NELSON MANDELA UNIVERSITY

INNOVATIVE CONSTRUCTION METHODS TO ADDRESS HOUSING DEMAND IN SOUTH AFRICA

MB TSOSANE

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INNOVATIVE CONSTRUCTION METHODS TO ADDRESS HOUSING DEMAND IN SOUTH AFRICA

By:

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A research treatise submitted in fulfilment/ partial fulfilment of the requirements for the degree of Master of Science in the Built Environment: Construction Management, in the Faculty of Engineering, the Built Environment and Technology
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ABSTRACT

In South Africa, there is a prolonged waiting period for the needy to receive subsidy housing. Due to several factors contributing to this housing delivery delay, there is proliferation of informal settlements. The factors include fast-paced urbanization, which is mostly triggered by rural-urban migration that prompts urban growth and its attendant challenges that exert intense demands on the local government, thus the government is unable to keep up with the demands for housing and other related needs. The currently used conventional method (masonry construction) of construction for the construction of subsidy housing is perceived to be procedural and time consuming which is also one of the factors contributing to the delay in housing delivery. According to the research, interventions in the built form could be applied to address these issues. The focus of this study was on the construction aspect of the factors that contribute to the delay/problem. The primary aim for this study was to explore innovative prefabricated modular construction methods, proposed as alternatives to the construction of government subsidy housing in order to address housing demands in informal settlements. The research onion diagram was adopted and methodically followed as the research design for this study, whereby the data collection method that was adopted as part of the research onion was included a Desktop Survey and a Site Survey. The population and sample of this study comprised of a mixed group of participants, which were selected in accordance with the research attributes. The research findings indicate that the modular construction methods can indeed be used as an alternative to address some of the subsidy housing delivery problems. However, the challenge of any new innovative solution is to overcome end-user scepticism as resistance is inevitable. The research recommendation is for this research work to be taken to the next phase which would involve simulations of life size experimental models of these proposed innovative methods of construction, to further assess the viability of these proposed construction methods, before they may be implemented.

DECLARATION

I, Mosa Brunette Tsosane (s209069658), hereby declare that the treatise/ dissertation/ thesis for the degree of MSc in the Built Environment: Construction Management is my own work and that it has not previously been submitted for assessment or completion of any postgraduate qualification to another university or for another qualification.


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Mosa Brunette Tsosane

DEDICATION

I dedicate this work to my husband, Moeketsi Goodwill Tsosane, who has been my motivation and support system and instilled in me a passion to further my studies and has shown through his hard work and dedication that with persistence, endurance and perseverance one can achieve greater things. Thank you so much my love.

I would also like to dedicate this work to my mother, Nomthandazo Mercy Siyila and my brother, Sizwe Siyila. Thank you for doing all in your power to provide me with every possible opportunity I needed to complete my studies and succeed in life.

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To my dear husband, Moeketsi, thank you for being my biggest cheer leader and reassuring me always, that all the time I have invested in this quest to further my studies is all worth it and will soon pay off. From the bottom of my heart, I would like to thank you for your unwavering love and support.

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1.1 INTRODUCTION

Since the advent of multiracial governance in South Africa (SA), almost all urban areas have been urbanising rapidly, resulting in the proliferation of informal settlements. The urban areas have been growing rapidly as a result of *inter alia*, rural-urban migration.

According to Statistics South Africa (StatsSA)'s General Households Survey, the population of households living in informal dwellings has increased by 0.6% between 2002 (13.3%) and 2016 (13.6%)*. These increasing figures of households living in informal settlements indicate that although the SA government aims to address housing demand, the slow paced delivery and the inevitable annual population growth are some of the inhibiting factors, on the government's intention to deliver affordable housing.

A lot of migrants arrive in SA with no resources of their own apart from their labour skills and sometimes low level of education. Considering that they have inadequate resources to afford quality urban services such as health, education, housing and its infrastructure, they end up doing with the little they can access. For housing, they end up squatting in settlements that are already in poor condition and lack basic infrastructure and other services, consequently adding to the existing demand and compounding the housing problem as shown in Figure 1.1. As a result of the above, the government is pressured into improving the conditions of these settlements but finds its resources stretched as it also has to cater for other needy functions. To alleviate the housing needs of the poor, the SA government in its commitment to the Reconstruction and Development Program (RDP) made in 1994 undertook to do all in its power to provide housing and to meet the needs of all the people (Republic of South Africa, 1994).

* These figures may have increased yet again between 2016 and the current year (2019), due to inevitable annual population growth.

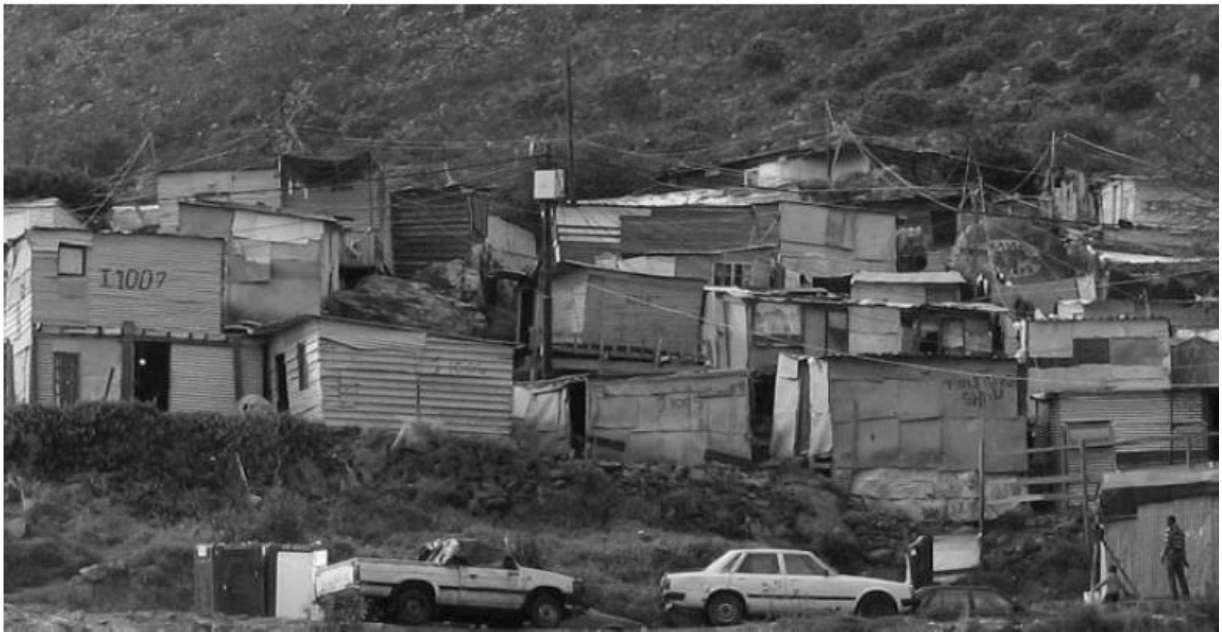


Figure 1.1: Informal Settlement in South Africa (Wekesa et al., 2011)

In its quest to fulfil its commitment to the subsidy housing delivery to meet the demands amongst the poor, the SA Government has various challenges when it comes to the provision of subsidy housing commonly known as “RDP housing”. The typical challenges of providing subsidy housing include budgetary constraints, lengthy supply-chain and procurement processes, corruption, tender irregularities, lengthy construction periods, poor construction workmanship and inadequate construction management resources from the government departments. The challenges are also exacerbated by the poor macro economy, which increases the demand for subsidy housing.

This study assesses innovative construction methods, which can be used to address the housing demand in informal settlements. It does this by focusing on providing a solution to part of these challenges, which would reduce construction periods and limitations of poor workmanship by providing alternative construction methods.
Based on the above, this study aims to explore innovative construction methods/alternatives that can fast track the provision of housing for informal settlement dwellers.

1.2 BACKGROUND - ISSUES THAT TRIGGER THE RESEARCH

Government delivery of RDP housing for informal settlement dwellers has prolonged lead times, due to various factors. One of the contributing factors is the conventional method of construction used.

This conventional method of construction is time consuming as projects are usually completed over long periods; however, the duration of construction tends to differ from project to project. Some small-scale projects may be completed within a few months whilst some big-scale projects may take years to complete.

Based on the above situation, it can be deduced that construction of RDP housing projects also takes long periods to complete due to the construction method used, which adds to the prolonged waiting period and delays in the receipt of subsidy housing. This therefore contributes to the increasing rate in the establishment of informal settlements. According to Huchzermeyer (2009) “the term ‘informal settlement’ can also be described as – a built environment which is a slum or a settlement of the poor that results from unauthorised occupation of land, with non-adherence to land use and building construction regulations”.

Rapid urbanization in South Africa has resulted in the proliferation of informal settlements, lacking in basic infrastructure and services (Shortt and Hammett, 2013), hence current social housing policy seeks to deliver other housing alternative methods, on a fully serviced property (plot) with freehold title, as that is what is currently offered in practice, also ensuring that the community networks are maintained (Del Mistro and Hensher, 2009).

It was documented by Shortt and Hammett (2013) that, “the scale and spread of informal settlements has however pressured the government towards upgrading of physical infrastructure, housing units and service connections and greater social and economic integration of informal settlements”. Del Mistro and Hensher (2009) recorded in 2009 that, there were 2 million households that lived in informal housing in South Africa.

These figures may have increased due to the population increasing annually. The government’s goal at the time was to overcome the housing backlog by 2014; however, even if they doubled the budget they had in order to accommodate the increase, they would only have met the housing demand in 2030.

1.3 PROBLEM FORMULATION

1.3.1 Background:

The lack of formal planning in informal settlements means that they are generally located in areas where the health, safety and security of the dwellers is compromised.

These locations include railway setbacks, dumpsites, marshland, riverbanks, etc. (Wekesa, Steyn and Otieno, 2011). The vehicular access in informal settlements is limited and implementation of infrastructure for basic services provision is a challenge due to structures being haphazardly laid-out and plots are small with little or no outside space. Some informal settlements suffer severe damage while the dwellers in these informal settlements suffer severe consequences from natural disasters where settlements are along environmental hazards like riverbanks (Felix, Feio, Branco and Machado, 2013). Due to the physical, unhealthy and unsafe environmental conditions under which they are subjected, sickness, violence and insecurity have increased drastically in many informal settlements of South Africa.

These abovementioned conditions present challenges for upgrade projects, therefore re-blocking of the informal settlement or relocating the informal dwellers to a completely new area with a proper town-planning layout may be necessary (Shortt and Hammett, 2013).

In SA, there is a prolonged waiting period for the needy to receive RDP housing, in addition, the construction period of RDP housing projects is time consuming. All these contribute to many informal settlements erupting illegally on available vacant lands, which has now led to land grabs.

Based on all the above highlighted issues, it is indicative that there are several factors contributing to the illegal eruption of informal settlements, however, interventions in the built form can be applied to address these issues (Brown-Luthango, Reyes and Gubevu, 2016).

1.3.2 Problem Statement:

The present method of RDP housing construction is one of the factors contributing to the delay of RDP housing delivery, thus resulting in the proliferation of informal settlements being the knock-on effect.

1.4 SUB-PROBLEMS (S-P)

S-P1: RDP housing construction method is time consuming.

S-P2: RDP housing construction method is cost ineffective.

S-P3: Technical assembly of building materials prescribed for RDP house construction requires skilled labour, to avoid future restoration works.

1.5 HYPOTHESES (H)

H1: The sequential method of construction for RDP housing has a restraining effect on the speed of construction.

H2: The various prescribed building materials incorporated in RDP housing construction and the required expertise of labour render the construction method cost ineffective.

H3: Construction work executed by unskilled labour results in poor workmanship, which prompts need for reparation of poorly constructed work, at additional cost and consequentially extending the construction time, ultimately resulting in the delayed handover of housing.

1.6 RESEARCH AIMS AND OBJECTIVES

1.6.1 Aims:

This primary aim of this research study is to: explore innovative construction methods that could be implemented in the construction of government subsidy housing in order to fast track delivery.

The secondary aim of the study is to: explore the possibility for future integration of the proposed innovative methods (prefabricated modular construction) of construction fully into other architectural applications in the building industry.

1.6.2 Objectives:

The objectives of this study are as follows:

Objective 1: To establish innovative construction methods that could be implemented in the construction of government subsidy housing, in order to fast track the construction and delivery of subsidy housing.

Objective 2: To establish cost effective construction methods/materials that could be used in the construction of government subsidy housing, in order to reduce construction costs.

Objective 3: To establish and introduce innovative construction methods that require a medium level of labour skills, that could be implemented in the construction of government subsidy housing, to guarantee quality construction, in order to prevent poor workmanship that may lead to delays in the delivery of housing.

1.7 DELIMITATIONS OF THE STUDY

This study only focuses on the construction aspects of subsidy housing in South Africa and not the government supply-chain procedures and procurement issues.

The research piloted a questionnaire to 6 participants for the purpose of checking if the questionnaire is setup in such a manner that participants are able to easily read and answer the questions asked.

The researcher was only able to administer the questionnaire to 60 participants for the purpose of data collection.

All site surveys that were in the form of interviews and administration of questionnaires were conducted in Port Elizabeth (PE) and some areas of Bloemfontein, South Africa. However, the findings are indicative and can only be extrapolated to the whole country if the same methodology is applied.

1.8 THE RATIONALE FOR INVESTIGATING THIS PROBLEM

1.8.1 Risks and threats that trigger the investigation

There are multiple issues found in research that trigger the immediate need to upgrade informal settlements. According to Brown-Luthango *et al*. (2016) “increasing levels of violence and violent crimes have been linked to the fast-paced urbanisation and informality in developing countries”. The United Nations Habitat’s 2007 Global Report on Human Settlements entitled ‘Enhancing Urban Safety and Security” states that the unsafe and unsecure nature of fast growing informal settlements results in the severity of crime and violence (UN Habitat, 2007). Another pressing reason to upgrade informal settlements is that they are usually on the periphery of major urban centres and are encroaching closer to where businesses are located (Shortt and Hammett, 2013), this can lower property value, taint the image of businesses, and threaten their security.

According to Mutero and Makwara (2018), land invasion is one of the major issues in most urban environments across the world, which is further exacerbated by rapid urbanisation coupled with rural- to-urban migration. In addition, Huchzermeye (2009), asserts that there is documented evidence of political influence in land invasions. Land invasion poses a big threat to the security of many businesses, as land invaders insert themselves on unused land – undeveloped land allocated/intended for public or commercial facilities, private farmlands, etc.; this puts businesses at risk as land that is intended for future business could be illegally occupied.

