July 25, 2023 12:16 PM
To: Harro Von Blottnitz <harro.vonblottnitz@uct.ac.za>; Khanyisa Tivaringe <khanyisa.tivaringe@uct.ac.za>; Mochelo Lefoka <mochelo.lefoka@uct.ac.za>
Cc: Frank Ametefe <frank.ametefe@uct.ac.za>
Subject: Re: MSc Thesis - Ethics approval ERA

Good day Prof Harro,

Thank you for the email last week regarding your recommendations to the Dean. Have you heard anything back from the Dean since the 17th of July 2023?

Thank you,

Kind Regards
Ashley

From: Harro Von Blottnitz <harro.vonblottnitz@uct.ac.za>
Sent: Monday, 17 July 2023 14:38
To: Ashley Butler <BTLASH004@myuct.ac.za>; Khanyisa Tivaringe <khanyisa.tivaringe@uct.ac.za>; Mochelo Lefoka <mochelo.lefoka@uct.ac.za>
Cc: Frank Ametefe <frank.ametefe@uct.ac.za>
Subject: RE: MSc Thesis - Ethics approval ERA

Dear Ashley,
Thanks for confirming. My report is complete and has been sent for the Dean's consideration. If she approves my recommendations, you'll hear from the Faculty Office. Unless the Dean refers the investigation report back to me, I have no further role in your journey as postgraduate student.
Best wishes, Harro.

From: Ashley Butler <BTLASH004@myuct.ac.za>
Sent: Monday, July 17, 2023 12:02 PM
To: Harro Von Blottnitz <harro.vonblottnitz@uct.ac.za>; Khanyisa Tivaringe <khanyisa.tivaringe@uct.ac.za>; Mochelo Lefoka <mochelo.lefoka@uct.ac.za>
Cc: Frank Ametefe <frank.ametefe@uct.ac.za>
Subject: Re: MSc Thesis - Ethics approval ERA

Good morning Prof Harro,

Thank you for the feedback on the process.

To answer your question above, I have not had a personal talk with Dr. Ametefe, I have been working through my supervisor Mr Lefoka most of the time, but to my knowledge, he knows about the ethics approval situation. I will prioritize a meeting with Dr.