It was recorded in the Stats SA that in 2014, 11% of the urban population was living in informal settlements and 13,1% households were living in informal dwellings during this same time period.

The SA population was 51, 8 million in 2011 and had increased to 55, 7 million in 2016, which means that the SA population had increased by 3,9 million within the space of 5 years (from 2011 to 2016). This inevitable annual increase of the overall SA population is a clear indication that the number of people living in informal settlements is likely to also increase on an annual basis, if no urgent intervention measures in the built form are put in place.

1.8.2 Benefits of the investigation

The major benefit of the study is acquisition of information to use in developing innovative construction methods that could be implemented and would significantly reduce the construction time for RDP housing. The added benefit is the provision of dignified housing, which can be laid out in a planned manner to allow for ease of integration of infrastructure and services.

According to Felix *et al*. (2013), housing is one of the most important needs for people. It is more than a physical structure, as it provides a sense of belonging, and partly one's source of identity, therefore it is essential to provide informal settlement dwellers with decent housing alternatives to re-establish their identity and integrity.

1.9 ASSUMPTIONS

The assumptions made with respect to this study are as follows:

- Firstly, the conventional method of construction uses bricks, mortar, concrete and other materials.

- Secondly, the standard RDP house is 40m^2 with 2 bedrooms, 1 bathroom and an open plan lounge and kitchen space.

- Thirdly, the proposed method of construction is to be implemented on levelled land; therefore, the land that would be used would factor no site clearance costs, soil retaining costs, etc.

- Fourthly, the proposed method of construction would be implemented on a fully serviced site with all of the required infrastructure for municipal services e.g. water supply, electricity supply, sewer connection, storm-water connection.

- Fifthly, the climatic conditions are restricted to the Port Elizabeth coastal climatic zone 4 in South Africa.

1.10 INDICATIVE RESEARCH METHODOLOGY

The research methodology that was found suitable to address the specific research attributes of this study and to achieve the aims and objectives was a mixed methods approach that included the triangulation of a qualitative approach with a statistically insignificant quantitative element. This was conducted in the form of a Desktop Survey and a Site Survey.

The Desktop Survey included: (i) literature review, and (ii) a simulation of basic designs, while the Site Survey was conducted in the form of (i) interviews and (ii) administration of questionnaires, which aimed to assess the opinions of a mixed group of participants (e.g. professionals in the AEC industry, informal settlement dwellers, RDP house dwellers, low-cost housing candidates and ordinary conventional construction residence dwellers) on the implementation of the proposed innovative methods of construction as alternatives in the construction of subsidy housing and other architectural applications. Furthermore, the Site Survey aimed at allowing for the involvement of the community in the process of determining how the settlement should be upgraded. All the participants that were involved in Site Survey, were strategically selected based on the research attributes of the study.

1.11 DEFINITION OF TERMS

Demand (noun): in this study 'demand' refers to the urgent need for something, e.g. urgent need for housing.

Informal settlement: a built environment which is a slum or a settlement of the poor that results from unauthorised occupation of land, with non-adherence to land use and building construction regulation (Huchzermeyer, 2009).

Informal settlement dwellers: poor people or migrants that have inadequate resources to afford quality urban services such as health, education, housing and its infrastructure, squatting illegally on land they have no claim to (Wekesa *et al*., 2011).

Innovative construction methods: refers to the use of building products, technologies or techniques that stray away from the conventional way of construction (Focus, 2018).

Housing *(noun)*: refers to a shelter in which people live (Collins English Dictionary, 2018), situated on a fully serviced property with free hold title and within a fully developed town planning context with adequate vehicular access and all required infrastructure for basic municipal services (Del Mistro and Hensher, 2009).

Housing *(verb)*: refers to the act or process of providing shelter (Turner and Fichter, 1972)

Housing demand: refers to the urgent need for shelter required by a large number of individuals that are living in informal settlements without decent shelter.

Low-cost housing: refers to affordable housing which is obtained at a lower/affordable price (Bhatta, 2010), which is a government subsidised type of housing, with a basic design layout that is constructed on a specific low-cost budget, using low-cost materials and methods.

Modular construction: refers to the practice of fabricating building components off-site at a factory and then transporting these components to the building site for installation.

Subsidy: a government incentive in the form of financial aid or support provided to qualifying beneficiaries (poor people, informal settlement dwellers, etc.) for housing purposes (South African Government, 2018).

Subsidy housing: refers to two types of government subsidised housing programs.

i) RDP (Reconstruction and Development Program) housing that is fully subsidised by the government with the aim of providing shelter for the needy (informal settlement dwellers) (South African Government, 2018).
ii) Low-cost housing whereby the government provides a grant to qualifying beneficiaries (e.g. low-income households) with the aim of providing financial aid to qualifying beneficiaries, this means that a substantial portion of the total cost to acquire housing is subsidised by the government to allow beneficiaries to afford to purchase a home (South African Government, 2018).

Proliferation: refers to the "rapid increase in number of something" (Oxford-Dictionaries, 2018)

Prefabrication: refers to the exercise of assembling buildings or building components in a factory, so that the complete prefabricated component can be transported to site for installation (Encyclopaedia Britannica, 2019).

Rural Area: refers to regions with a lot of undeveloped land with only a few homes and farms; the population density of such regions is very low with most inhabitants having agricultural jobs (National Geographic, 2019).

Rural-urban migration: refers to the movement or shift of people from rural areas to urban areas in pursuit of better job opportunities that will benefit their economic circumstances (National Geographic, 2019).

Urbanisation: refers to the rapid increase in population or number of people that live in a particular area i.e. urban area, etc. (Sience Daily, 2018).

Urban Area: refers to a more developed region i.e. city, town, suburb, etc.; such regions have a lot of job opportunities, high population density and a structured distribution of homes, commercial buildings, bridges, roads, railways, etc. (National Geographic, 2019).

1.12 LIST OF ACRONYMS AND ABBREVIATIONS

AEC	Architecture, Engineering and Construction
EPS	Expanded Polystyrene
IBS	Industrialised Building System
PE	Port Elizabeth
RSA	Republic of South Africa
SA	South Africa
RDP	Reconstruction and Development Program
NMU	Nelson Mandela University

1.13 CHAPTER OUTLINE OF THE STUDY

1.13.1 Introduction

This study is structured into five (5) chapters as shown in the following sections.

1.13.1.1 Chapter 1: Introduction to the Study

This chapter discusses the literature behind the existence and rapid proliferation of informal settlements in SA (it focuses on the cause and the conditions of informal settlements) which is due to the issue of delayed subsidy housing delivery.

This issue is identified as the problem. This chapter goes on to discuss the built environment management issues that have triggered this investigation, the research problem with sub-problems and hypotheses as well as the importance of this research.

1.13.1.2 Chapter 2: Literature Review

This chapter discusses the gaps identified in the literature review, around the subject of provision of housing and upgrade projects for informal settlements and the importance of the involvement of informal settlement dwellers in such projects. This chapter further discusses the interest of social housing policy in finding alternative construction methods for subsidy housing.

1.13.1.3 Chapter 3: Research Methodology and Data Collection

This chapter explains the triangulation research methodology and research design that was adopted in this study, which includes both qualitative and quantitative approaches. In addition, this chapter discusses other research methods used for the purpose of data collection and the ethical considerations that were adopted and applied to this study.

1.13.1.4 Chapter 4: Data Analysis and Interpretation of Findings

This chapter discusses the data presentation, analysis and interpretation of findings. In this chapter the researcher identifies and proposes two innovative construction methods which are suitable for use as alternatives for government subsidy housing construction in SA.

1.13.1.5 Chapter 5: Conclusions and Recommendations

This chapter concludes the research and makes recommendations based on the literature review findings and the site survey findings.

Chapter 2 : LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discusses the literature undertaken by other researchers pertaining to what was found and reported as gaps in literature regarding the issues around the improvement of subsidy housing delivery. Furthermore, this chapter discusses the introduction of innovative construction methods that could be implemented for subsidy housing construction specifically to address the housing demand, and also be implemented in other types of buildings in general. By doing this the study explores existing knowledge gaps which it then endeavours to fill.

A Desktop Survey was conducted in this study, for the purpose of collecting the relevant data from various sources, that speaks to the subject matter of this study. Some of the data that was collected through Desktop Survey is introduced and discussed in this chapter. However, a more in depth discussion of the collected data can be found in Chapter Four.

In pursuit of the aims and objectives of this study the themes found central to this study are: (i) urbanisation, (ii) rural-urban migration; (iii) subsidy housing; and (iv) innovative construction methods. These and others found central will be discussed. It is only after this has been done that the research gaps reported in the literature are highlighted and reviewed.

2.1.1 Literature Review

According to Brocke *et al*. (2009) Literature Review is a comprehensive summary of previous research on the study topic, which discloses other available valuable knowledge based on the perspective of other researchers. Makasa (2010) defines it as an intensive review of relevant information on a study topic using Desktop Surveys, which include gathering of information from electronic and print media. In this study Literature Review enumerates, describes, summarises, objectively evaluates and clarifies previous research. In this case it gives a theoretical base for the research and helps the author to determine the nature of the research.

The purpose of literature review is to provide researchers with a framework to establish the relevance of the study topic and it also provides a benchmark that enables researchers to compare the results of their study topic with other findings recorded by

other researchers (Creswell, 2003). In addition, literature review allows researchers to expand prior studies and fill in the gaps reported in other studies on a particular topic, and helps to guide researchers on how to limit the scope of their study by focusing on the needed area of inquiry (Creswell, 2014).

2.1.2 What is urbanisation?

Makasa (2019) defines *urbanisation* as the physical increase of the population within an urban area, resulting in the physical growth of such an area in addition to its natural population growth. According to Potts (2012), it can be defined as "the demographic process whereby an increasing share of the national population lives within urban settlements". Makasa (2019) further elaborates that this process is mostly triggered by rural-urban migration that prompts urban growth and its attendant challenges that exert intense demands on the local government. Which raises the question, what then is *rural-urban migration?*

2.1.3 Understanding rural-urban migration

In order to understand rural-urban migration, its existence must first be explained. According to Makasa (2019), the rural-urban migration dates back to the 1900s, as it was around that time that the locals (Sub Saharan African natives) believed in the barter system (exchange of goods) as their countries were predominantly rural and agrarian based, and therefore, there was no need to provide their labour in exchange for money. However this later changed when the sub Saharan African countries experienced transformation from being agrarian based countries to being industrial based countries; this is when the colonial rulers enforced the need for money, which destroyed production initiatives and led to locals having to offer their labour for money, and the need to relocate from their rural areas to urban areas where there are more job opportunities that are economically beneficial (Makasa, 2019).

Based on the above, rural-urban migration can be defined as a process of voluntary or forced relocation of people from rural areas to urban areas as a result of the desire to seek greener pastures or a way to escape civil strife (Makasa, 2019). Economic development was therefore, the driving force behind urbanisation (Makasa, 2010). Rural-urban migration is one of the many factors that contribute to the emergence of informal settlements (Nassar and Elsayed, 2018), whereby the proliferation of informal settlement is due to the fact that most migrants are jobless and cannot afford housing hence the government has undertaken to provide subsidy housing.

2.1.4 Subsidy Housing

In order to understand the double concept of *'subsidy housing'*, it is first broken into individual concepts of *'subsidy'* and *'housing'* then it is defined as one concept.

Subsidy is defined as a government incentive in the form of financial aid or support provided to qualifying beneficiaries (poor people, informal settlement dwellers, etc.) for housing purposes (South African Government, 2018), while the housing concept can either be seen as a verb or as a noun (Hannu Ruonavaara, 2018). When seen as a verb, housing is the act or process of providing shelter (Turner and Fichter, 1972, p. 151), and when seen as a noun, it is a shelter in which people live (Collins English Dictionary, 2018). Clapham (2018) suggests that housing is the main location in which families spend most of their time. According to Makasa (2010), housing is a spatially fixed and multifaceted commodity that is purchased for a number of reasons including an investment and provision of shelter.

Therefore based on the above, in this study the concept of '*subsidy housing'* therefore means provision of fully subsidised housing by the government with the aim of providing shelter for the needy (South African Government, 2018).

There is, however, a housing backlog of over two million houses (2.1million units to be exact) in South Africa. This figure continues to rise annually, which is why the demand for housing remains extremely critical in South Africa (Fuller Center Housing Report (2014, p. 13-14). The backlog in the delivery of subsidy housing is due to a number of factors, including the method of construction used for subsidy housing, which gives rise to the need to explore innovative construction methods.

2.1.5 Innovative construction methods

In literature review *'innovation'* is defined as the generation of new and improved ideas, concepts and practices that alter the routine or the way of doing things within a particular industry (Yusof *et al*., 2014). Therefore, *'Innovative construction methods'* refer to the use of building products, technologies, techniques or routines that stray away from the conventional way of construction (Focus, 2018), which improve the status quo.

According to Yusof *et al*. (2014), some of the things that the construction industry has been criticized for include slow productivity and low quality of products, therefore innovation is much needed to ensure survival of the construction industry. Yusof *et al*. (2014) further asserts that there is a necessity for the level of innovation in the construction industry to improve in order to increase the construction industry's contribution towards economic growth.

2.2 RESEARCH GAPS NOTICED IN THE LITERATURE

There are a number of gaps discovered in the literature review and these are discussed and structured as follows: (i) community involvement in upgrading processes of informal settlements, (ii) housing policy aims, and (iii) Introduction of innovative construction methods as alternatives for subsidy housing construction.

2.2.1 Community Involvement

According to Del Mistro and Hensher (2009), it is important to involve the community of an informal settlement in the process of determining how the settlement should be upgraded. Del Mistro and Hensher (2009), suggests that, the questions therefore become as follows:

- "What aspects do residents of informal settlements value, when the settlement is to be upgraded?
- How important are these aspects?
- How should these values be incorporated into informal settlement upgrade policy and practice?"

Informal settlement dwellers' views have never been considered regarding other alternative methods of construction that can be implemented in the construction of government subsidy housing, they have not been asked if they are open to other housing alternatives other than the currently offered type of housing (conventional construction). Informal settlement dwellers need to be educated about other alternative methods of construction that can be implemented for subsidy housing, to avoid rejection and resistance towards proposals which incorporate alternative building technologies (Own Construction, 2012).

2.2.2 Housing Policy Aims

Current social housing policy seeks to deliver other innovative housing methods to be implemented as an alternative for subsidy housing construction, on a fully serviced

property (plot) with freehold title, as that is what is currently offered in practice, also ensuring that the community networks are maintained (Del Mistro and Hensher, 2009).

2.2.3 Introduction of Innovative Construction Methods for Subsidy Housing

According to Bertram, Fuchs, Mischke, Palter, Strube and Woetzel (2019), the concept of modular construction, involves designing and prefabricating standardised building components in an offsite factory, then the building components are transported to site, where they would be assembled together into a building. Bertram *et al.* (2019) further asserts that modular construction presents the ability to accelerate construction time, which results in cost savings, fast construction completion and handover.

Furthermore, with the use of modular construction methods, the onsite construction is more simplified compared to the traditional method of construction, thus the onsite assembly of modules requires a medium level of labour skills (lower-skilled labour force), thus resulting in lower labour costs (Bertram *et al.,* 2019).

The research has identified two innovative construction methods, which include the use of prefabricated modular construction specifically in the form of (i) Shipping Container construction and (ii) Precast Concrete Modular construction. These prefabricated modular construction methods have not been explored/introduced for implementation as alternative solutions for subsidy housing construction for the sole purpose of fast tracking the delivery of subsidy housing. Which could eventually result in the reduced proliferation of informal settlements, as Bertram *et al. (*2019), guarantees that modular construction presents the ability to fast-track construction time and handover.

The concept of modular construction has been introduced in the building industry, however, only a few of such buildings have been built (Gunawardena, *Mendis, Nqo, Aye and Alfano,* 2014), and this method has not been considered for subsidy housing construction in South Africa.

2.2.3.1 What is a Shipping Container?

There is a lot of content documented by Bernardo, Oliveira, Nepomuceno and Andrade (2013) and Islam, Zhang, Setunge and Bhuiyan (2016) about shipping containers. Therefore based on literature review shipping containers are seen as large metal boxes constructed to be very strong, durable and structurally sound and are commonly

used for storage and transportation of goods. However, they are suitable for reuse as base structures for building purposes.

2.2.3.2 Design and Structural Composition of Shipping Containers

Shipping containers are manufactured with anticorrosive primer that prevents surface corrosion or severe rusting. These structures are inherently strong as they can be stacked up to nine rows high, with one container above the other without compromising their structural integrity (Islam *et al*., 2016).

The structural design of a shipping container makes it adaptable for home building purposes (Islam *et al*., 2016), as it provides a good sturdy shell that can be used as a base that can be prefabricated with all required building components to render a suitable, habitable and durable house.

The type of metal that shipping containers are made from is Cor-Ten® steel (Peña and Schuzer, 2012), which is also known as weathering steel which is an alloy steel mixed with other metals, in order to prevent further corrosion (Big Box, 2019). Shipping containers are available in various dimensions, however, the two commonly used dimensions are the 6m and 12m long containers that have the width of about 2.4m and a height of 2.7m. The height provides good ceiling height which complies with most clear ceiling height (i.e. 2.4m) required by the national building regulations (Bernardo *et al*., 2013), in SANS10400 part C. According to Bernardo *et al*. (2013), these types of containers are known as HC (High Cube), and their commercial names are 20'HC-6m long and 40'HC-12m long. [Refer to illustration by Bernardo *et al*. (2013) in Figure 2.1 and Table 2.1.]

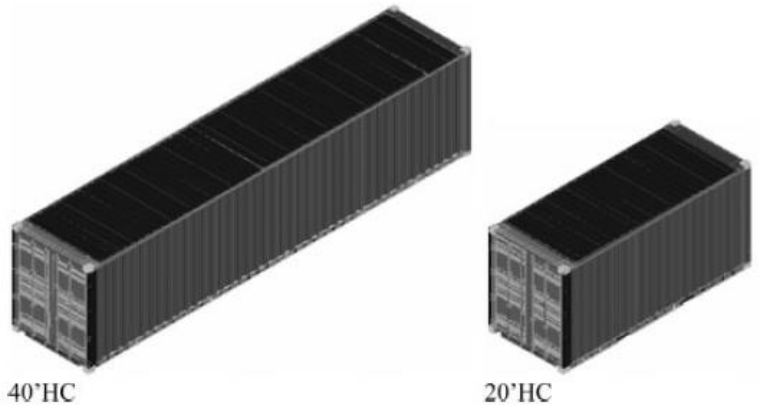


Figure 2.1: Containers 20'HC and 40'HC (Bernardo et al., 2013)

Table 2.1: Specifications of 20'HC-6m and 40'HC-12m containers adopted from Bernardo *et al*. (2013).

Model	Length (m), internal/external	Width (m) Internal/external	Height (m), Internal/external	Capacity volume (m^3)
20'HC - 6m long	5.9/6.0	2.34/2.40	2.71/2.89	**37.4**
40'HC - 12m long	12.0/12.2	2.34/2.40	2.71/2.89	**76.1**

The structural composition of shipping containers consists of steel frame work with composite steel sheet panels with a trapezoidal profile. These steel sheets form the horizontal top and bottom walls, the two vertical side walls and a vertical end wall and a set of double leaf doors on the other end. These parts are all joined together at the edges of the steel frame to form the container "box" (Bernardo *et al*., 2013). Figure 2.2 illustrates the basic structural composition of the shipping container. The vertical posts of the steel framework act as supporting columns that hold up the structure and bear the live and dead-loads. The horizontal posts of the steel framework act as self-supporting beams, the containers are fitted with a plywood flooring (Islam *et al*., 2016). The container structure has steel blocks to allow for connection between containers.

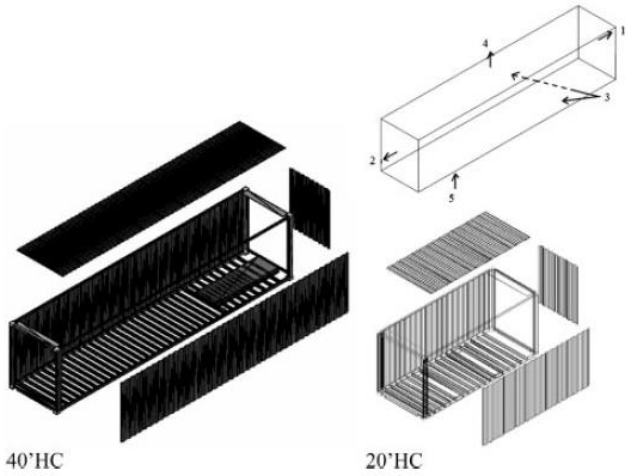


Figure 2.2: Container Composition (Bernardo et al., 2013)

2.2.3.3 What is Precast Concrete?

In understanding precast concrete modular construction, precast concrete must first be understood. Precast concrete refers to the process of firstly casting or forming of the concrete products in a mould at a factory, with reinforcement metal wires/rods added to provide additional strength to the cast concrete products then they are allowed to cure to their final form, hence the name "precast concrete" since the precast concrete is manufactured off site at a factory. This differentiates it from site cast or cast *'in situ'* concrete because precast concrete products are delivered to site for installation (Nitterhouse - Concrete Prouducts, 2019).

2.2.3.4 Precast Concrete in construction and Local Manufacturers

Rahima, Hamidb, Zena, Ismiala and Kamarb (2012) assert that precast concrete has been used in the building industry since the 1920s and has been gaining popularity since the 1950s. Manufacturers of precast concrete have broadened the range of precast concrete products by incorporating new design aesthetics of various shapes and finishes, which indicates that there is indeed a growth towards industrialization in construction, through implementation of industrialized building systems such as precast concrete panels and many more other precast concrete products. However, there is still a gap between the manufacturing industry and the construction industry because in this day and age buildings are still constructed using the conventional method of construction.

The research has identified a local company called ‘Concretex’, located in Cape Town, South Africa. This company has invented a Concretex Building System (illustrated in Figure 2.3) which is a prefabricated concrete modular building system that uses custom-made lightweight precast concrete panels that can be assembled as per the client’s design requirements (Concretex, 2019).

Concretex (2019) patented their innovative construction method in 1989. This concrete modular building system construction method has been implemented in the construction of medium size dwellings, school classrooms, offices, garages, etc. including the construction of affordable housing. However this innovative construction method has not been considered for implementation in the construction of government subsidy housing.

Figure 2.3: Conretex Building System (Concretex, 2019)

2.3 CONCLUSION

This chapter has highlighted the important research gaps that were reported in literature, which must be taken into account when addressing the improvement of subsidy housing delivery and subsidy housing projects in general. There is convincing evidence that the perceptions of the subsidy housing beneficiaries have not been measured towards subsidy housing projects, to determine the extent to which the subsidy housing programme fulfils its objectives and the needs of the end-users (Manomano, 2013).

Thus it is necessary to consider the involvement of informal settlement dwellers as the beneficiaries of subsidy housing, in the discussions about how their settlement should be upgraded as their input can be helpful in or with ensuring that their needs are addressed, and their living conditions and community social networks are not negatively impacted by the upgrade projects.

The following chapter discusses the methodology, research design, data collection and analysis, study population and sample, as well as the ethical considerations that were adopted and carefully applied in collecting data for this study.

Chapter 3 : RESEARCH METHODOLOGY AND DATA COLLECTION

3.1 INTRODUCTION

The previous chapters have carefully discussed the process of rural-urban migration as the root cause of the establishment of informal settlements, which has led to the increasing demand for housing. In addition, the increase in the establishment of informal settlements has been exacerbated by the delayed receipt of government subsidy housing as the nature of its construction is considered to be procedural and labour intensive, as a result it is time consuming.

The research has thus identified innovative construction methods that could be used to upgrade informal settlement and address the housing demand.

According to literature review, it is essential for the opinions of the community of an informal settlement (Del Mistro and Hensher, 2009) and other stakeholders in the construction industry to be taken into consideration in the process of upgrading or developing such a settlement.

Therefore, this chapter thoroughly discusses the research methodology that was adopted in this study for the purpose of allowing for the involvement of the abovementioned stake holders and acquisition of the relevant data to address the research attributes of this study and to archive the aims and objectives. The research methodology of this study will be analytically unpacked and structured as follows: (i) research design, (ii) research philosophy, (iii) research approaches, (iv) research methods, (v) research strategy, (vi) data collection methods, (vii) study population and sample, and (viii) ethical considerations.

3.2 RESEARCH DESIGN

Creswell (2014) defines ‘research design’ as “types of inquiry within qualitative, quantitative, and mixed methods approaches that provide specific direction for procedures in a research study”. This study has adopted the research structure depicted in the research onion diagram by Saunders, Lewis and Thornhill (2015), as the data collection techniques and analysis procedures form the center layers of the research onion, as illustrated in Figure 5. With regard to the application of the 6 stages of the reseach onion, each layer of the onion has to be figuratively peeled back one at

a time, therefore in this chapter, the layers/stages of the research onion are applied/address from the outer layer to the inner most layer.

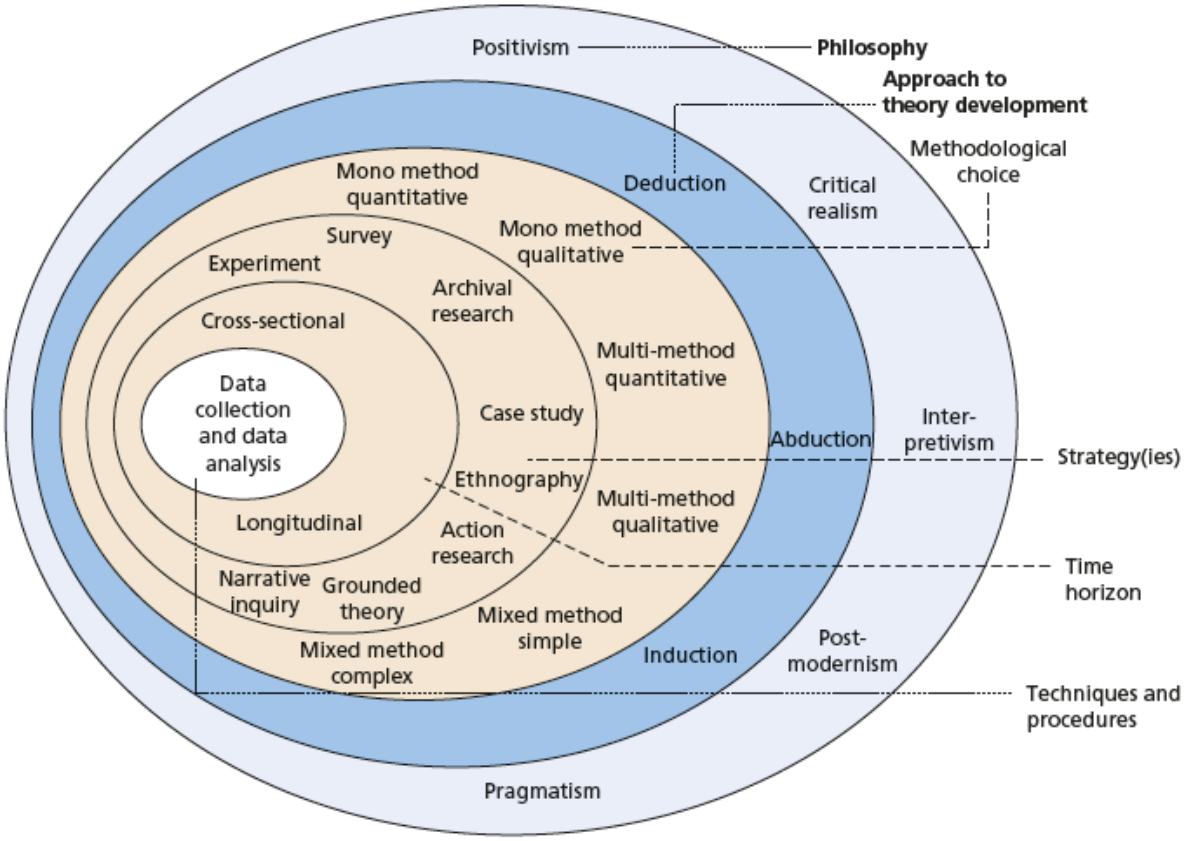


Figure 3.1: The Research Onion (Saunders et al., 2015)

3.2.1 Research Philosophy

Research philosophy forms the first outer layer of the research onion (Figure 3.1), it refers to the philosophical assumptions in line with the research that a researcher may possess when embarking on research (Saunders *et al*., 2015).

These Philosophical assumptions (hypotheses) assist in guiding the study for the purpose of developing knowledge in a particular field of study. Saunders *et al*. (2009) advice that “a well thought-out and consistent set of assumptions would constitute a credible research philosophy”, which would inevitably have a great impact on how the researcher understands the research questions, the methods used in data collection and interpretation of findings, furthermore, it would have influence the choice of research strategy that the researcher would adopt, which would ensure a comprehensible research project whereby all elements of the research fit and flow well together.

There are three types of philosophical assumptions that must be considered in order to distinguish the research philosophies. These assumptions include (i) Ontological assumptions – which are about the nature of reality that the researcher may encounter while embarking on research, which would influence the direction of the research, (ii) Epistemological assumptions – which are about knowledge, the extent of what is deemed to be authentic and acceptable knowledge and the manner in which it can be communicated to others, and (iii) Axiological assumptions – which are based on the values and ethics of the researcher and the research participants within the research process (Saunders *et al*., 2015).

Figure 3.2 illustrates the reflexive process of developing the research philosophy in research, which requires the researcher to reflect on the research assumptions in relation to the five research philosophies (shown in Figure 3.1) and the research design.

According to Saunders *et al.* (2015), the research philosophies can be classified as:

i. Positivism – refers to a philosophical approach affirming that certain knowledge is based on natural phenomena that can be scientifically verified. It focuses strictly on scientific methods designed to yield pure and accurate data that is uninfluenced by human interpretation or bias opinions. Furthermore, it emphasises on quantifiable observations resulting in statistical analysis.
ii. Critical realism – refers to a philosophical approach that distinguishes between the real world and the observed world. It focuses on elucidating what humans see, experience and understand in terms of reality events that shape the observable events, and it identifies a relationship between what is real in terms of nature and human observations, perceptions and theories.
iii. Interpretivism – refers to a philosophical approach that emphasises that humans are different from physical realities; interpretivists argue that different people from different disciplines, backgrounds and cultures, would experience the social realities in different ways.
iv. Postmodernism – aims to challenge the established/accepted ways of thinking therefore giving voice to the alternative suppressed views.
v. Pragmatism – this approach is more interested in the practical outcomes (i.e. theories, hypotheses and research findings), as it strives to reconcile facts and values, objectivism and subjectivism, as well as logical knowledge and contextualized experiences.

A positivist paradigm was adopted in this study, as it allowed the researcher to make use of existing theory to formulate hypotheses, and Saunders *et al*. (2015) affirm that this is a plausible approach for positivists due to the quantifiable data (quantifiable observations) that they collect. Other qualities of positivists include the use of scientific methods, statistical analysis of the collected quantifiable data, unbiased approach and generalizable findings. Which render this approach suitable for a survey type of research strategy (discussed in section 3.2.3).

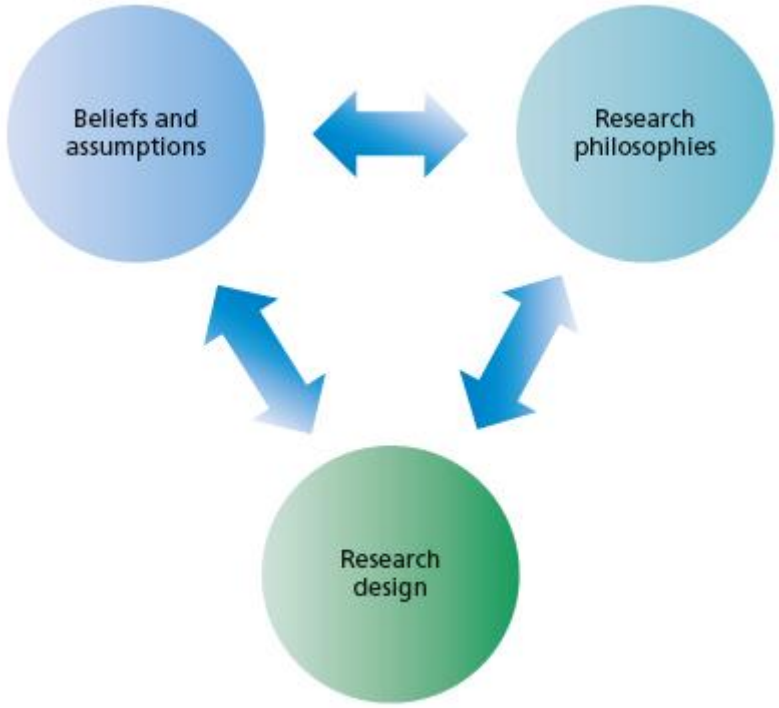


Figure 3.2: A reflexive Process to Developing a Research Philosophy (Saunders et al., 2015)

3.2.2 Research Approaches

The second layer of the research onion (Figure 3.1), addresses the reasoning adopted in the research. Reasoning refers to the act or process of thinking or arguing in a logical and sensible manner, with the aim of drawing a conclusion or judgement (Merriam-Webster, 2019). Therefore, this layer of the research onion deals with the process of choosing the suitable reasoning approach to the research. The two most common contrasting approaches of reasoning that a researcher can adopt include: (i) deductive and (ii) inductive reasoning; the major differences between these approaches are depicted in Table 3.1. However, according to Ketokivi and Mantere (2010), there is a third reasoning approach to theory development known as abductive reasoning, similarities and differences of all the three approaches are explored in Table 3.2.

3.2.2.1 Deductive Reasoning Approach

Deductive reasoning occurs when a conclusion is drawn logically from a set of assumptions or statements, after assessing the scientific evidence that can either validate or invalidate these assumptions or statements. According to Ketokivi and Mantere (2010), in order to logically establish or deduce a true conclusion, all the formed assumptions (hypotheses) observed must be true, as recorded by Saunders *et al.* (2015).

The diagram presented in Figure 3.3, graphically illustrates the different processes undertaken by both the deductive and the inductive approaches. In this diagram it can be seen that the deductive reasoning begins with the development of a theory about the identified problem which the researcher endeavours to investigate; the theory is then narrowed down to a series of hypotheses (propositions) that are subject to rigorous testing. The appropriate data (observations) is collected through literature review and other methods of data collection to allow the researcher to test the hypotheses, and to measure certain variables and analyse them with specific evidence on the identified theory in order to draw conclusions that can either confirm the theory or indicate the need for its modification if necessary (Saunders *et al*., 2015).

3.2.2.2 Inductive Reasoning Approach

In contrast, inductive reasoning is the opposite of deductive reasoning or rather an alternative approach to developing theory. Saunders *et al.* (2015) elucidate that in inductive reasoning, there is a gap in the logic argument between the drawn conclusion and the assumptions (findings) observed. In this case inductive reasoning refers to the process whereby investigations are carried out, then the gathered findings are analysed to form a true conclusion.

Inductive reasoning begins with the researcher comprehensively observing a phenomena under investigation through the use of inductive methods of data collection. Then the collected data is analysed to study the themes and patterns in the observations (findings), a generalization is then developed based on the investigation of these themes and the outcome of the analysis is used to formulate a theory (Saunders *et al*., 2015).

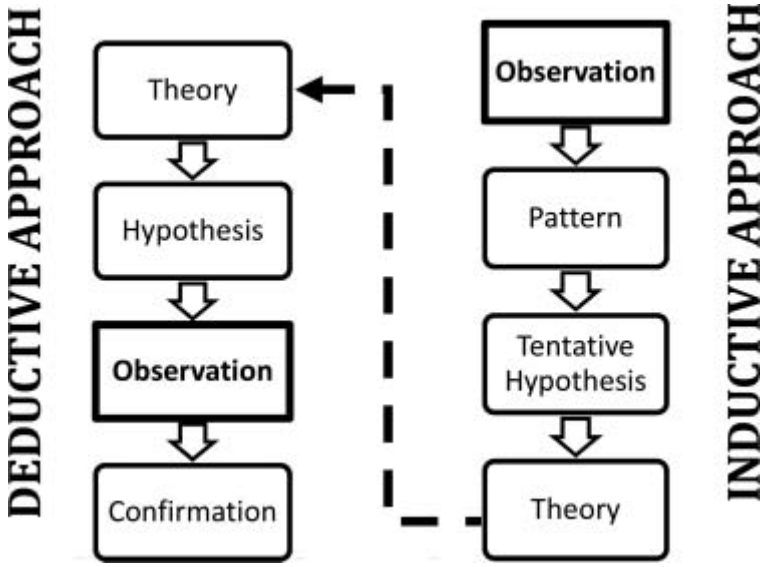


Figure 3.3: Deductive vs. Inductive Reasoning Approaches (Balderacchi et al., 2013)

3.2.2.3 Abductive Reasoning Approach

The abductive reasoning approach successfully combines both the deductive and inductive reasoning approaches, instead of progressing from theory to data (as in deduction) or from data to theory (as in induction), it goes back and forth. Saunders, Lewis and Thornhill (2009), noted that "abduction begins with the introduction of a 'surprising fact', it then works out a plausible theory of how this could have occurred". These surprising facts can occur at any stage of the research, either at the beginning of the research when a researcher has a new theory to investigate based on existing information, during or at the end of research when a researcher uncovers new theories which have never been investigated. Therefore the deductive and inductive reasoning approaches indeed complement the abductive reasoning approach as logic for testing plausible theories (Saunders *et al*., 2015).

For the purpose of this study, the deductive reasoning approach was adopted due to the fact that it is a highly structured approach that progresses from theory developed from the academic literature review and other data collection methods, with a research strategy designed to test the theory. Furthermore, this approach allows for the collection of quantitative data, the application of controls to validate the collected data, and it allows for the necessity to select sizable samples in order to generalize the conclusions from observations (Saunders *et al*., 2009).

Table 3.1: Major differences between deductive and inductive approaches to research as adopted from Saunders *et al.* (2009)

Deduction Emphasises	Induction Emphasises
▪ Scientific principles ▪ Moving from theory to data ▪ The need to explain causal relationships between variables ▪ The collection of quantitative data ▪ The application of controls to ensure validity of data ▪ The operationalisation of concepts to ensure clarity of definition ▪ A highly structured approach ▪ Researcher independence of what is to be researched ▪ The necessity to select samples of sufficient size in order to generalise conclusions	▪ Gaining an understanding of meanings humans attach to events ▪ A close understanding of research context ▪ The collection of qualitative data ▪ A more flexible structure to permit changes of research emphasis as the research progresses ▪ A realisation that the researcher is part of the research process ▪ Less concern with the need to generalise

Table 3.2: Similarities and differences between deduction, induction and reduction approach (Saunders *et al*., 2015)

	Deduction	**Induction**	**Abduction**
Logic	In a deductive interference, when the premises are true, the conclusion must also be true	In the an inductive interference, known premises are used to generate untested conclusions	In an abductive interference, known premises are used to generate testable conclusions
Generalisability	Generalising from the general to the specific	Generalising from the specific to the general	Generalising from the interactions between the specific and the general
Use of data	Data collection is used to evaluate propositions or hypotheses related to an existing theory	Data collection is used to explore a phenomenon, identify themes and patterns and create a conceptual framework	Data collection is used to explore a phenomenon, identify themes and patterns, locate these in a conceptual framework and test this through subsequent data collection and so forth

Theory	Theory falsification or verification	Theory generation and building	Theory generation or modification; incorporating existing theory where appropriate, to build new theory or modify existing theory

3.2.3 Research Methods

The third layer of the research onion (Figure 3.1) addresses the research methods/methodology adopted in the research. According to Durrheim, Painter and Terre Blanche (2006), the concept of '*research methodology'* refers to the methods that researchers utilise in conducting a research for the purpose of data collection, while Creswell (2014) elaborates that, '*research methodology'* refers to the research methods used by the researcher in carrying out the research for the purpose of data collection. These methods can either be quantitative (which focuses on acquiring a numerical value of information from responses of the participants) or qualitative (which focuses more on acquiring detailed information through the administration of among other research instruments, open-ended, otherwise called structured questions, in closed session interviews). Creswell (2014) advises that both approaches can be used or triangulated together as a mixed methods approach, as this approach incorporates elements of both quantitative and qualitative approaches, as shown in Figure 3.4.

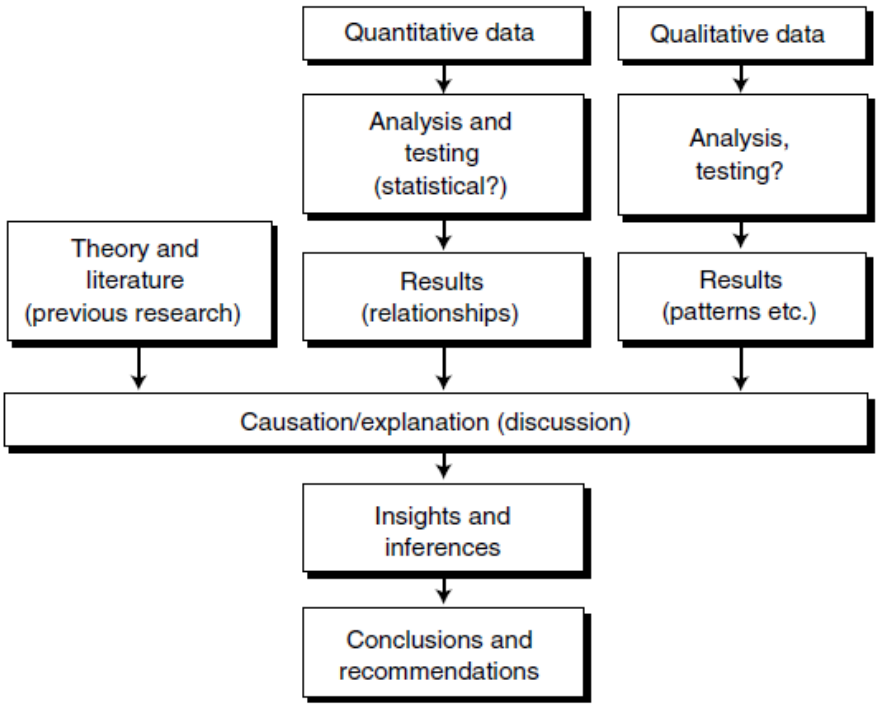


Figure 3.4: Triangulation of Quantitative and Qualitative Methods (Fellows and Liu, 2015)

The research methodology that was found suitable to achieve the aims and objectives of this study and assist the researcher in acquiring of a numeric and detailed description of the opinions of the population that was sampled, was a mixed methods approach that includes the use of a quantitative approach with a statistically insignificant qualitative element.

The triangulation (Figure 3.4) of the methods of inquiry enabled the research to gain in-depth information on the potential use of the proposed innovative methods of construction for subsidy housing. The quantitative approach was aimed at acquiring a numeric measurement of the level of satisfaction and social acceptance from the specific participants who would be the potential end users of these proposed structures, while the qualitative approach was aimed at obtaining detailed information from the key informants of this study, which are the professionals in the Architecture, Engineering and Construction (AEC) industry with specific regards to the implementation of the proposed innovative methods of construction as alternatives for subsidy housing and other architectural applications (Creswell, 2014). It also allows for the use of descriptive statistics to analyse data (Brown, 2011). According to McKenna and Main (2013), key informants are very important as they are more knowledgeable and can provide vital information that is relevant to the study. Their perspectives can have influence on particular areas of the study.

A comparative study between the conventional method of construction and the two proposed innovative methods of construction for subsidy housing was conducted, to evaluate the used materials, required level of skilled labour, cost effectiveness and time taken for construction between these construction methods.

3.2.4 Research Strategy

The forth layer of the research onion (Figure 3.1) addresses research strategies, which according to Saunders *et al.* (2015), these research strategies includes: (i) Experiment, (ii) Survey, (iii) Archival research, (iv) Case Study, (v) Ethnography, (vi) Action Research, (vii) Grounded theory and (viii) Narrative Inquiry.

For the purpose of this study, the survey strategy was used, as it is usually associated with the deductive approach and the most commonly used strategy, as it helps the

researcher to answer the ‘who, what, where, how much and how many’ questions which makes it ideal for exploratory and descriptive research (Saunders *et al*., 2009). The survey research strategy was found suitable for this study as it allows the researcher to collect large amounts of data from a sizeable population by means of administering a questionnaire to a sample of the population (Saunders *et al*., 2009), and it allowed the researcher to acquire a numerical value (quantitative data) of information from responses of the participants.

Therefore, this strategy was favourable to the research as it gave the researcher control over the whole research process to generate findings from a sample (portion) of the population that are representative to the whole population, which works out to be time-saving and cost effective for the research instead of collecting data from the whole population.

3.3 DATA COLLECTION AND ANALYSIS

Data collection and data analysis form the inner layer of the research onion (Figure 3.1).
Data collection is discussed in this section (3.4) and data analysis is explicitly discussed in the next chapter (chapter 4).

The data collection methods for this study were through a Desktop Survey and Site Survey.

The Desktop Survey included sourcing information from electronic and print media, books, literature review and simulations of basic designs (Chapter Four discusses this sourced information to further detail), while the Site Survey was in the form of administration of questionnaires in order to facilitate Focused Group Discussions (Focus Group) assessing the opinions of a mixed group of participants (e.g. professionals in the AEC industry, informal settlement dwellers, RDP house dwellers, low-cost housing candidates and ordinary conventional construction residence dwellers) on the implementation of the proposed innovative methods of construction as alternatives for subsidy housing and other architectural applications.

In addition, the Site Survey was conducted to further facilitate the involvement of the community, as according to Del Mistro and Hensher (2009) it is imperative that the community members of an informal settlement be involved in the process of their

settlement. Therefore, a structured questionnaire was administered to the mixed group of participants in the Port Elizabeth area for the purpose of data collection. The gathered findings have been analysed in the form of graphs, tables and reports.

3.4 STUDY POPULATION AND SAMPLE

The research drew/obtained samples from a mixed group of participants, as the research had different attributes to investigate. The groups of participants were divided and identified as sample group A participants – comprising of (i) professionals in the AEC industry, and sample group B participants – comprising of (ii) informal settlement dwellers, (iii) RDP house dwellers, (iv) low-cost housing candidates and (v) conventional construction residence dwellers, as shown in Table 3.3.

According to Neuman (2014), a sample can be defined as a portion of the population from which the research investigations would be conducted. The participants that were involved in this study were strategically selected in accordance with the research attributes that aligned with the purpose of this study, which the research endeavoured to investigate. The participants in sample group A, were professionals in the AEC industry, who were selected to offer their specialist knowledge in the industry to address specific attributes of the study. This group of professionals included Architects, Contractors, Engineers, Quantity Surveyors and suppliers of construction materials. However, the participants in sample group B, were selected to offer their opinions about the proposed innovative methods of construction, based on their experience on the type of dwellings that they are currently living in.

Table 3.3: Self-Administrated Questionnaires

Number	Survey Sample Group	Sample Scale
1.	Sample Group A - Professionals in the AEC	20
2.	Sample Group B - Residents	40
Total		**60**

3.5 ETHICAL CONSIDERATIONS

According to Creswell (2014), where a research design includes discussion of any qualitative elements, the importance of ethical considerations must be addressed. Creswell (2014), further states that the researcher is under obligation to respect the rights, values, needs as well as the desires of the participants. Therefore, all participants in this study were treated with respect and dignity and were not forced to

participate against their will. Participants were made aware of their rights to withdraw from the proceedings/interviews at any given time.

A consent form was given to each participant to signoff, to grant permission that the information that they have provided may be used in this study. The consent form in question was written in the English language, however, the researcher was able to translate it to the isiXhosa speaking participants who do not understand English very well, to ensure that they can fully comprehend what the research entails and what is required from them. The researcher ensured that any information that was obtained from participants does not reveal or expose the personal identity of the participants. Participants were given a chance to read and approve the final draft of their responses before it is analysed, and interpreted. The Nelson Mandela University (NMU) ethics code was followed.

Chapter 4 : DATA ANALYSIS AND APPROACH TO INTERPET THE FINDINGS

4.1 INTRODUCTION

The previous chapter explained that the data collection methods for this study were through a Desktop Survey and Site Survey. Therefore, this chapter first discusses the Desktop Survey findings which include extensive research on (i) the proposed innovative housing construction methods that could be used for subsidy housing construction. Then secondly, this chapter discusses the (ii) findings acquired through the Site Survey, which are analysed, interpreted in full detail and presented in the form of reports, tables and graphs. Lastly, this chapter presents a (iii) comparative study of the proposed innovative housing construction methods against the currently used conventional construction method and (iv) evaluates the hypotheses.

4.2 PROPOSED INNOVATIVE HOUSING CONSTRUCTION METHODS

The research has identified two innovative prefabricated modular construction methods e.g. (i) shipping container construction and (ii) precast concrete modular construction, which the research espouses as having potential to be applied as construction alternatives for subsidy housing which would require additional architectural flair and innovative construction application methods in order to achieve an aesthetically appealing and socially acceptable appearance. Therefore, this study discusses the two identified innovative construction methods in great detail and compiles a comparative study of these two alternative methods against the currently used conventional method of construction in SA.

4.2.1 Shipping Container Construction

4.2.1.1 Background Study on Shipping Containers

Due to the high cost of transporting empty shipping containers back to their origins, companies nationwide that are involved in merchandise imports and exports prefer to leave them in the ports of destination, whereby they accumulate and take up huge amounts of space at seaports (Islam *et al*., 2016). Peña and Schuzer (2012) documented that “these unused containers take up valuable space at shipping docks while waiting to be loaded, repositioned to different locations, resold or disposed of”. In 2014, Martinez-Garcia recorded that there was an estimated 300 million shipping containers, which were just occupying space at many sea ports all over the world, these containers can be repurposed for reuse as homes, as they provide a sturdy and

long lasting structure. People in general, however, more especially the informal settlement dwellers, need to be educated on the features of shipping container homes. Islam *et al*. (2016) believes that the reuse of this large surplus of shipping containers for home building purposes must be given further attention due to development of technical innovation whereby containers have been successfully converted into various architectural forms such as classrooms, clinics, offices, emergency shelters, etc. however, this kind of building innovation has not been fully explored in South Africa, as the current conventional method of construction remains dominantly used.

The reuse of shipping containers for subsidy housing construction can yield the following benefits amongst others:

- Reduced need for new construction materials compared to conventional construction;
- Reduced construction costs;
- Reduced construction time, due to the standardized sizes of shipping containers; which makes them suitable for modular construction;
- Fast tracked delivery of subsidy housing;
- Potential reduction of subsidy housing demand; and,
- Reduced carbon foot print/ emissions and energy savings.

4.2.1.2 Advantages

The use of shipping containers for housing construction presents numerous advantages e.g. they are sturdy, water, wind, rust, mold, and pest resistant, and they are made of non-combustible material and are therefore fire resistant (Martinez-Garcia, 2014). Their use would reduce the prevailing number of fire incidents in informal settlements. A case in point is, in October 2018, fires raged with unrelenting force in the informal settlement of Khayelitsha in Cape Town, killing at least one person and destroying 500 shacks. It was recorded in Financial Mail (2018), that according to Stats SA, each shack in Khayelitsha had 3.3 occupants on average, which means that about 1,500 people lost their shelter during this fire disaster. Due to the lack of planning in the Khayelitsha informal settlement, with shacks built right close to each other leaving very narrow paths used to navigate the settlement, the firefighting trucks were unable to gain access (Financial Mail, 2018).

Another advantage noted with using shipping container units for home construction is that they are versatile, they can be assembled into multiple layouts and be pre-fitted

with the typical building services (i.e. water, drainage and electricity) to make them self-sufficient (Peña and Schuzer, 2012). Shipping containers can be used to provide single homes for subsidy housing. With some additional decorative architectural features, the shipping container can look lavish and spacious as any traditionally built home[1] or can be stacked like building blocks to provide multi-storey structures for low-cost housing[2]. With low-cost housing, affordability should be paired with sustainability to reduce maintenance costs (Manshawy, Shafik and Khedr, 2016), as the government cannot afford to provide housing and in addition to that provide maintenance for the housing. The houses must be constructed in such a manner that they require very little or no maintenance.

According to Bernardo *et al*. (2013) the use of these units contributes towards recycling and construction sustainability.

A number of container building constructions e.g. single-family buildings, dormitories, site offices etc. have been in existence for over a decade in many countries across the world including South Africa, as reported by Bernardo *et al*. (2013), however, this method of construction has not been considered for implementation in subsidy housing construction in South Africa.

[1] Figure 4.1: Single Home Unit example (Martinez-Garcia, 2014) http://www.winghouses.com/gallery.html

[2] Figure 4.2: Multi-Storey Units example (Martinez-Garcia, 2014) https://www1.nyc.gov/site/whatifnyc/index.page

Figure 4.1: Single Home Unit example (Martinez-Garcia, 2014)

Figure 4.2: Multi-Storey Units example (Martinez-Garcia, 2014)

4.2.1.3 Disadvantages

As previously mentioned, the use of shipping containers can present numerous advantages; they can also present a few disadvantages. They are known to be made of a thin metal structure, they are not insulated which renders them to be acoustically inferior in terms of sound and thermal insulation, therefore comfortability would be an issue in this regard (Peña and Schuzer, 2012), which may be observed as a disadvantage. However Islam *et al.* (2016) suggests that insulation technologies can be fitted in these structures to improve their acoustics properties although this fitting may require additional costs to implement.

One other disadvantage documented by Islam *et al*. (2016), which poses difficulty in working with shipping containers in the construction industry is that current building regulations do not recognise shipping containers as a building material. Islam *et al*. (2016) asset that there are a few aspects that must be considered when using shipping containers for home construction, such as i) the thermal performance – in order for the container to be suitable for local climate conditions, ii) energy consumption, iii) environmental impact and lastly iv) ensuring that the container home is as habitable as the conventional residences.

There is a number of local companies, which specialise in sales of new and used shipping containers for various purposes. However, there are a few companies that convert and customise the shipping containers to living spaces made with a careful design consideration of the number of individuals who would be sharing the space. They also take into account the right living conditions appropriate for a family. The modularity and uniformity of these structures allows for efficient building construction, therefore substituting the current conventional method of construction with the use of shipping containers as an alternative method for subsidy home construction would assist greatly in reducing the prolonged waiting period for receipt of subsidy housing and alleviate the housing demand as well as reducing the number of containers taking up space at sea ports.

4.2.1.4 Design philosophy of a container house (on and off site work)

In order to secure the container house structure, a concrete surface bed with a shallow foundation must first be cast in place on site to provide a plinth, onto which the container will be placed. Peña and Schuzer (2012) suggests that concrete piers can be set up on top of the concrete foundation to keep the container off the ground, however this would create a void below the container. Therefore, it is advised that a short wall must be built around the bottom of the container to conceal the void below the container, air-bricks can be added to such a wall to allow for adequate ventilation below the container. Alternatively the void below the container can be filled with hard-core fill with a concrete floor slab cast over the filling to create a plinth onto which the container would be placed. The concrete slab would provide additional sound insulation to the hallow floor base of the container structure and eliminate the noisy sound that may be caused by foot traffic.

Another option that can be considered is to remove the existing steel and plywood floor base of the container and raise the concrete plinth to provide a concrete floor for the container house[3], this option would allow for the possibility to install certain durable floor finishes (i.e. tiles).

The bottom of the container would be bolted on to the concrete surface bed or welded onto the steel plates that will be entrenched into the concrete surface bed.

With the use of shallow foundations the construction of complex foundations is not required, this would eliminate the need for major excavation works (Peña and Schuzer, 2012). Final installation of the container which includes permanent fixing of the container house to the ground, installation of municipal services (e.g. water, drainage and electricity), and installation of other building components (e.g. floor finish, windows, doors, cabinetry, sanitary fittings, geyser, pitched roof, etc.) would all take place on site.

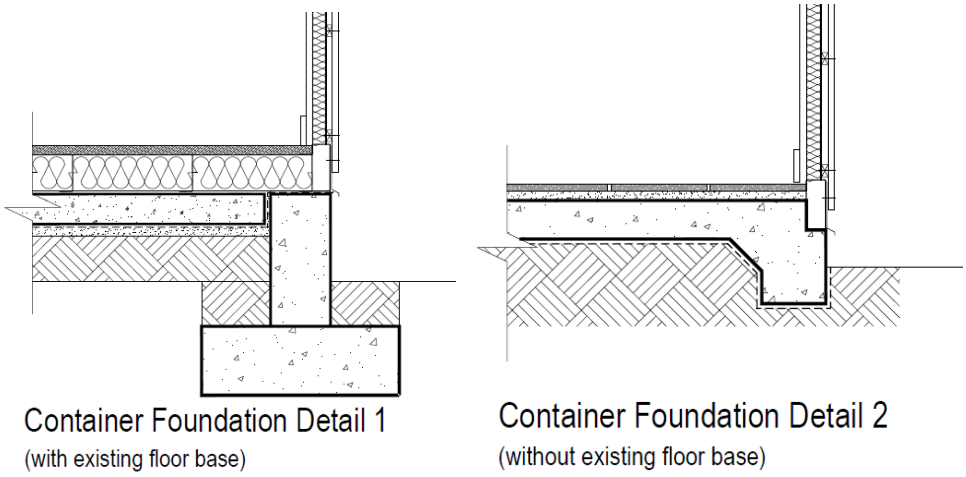


Figure 4.3: Container House Foundation Details

Prefabrication of the container would take place off site in a factory, whereby the container house can be pre-fitted with all the required building components (Islam *et al*., 2016), such as insulation, drywall systems, painted weatherproof external wall cladding, electrical fittings (e.g. lights, plugs and switches) and ceiling, all to be in accordance with the national building regulations. The prefabricated container can be transported to the construction site for final installation. Once the container house has been secured to the foundation, the angled roof design can be constructed as a final

[3] Figure 4.3: Container House Foundation Details

touch to the container house, to add a modern aesthetically pleasing appearance to the final look of the container house, which would be socially acceptable and pleasing to the eye. This would ensure that the final look of the container house matches that of a typical conventional construction house[4].

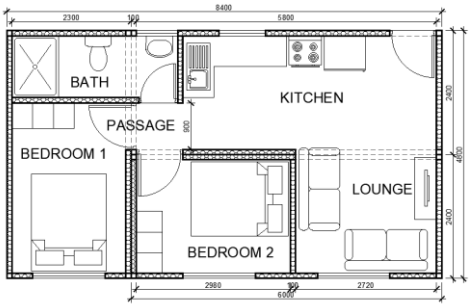
InSoFast (2019) is a manufacturer of insulation systems and has a variety of insulation types that can be used for shipping container homes. Out of the variety of insulation types manufactured by InSoFast (2019), the Expanded Polystyrene (EPS) foam continuous insulation panels is the most appealing option, as it can be used on the interior and exterior walls of any container intended for building purposes to provide an even smooth surface for installation of drywall panes or other wall finishes and to ensure that the container is well insulated and comfortable. Additional benefits of the EPS foam panels manufactured by InSoFast (2019) include cost-effectiveness, has very high R-values and easy installation as illustrated in Figure 4.4.

Figure 4.4: InSoFast Insulation Panels (InSoFast, 2019)

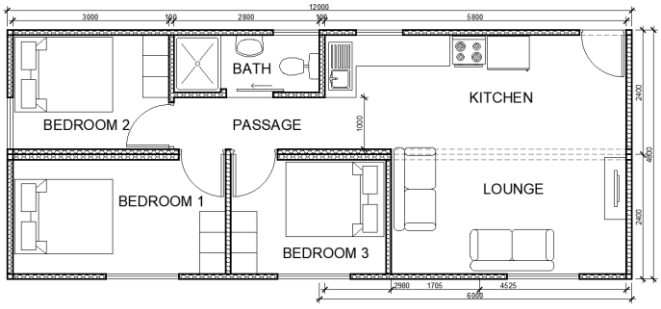
Container units can be arranged into a number of different layouts to accommodate the special requirements of a single family. In Figure 4.5, the research has illustrated three different floor plan layouts that can be achieved by making use of different combinations of the container units. Layout 1 uses three 6m long containers. Layout 2 uses two 12m long containers; while Layout 3 uses a combination of the 6m long container and the 12m long container. The 6m long containers are ideal to work with

[4] Figure 4.6: Container House - Elevations of Layout 1 & 2, Figure 4.7: Container House - Elevations of Layout 3

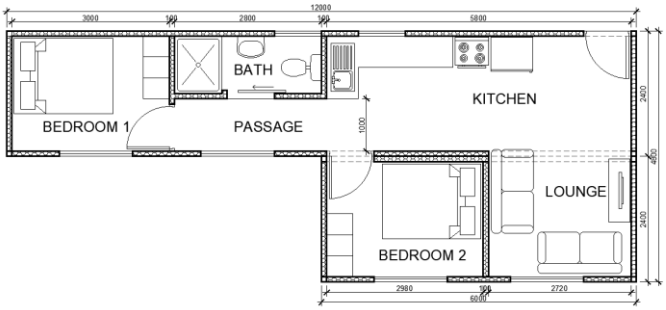
in building construction, as they are not too long, they are easy to work with and manoeuvre on site with a crane, and they would be easy to transport with trucks being able to load two of the 6m long containers at a time.



FLOOR PLAN - LAYOUT 1
(using 3 containers - 3 x 6m long containers)



FLOOR PLAN - LAYOUT 2
(using 2 containers - 2 x 12m long containers)



FLOOR PLAN - LAYOUT 3
(using 2 containers - 12m long & 6m long container)

Figure 4.5: Single Family Container House - Layout 1, 2 and 3

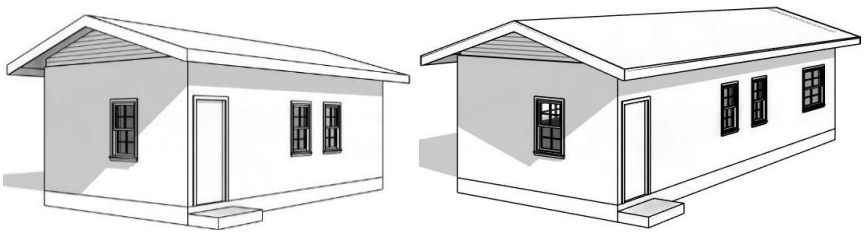


Figure 4.6: Container House - Elevations of Layout 1 and 2

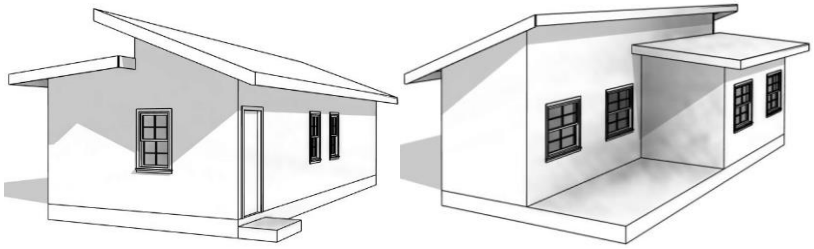


Figure 4.7: Container House - Elevations of Layout 3

4.2.2 Precast Concrete Modular Construction

4.2.2.1 Background Study on Precast Concrete Modular Construction

According to Gunawardena *et al*. (2014) the use of innovative prefabricated modular structures is one key strategy used to achieve variables such as cost effective housing, reduced construction periods and improved environmental performance. In addition prefabricated modular structures such as concrete modular construction (e.g. precast concrete panel systems) can potentially fast track housing delivery due to the fact that they can be manufactured or mass produced off site in a quality controlled factory with all the necessary architectural aesthetic finishes and required services pre-fitted so the structures are ready to be delivered and assembled in place on site. The building components of the precast concrete panels can be mass produced into modular systems that are sized to suit transportation and lifting by crane. The use of prefabricated modular systems has proven to be good; reducing construction time by 50% (Lawson *et al*., 2012) and in reducing construction waste by up to 52% compared to conventional construction (Jaillon *et al*., 2009), this mainly through minimizing off-cuts of materials.

Gunawardena *et al*. (2014) conducted a comparative analysis on three material options steel, concrete and timber, they discovered that due to the less intense manufacturing processes used to produce concrete, a concrete building would result in lower embodied energy compared to that of steel and timber buildings, Figure 4.8 illustrates the findings of Gunawardena *et al*. (2014) which confirm that the use of concrete “has the potential to contribute significantly towards improved environmental sustainability in the construction industry while providing fast outputs with value for the investments”.

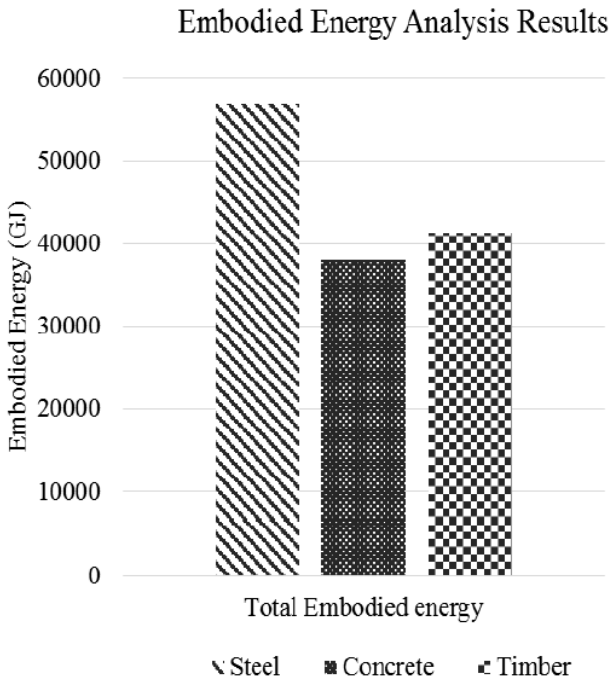


Figure 4.8: Comparison of Total Embodied Energy between three building materials (Gunawardena et al., 2014)

4.2.2.2 Advantages

The use of precast concrete modular construction can bring about potential environmental benefits such as energy savings and efficiency of building material usage (material waste reduction) (Gunawardena *et al*., 2014). In addition these precast concrete modules can be designed in such a way that they have an interlocking system of assembly and can be easily removed from the main structure for the purpose of future reuse, relocation, or rearrangement to allow for any desired future extensions (Rahima *et al*., 2012).

Precast concrete modular construction can provide the convenience of fast housing delivery, which allows houses to be habitable much sooner compared to the conventional method of construction (Gunawardena *et al*., 2014).

The concept for pre-constructed building sections/modules can be applied as an innovative alternative method to subsidy housing construction with the aim to fast track delivery and reduce construction costs. The ‘Little Hero’ multi-storey apartment block located in Melbourne, Australia is a good example (see Figure 4.9) to demonstrate how massive building construction can be completed in a short time frame as it was constructed within 8 days with minimal work on site. An added advantage that comes with this concept is that when building components are pre-built or pre-constructed in

a factory, this offers better quality control and eliminates weather delays (JWCC, 2019).

Figure 4.9: Multi storey modular building - 'Little Hero' in Melbourne, Australia (Gunawardena et al., 2014)

The Concretex Building System uses precast concrete panels illustrated in Figure 4.10a, that are manufactured at a height of 2.4m which complies with national building regulations for head clearance height. These precast concrete panels have an interlocking tongue-and-groove joint system to allow panels to be fixed to one another. Once all panels are fixed in place they are plastered to conceal the fixing joints. All panels are cast with openings for doors and windows, including conduiting for plumbing and electrical services as illustrated in Figure 4.10b, to minimise the need for additional sub-contractors on site (Concretex, 2019). Concretex (2019) manufacture their own windows and doors to ensure that the sizes are as required to avoid quality-control issues.

Figure 4.10: (a) Concretex Building System and (b) Conduiting cast into panels (Concretex, 2019)

4.2.2.3 Design Philosophy

Concretex (2019) assures that the modularity of the Concretex Building System reduces construction time significantly, as it guarantees structures to be constructed at a much greater speed that is about 4 to 5 times faster compared to conventional construction.

This building system requires a shallow concrete foundation to form a plinth, on to which the concrete modular structure can be built. Concretex Building System can then be delivered and assembled on site. This building system doesn't require the use of any complex tools, due to the fact that the precast concrete panels have an interlocking tongue-and-groove joint system to allow panels to be fixed to one another, once all panels are fixed in place they are plastered to conceal the fixing joints as illustrated in Figure 4.11a (Concretex, 2019).

Windows and doors are installed simultaneously with the precast concrete panels as they are designed to clip into the tongue-and-groove joint system. Once the concrete modular shell is up (see Figure 4.11b), other building components and finishes such as floor finish, cabinetry, sanitary fittings, roof structure, painting etc. are installed last, to finish the building off (see Figure 12).

Figure 4.11: (a) Plastered walls and (b) Roof installation on complete modular shell (Concretex, 2019)

Figure 4.12: Appearance of the Completed Building - Concrete Modular Construction (Concretex, 2019)

4.3 ANALYSIS, INTERPRETATION AND PRESENTATION OF FINDINGS

The data collection was through the administration of 2 different questionnaires, A and B, targeted at acquiring data on specific study attributes. Questionnaire A – was an electronic questionnaire that was sent via email to sample group A participants, while Questionnaire B – was self-administered through closed session interviews with sample group B participants. Sample group A consisted of a total number of 20 participants and sample group B consisted of a total number of 40 participants.

4.3.1 SAMPLE GROUP A FINDINGS

4.3.1.1 Occupation of study participants – Sample Group A

Questionnaire A was administered to sample group A, which consisted of 20 different professionals in the AEC industry from PE. The number ratios of the population are presented in Table 4.1, while the percentage ratios are presented in Figure 4.13. According to Neuman (2014), a sample refers to a sizeable portion of the population from which the research investigations would be conducted.

Table 4.1: Occupation of study participants – Sample Group A

No.	Occupation	Frequency of responses	Percentage
1.	Architect	5	25%
2.	Structural Engineer	5	25%
3.	Contractor	5	25%
4.	Quantity Surveyor	5	25%
5.	Other		
Total		**20**	**100%**

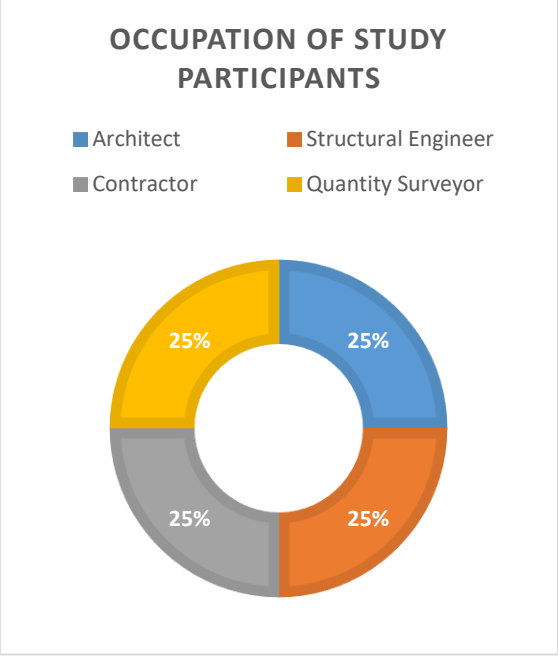


Figure 4.13: Sample Group A - Professionals in the AEC Industry

4.3.1.2 Estimated cost - Conventional Construction

The findings for this study revealed that out of the total of 20 professionals that were surveyed, a small portion of only 5% of the participants estimated the cost for a 40sqm government subsidy house constructed using the conventional method of construction (brick and mortar) to be between R151 000 – R200 000, however majority (75%) of them estimated the cost to be between R201 000 – R250 000 and the other 20% of the participants estimated the cost to be between R251 000 – R300 000. Therefore based on the ranking presented in Table 4.2 and the percentage distribution of responses presented in Figure 4.10, it was established that the cost of constructing a standard 40sqm subsidy dwelling using the conventional method of construction is believed to be approx. R201 000 - R250 000.

With regards to using shipping container construction for constructing a 40sqm subsidy house, the findings revealed that out of the total of 20 professionals that were surveyed, the majority (75%) of them estimated the cost to be between R100 000 – R150 000 and only a small portion of about 25% estimated the cost to be between R151 000 – R200 000. Therefore based on the ranking presented in Table 4.2 and the percentage distribution of responses presented in Figure 4.14, it was established that the cost of constructing a standard 40sqm subsidy dwelling using shipping container construction is believed to be approx. R100 000 – R150 000.

The findings also revealed that if concrete modular construction was used to construct a 40sqm government subsidy house, only 5% of the surveyed participants have estimated the cost to be between R100 000 – R150 000, however the majority (90%) of the participants estimated the cost to be between R151 000 – R200 000 and the remaining 5% estimated the it to be between R201 000 – R250 000. Therefore based on the ranking presented in Table 4.2 and the percentage distribution of responses presented in Figure 4.10, it was established that the cost of constructing a standard 40sqm subsidy dwelling using concrete modular construction is believed to be approx. R151 000 – R200 000.

The above findings indicate that the estimated cost of using the conventional method of construction to construct a standard 40sqm subsidy unit is very high (R201 000 - R250 000) compared to a subsidy unit constructed using concrete modular construction (R151 000 – R200 000) or shipping container construction (R100 000 – R150 000). It is clear that out of the 3 methods of construction, the proposed innovative

methods of construction can reduce construction costs drastically as their costs were estimated to be relatively lower than the cost of the currently used conventional method of construction.

Table 4.2: Estimated cost - Conventional Construction

No.	Conventional Construction	Frequency of responses	Ranking
1.	R 100 000 – R 150 000	0	4
2.	R 151 000 – R 200 000	1	3
3.	R 201 000 – R 250 000	15	1
4.	R 251 000 – R 300 000	4	2
5.	Other:		
Total		**20**	
No.	**Shipping Container Construction**	**Frequency of responses**	**Ranking**
1.	R 100 000 – R 150 000	15	1
2.	R 151 000 – R 200 000	5	2
3.	R 201 000 – R 250 000	0	
4.	R 251 000 – R 300 000	0	
5.	Other:		
Total		**20**	
No.	**Concrete Modular Construction**	**Frequency of responses**	**Ranking**
1.	R 100 000 – R 150 000	1	2
2.	R 151 000 – R 200 000	18	1
3.	R 201 000 – R 250 000	1	2
4.	R 251 000 – R 300 000	0	3
5.	Other:		
Total		**20**	

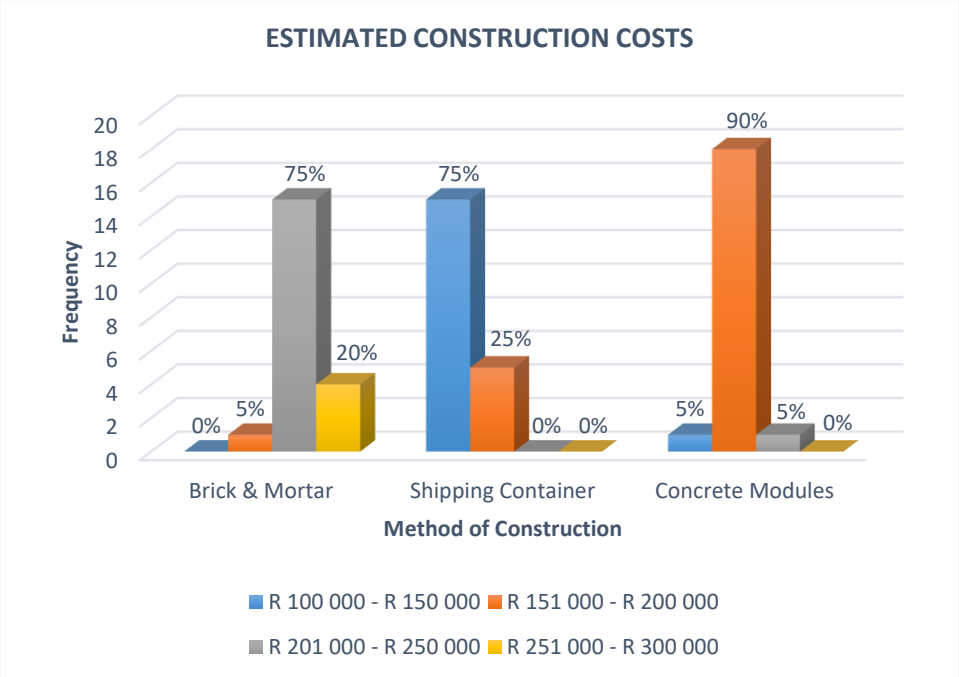


Figure 4.14: Estimated Construction Costs

4.3.1.3 Estimated construction time

The findings for this study revealed that 65% of the participants have estimated the construction time frame for a standard 40sqm subsidy house that is constructed using the conventional method of construction to be 1-2 months, while 35% estimated it to be 3-4 months. With regards to using shipping container construction for the construction of a standard 40sqm subsidy house, the findings revealed that 70% estimated the construction time frame to be 2 weeks, 20% estimated it to be 1 week, while 10% estimated it to be 1-2 months. The findings also revealed that if concrete modular construction was used for the construction of a standard 40sqm subsidy house, about 70% of the participants estimated the construction time frame to be 2 weeks, 10% estimated it to be 1 week, while 20% estimated it to be 1-2 months (see Table 4.3 and Figure 4.15).

These findings indicated that the construction time frame for a standard 40sqm subsidy house can be limited to 1-2 months when the conventional method of construction (brick and mortar) is used, however if shipping container construction or concrete modular construction is used to construct subsidy housing, then the overall construction time frame can be drastically reduced to a maximum of 2 weeks. Which shows that the use of innovative construction methods provides the advantage of reducing construction time.

Table 4.3: Estimated construction time frame

No.	Conventional Construction	Frequency of responses	Ranking
1.	1 week	0	
2.	2 weeks	0	
3.	1 – 2 months (4 – 8 weeks)	13	1
4.	3 – 4 months (12 – 16 weeks)	7	2
5.	5 – 6 months (20 – 24 weeks)	0	
6.	Other:		
Total		**20**	
No.	**Shipping Container Construction**	**Frequency of responses**	**Ranking**
1.	1 week	4	2
2.	2 weeks	14	1
3.	1 – 2 months (4 – 8 weeks)	2	3
4.	3 – 4 months (12 – 16 weeks)	0	
5.	5 – 6 months (20 – 24 weeks)	0	
6.	Other:		
Total		**20**	
No.	**Concrete Modular Construction**	**Frequency of responses**	**Ranking**
1.	1 week	2	3
2.	2 weeks	14	1
3.	1 – 2 months (4 – 8 weeks)	4	2
4.	3 – 4 months (12 – 16 weeks)	0	
5.	5 – 6 months (20 – 24 weeks)	0	
6.	Other:		
Total		20	

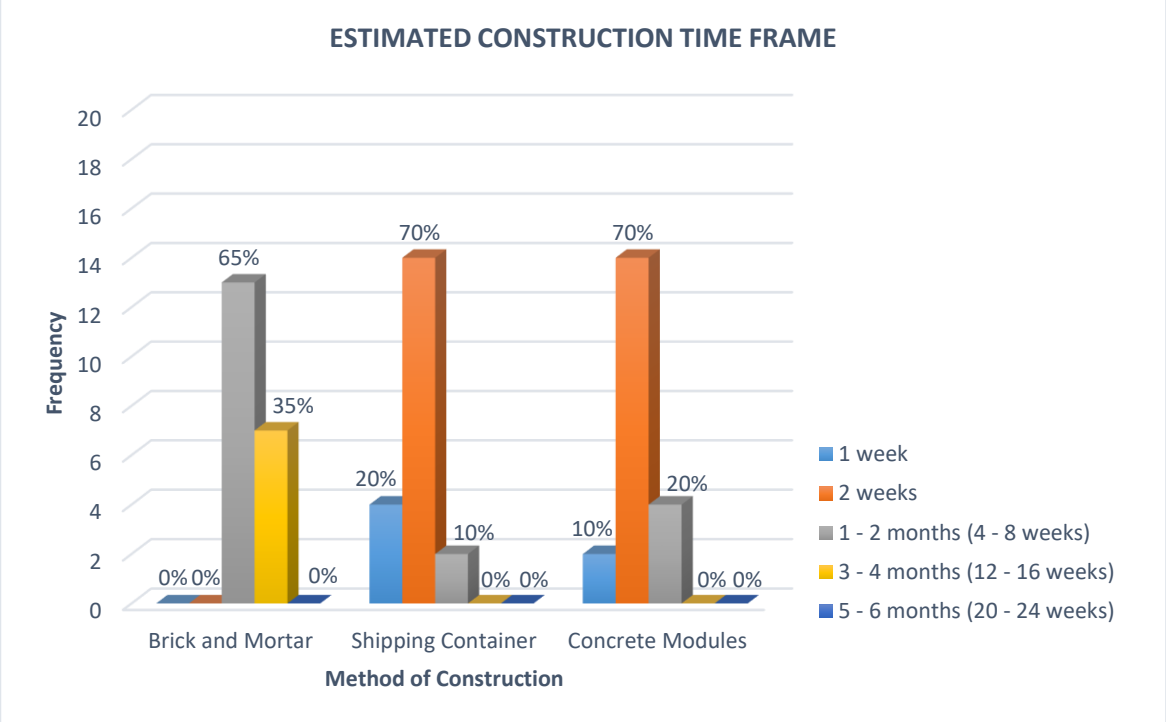


Figure 4.15: Estimated Construction Time Frame

4.3.1.4 Execution Difficulty

The findings for this study revealed that 90% of the participants have rated the level of execution difficulty when using the conventional method of construction to be high, while 10% rated it to be medium (see Table 4.4 and Figure 4.16). With regards to using shipping container construction, the findings revealed that majority (60%) of the participants rated the level of execution difficulty to be medium, 30% rated it to be potentially high, while 10% rated it to be low and with regards to using concrete modular construction, the findings revealed that majority (85%) of the participants rated the level of execution difficulty to be medium, only 10% rated it to be possibly high, while 5% rated it to be low (see Table 4.4 and Figure 4.16).

These findings indicate that the level of execution difficulty of all the above-mentioned methods of construction differs, as the level of execution difficulty for the conventional method of construction is perceived to be high, while the level of execution difficulty of the proposed innovative methods of construction is perceived to be comparatively medium.

Table 4.4: Perceptions on execution difficulty

No.	Execution Difficulty	Frequency of responses		
		Conventional Construction	Shipping Container Construction	Concrete Modular Construction
1.	Low	0	2	1
2.	Medium	2	12	17
3.	High	18	6	2
Total		**20**	**20**	**20**

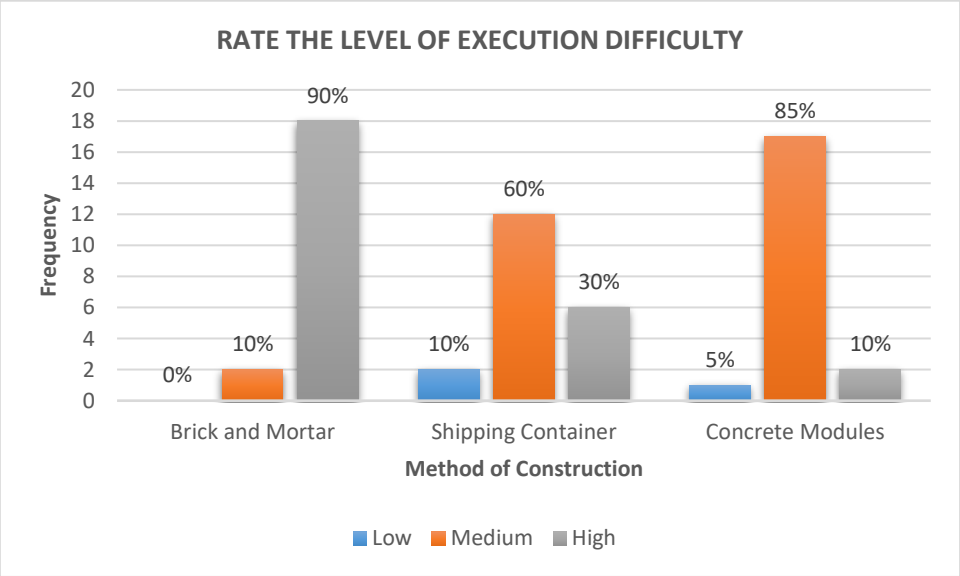


Figure 4.16: Perceptions on Execution Difficulty

4.3.1.5 Required Labour Skills

The findings for this study revealed that 90% of the participants have rated the level of required labour skills when constructing using the conventional method of construction to be high, while 10% rated it to be medium (see Table 4.5 and Figure 4.17). When using shipping container construction, the findings revealed that the majority (70%) of the participants rated the level of required labour skills to be medium, 25% rated it to be potentially high, while 5% rated it to be low. However with regards to using concrete modular construction, the findings revealed that the majority (100%) of the participants rated the level of required skills labour to be medium (see Table 4.5 and Figure 4.17).

These findings indicate that the level of labour skills required for all the above-mentioned methods of construction differ. The level of required labour skills for the conventional method of construction is perceived to be high, compared to that of the proposed innovative methods of construction, which is perceived to be comparatively medium.

Table 4.5: Perceptions on required labour skills

No.	Labour Skills	Frequency of response		
		Conventional Construction	Shipping Container Construction	Concrete Modular Construction
1.	Low	0	1	0
2.	Medium	2	14	20
3.	High	18	5	0
Total		**20**	**20**	**20**

Figure 4.17: Perceptions on Required Labour Skills

4.3.1.6 Ease to Achieve Quality

The findings for this study revealed that according to 65% of the participants the level of ease to achieve quality when constructing the 40sqm subsidy house using the conventional method of construction is not easy, while 25% rated it to be moderate and according to the remaining 10% it is very easy (see Table 4.6 and Figure 4.18). The findings also revealed that using shipping container construction, 75% of the participants rated the level of ease to achieve quality as moderate, 20% rated it as potentially not easy, while 10% rated it as very easy (see Table 4.6 and Figure 4.18). With regard to using concrete modular construction, the findings revealed that the majority (80%) of the participants rated the level of ease to achieve quality as moderate, 15% rated it as very easy, while only 5% rated it as not easy (see Table 4.6 and Figure 4.18).

These findings indicate that the level of ease to achieve quality of all the above-mentioned methods of construction differ. However the level of ease to achieve quality for the conventional method of construction is perceived to be not easy, compared to the proposed innovative methods of construction, which are perceived to be comparatively moderate in terms of ease to achieve quality.

Table 4.6: Perceptions on the ease to achieve quality

No.	Ease to Achieve Quality	Frequency of responses		
		Conventional Construction	Shipping Container Construction	Concrete Modular Construction
1.	Not Easy	13	4	1
2.	Moderate	5	15	16
3.	Very Easy	2	1	3
Total		**20**	**20**	**20**

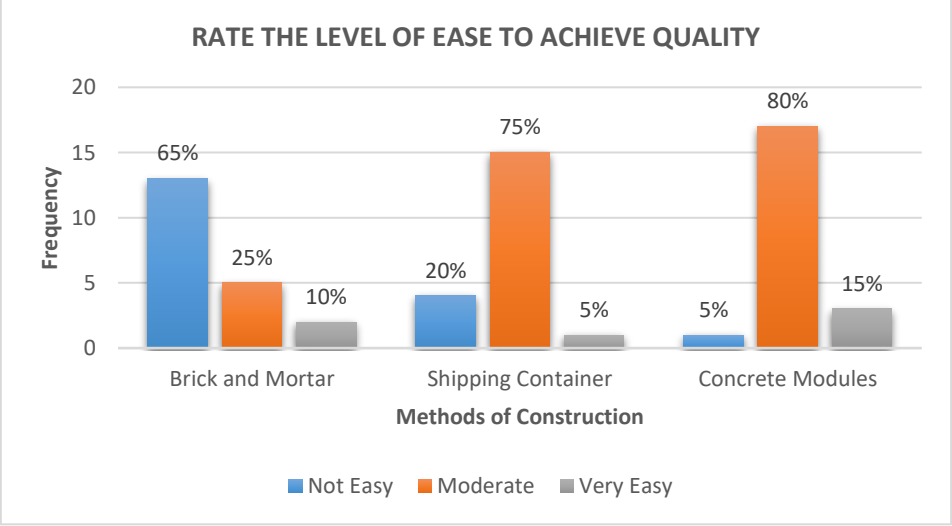


Figure 4.18: Perception on Ease to Achieve Quality

4.3.1.7 Perception on use of modular construction methods (MCM) in subsidy housing

The findings for this study revealed that 100% of the participants support that the use of MCMs can be adopted/implemented in other architectural forms (i.e. single/double storey residential houses, hospitals, schools etc.), see Table 4.7 and Figure 4.19.

The surveyed participants, who are professionals in the AEC industry, were asked for their opinion on the use of prefabricated modular construction methods (e.g. shipping containers, precast concrete panels) in all government subsidy housing types (i.e. RDP housing, multi-storey low-cost housing, cluster housing etc.), The findings, which were corroborated by some of the qualitative sentiments from participants, are as follows:

> *"It is a good solution because modular construction offers the advantages of reduced construction time and costs".*
>
> *"It is a good idea for solving the problem in question".*
>
> *"It is the best solution available".*
>
> *"Fantastic idea. A high number of units can be built in a single day. This will definitely speed up delivery of housing".*
>
> *"The proposed options are good. They may both be cost effective and cut down on construction time. The Container option may require some level of skilled labour in cutting steel work".*
>
> *"These options would reduce construction time drastically, as well as the price per unit/house would be reduced".*
>
> *"It's not a bad idea. This is achievable. This would significantly reduce the price per unit of housing, and speed up the construction process and delivery".*

This research agrees with the finding that the implementation of innovative construction methods in the construction of government subsidy housing could yield a lot of benefits including reduced overall construction costs and reduced overall construction time, which could allow for the delivery of housing to be fast tracked.

Table 4.7: Perception on implementation of modular construction methods (MCM) in other architectural forms

No.	Can MCM's be implemented in other architectural forms?	Frequency of responses	Percentage
1.	Yes	20	100%
2.	No	0	0%
Total		**20**	**100%**

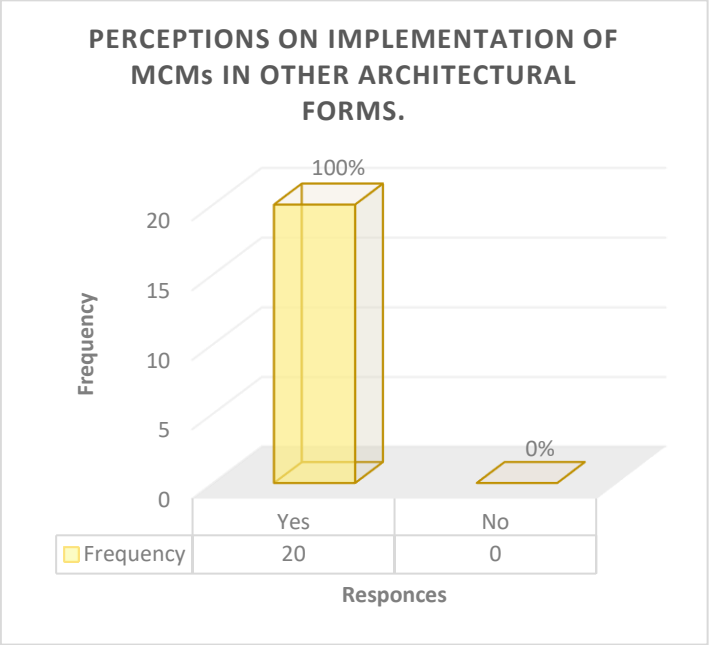


Figure 4.19: Perceptions on Implementation of MCMs in other architectural forms

4.3.2 SAMPLE GROUP B FINDINGS

4.3.2.1 Classification of study participants – Group Sample B

The findings indicate that a total of 40 participants that form group sample B were surveyed. The group consists of people currently living in different residence types. A large portion of about 50% of these participants are people currently living in shacks situated in informal settlements, followed by 25% of people who live in social housing (RDP and low-cost housing), and another 25% of people who live in conventional construction houses (see Table 4.8 and Figure 4.20). The findings also revealed that the majority (65%) of the participants that were surveyed were from PE and 35% are from Bloemfontein (see Figure 4.21).

Table 4.8: Classification of study participants

No.	Classification of participants by residence type	Frequency of responses	Percentage
1.	Conventional Construction House	10	25%
2.	Social Housing (RDP)	5	12.5%
3.	Social Housing (Low-cost)	5	12.5%
4.	Shack (Informal settlement)	20	50%
Total		**40**	**100%**

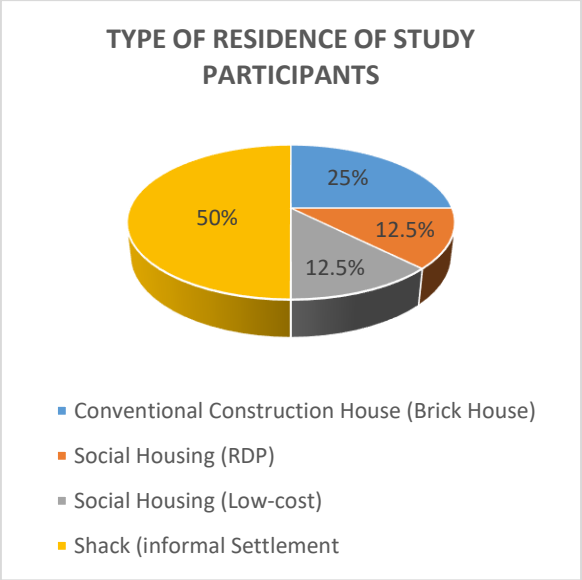


Figure 4.20: Classification of Study Participants by Residence Type

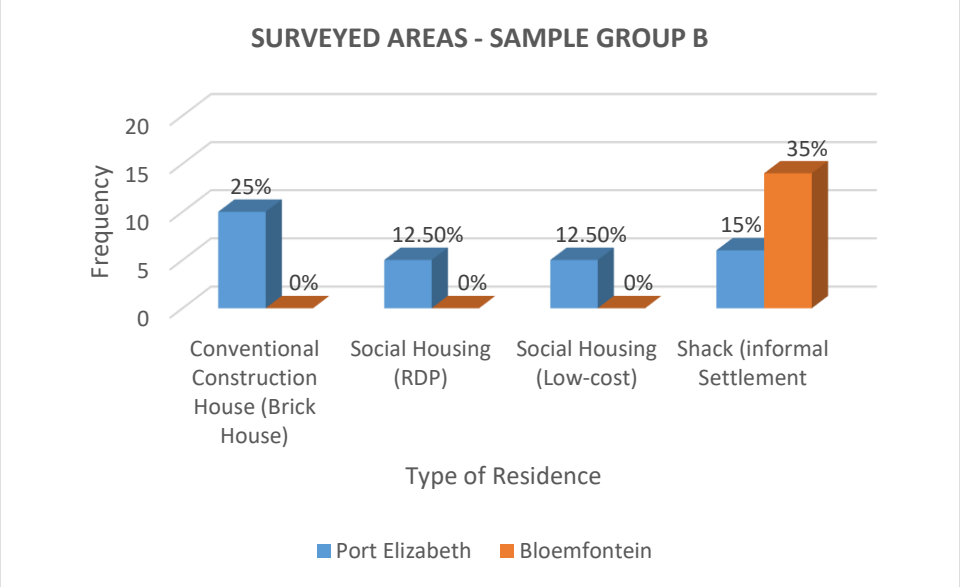


Figure 4.21: Surveyed Areas - Sample Group B

4.3.2.2 Job status of study participants

The findings of this study indicated that a large portion of about 57.5% of the participants that were surveyed were employed, 25% were unemployed, 12.5% were casual/part time workers and 5% were self-employed (see Table 4.9 and Figure 4.22).

Table 4.9: Job status of study participants

No.	Occupation	Frequency of responses	Percentage
1.	Employed	23	57.5%
2.	Unemployed	10	25%
3.	Casual / Part time worker	5	12.5%
4.	Self employed	2	5%
Total		**40**	**100%**

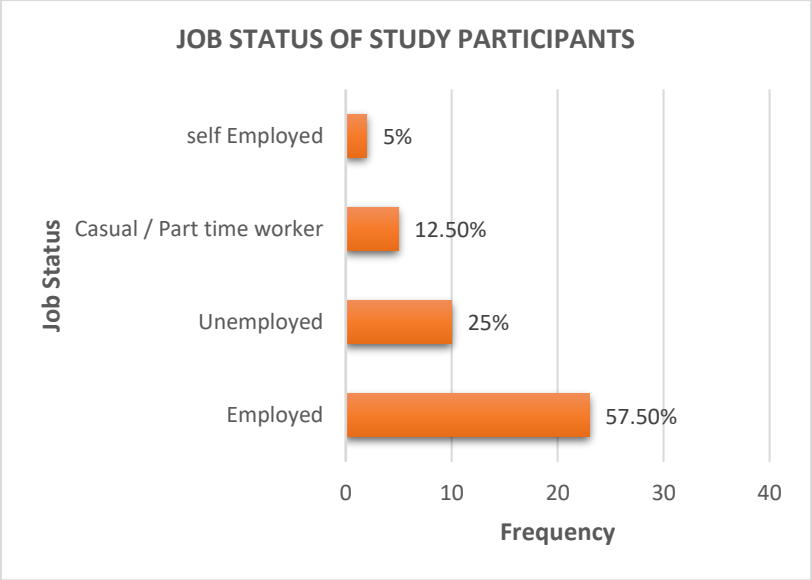


Figure 4.22: Job Status of Study Participants

4.3.2.3 Age Group of participants

The findings of this study indicate that most participants were in the age range categories of 31-40 years (42.5%), 25-30 years (22.5%), 41-50 years (22.5%) and a few of the participants were in the age range categories of 51-60 years (7.5%), 61-70 years (2.5%) and only 1 participants was over 70 years (2.5%) (See Table 4.10 and Figure 4.23).

Table 4.10: Number of people per residence

No.	Age Group	Frequency of responses	Percentage
1.	25 - 30 years	9	22.5%
2.	31 - 40 years	17	42.5%
3.	41 - 50 years	9	22.5%
4.	51 - 60 years	3	7.5%
5.	61 - 70 years	1	2.5%
6.	Over 70 years	1	2.5%
Total		**40**	**100%**

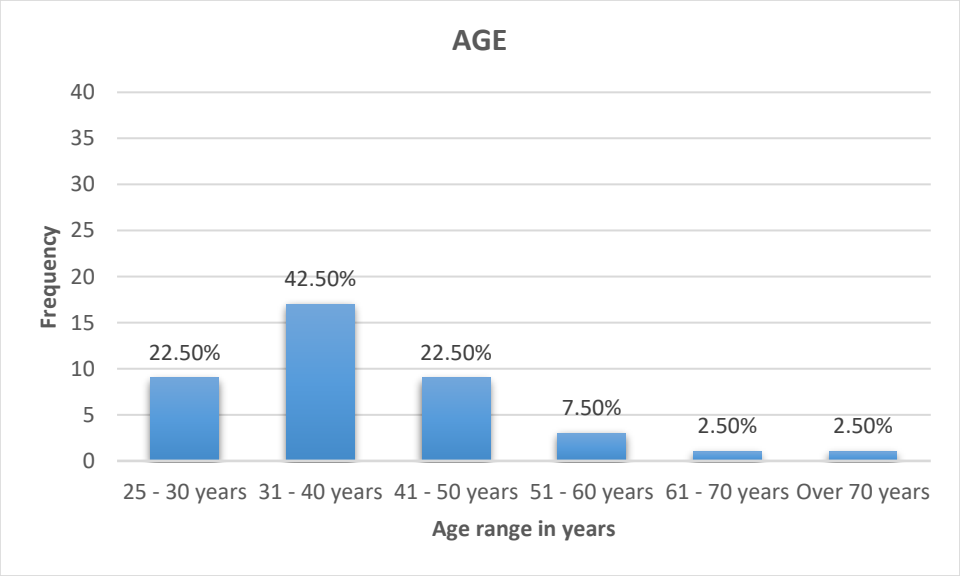


Figure 4.23: Age Distribution of Participants

4.3.2.4 Number of people per residence

The findings from this study indicate that the most common number of people per residence was in the ranges of 3-4 (52.5%) and 1-2 (37.5%) the remaining 10% had 5 or more which was the least common number of people per residence (see Table 4.11 and Figure 4.24).

Table 4.11: Number of people per residence

No.	No. of people per residence	Frequency of responses	Percentage
1.	1 – 2	15	37.5%
2.	3 – 4	21	52.5%
3.	5 or more	4	10%
Total		**40**	**100%**

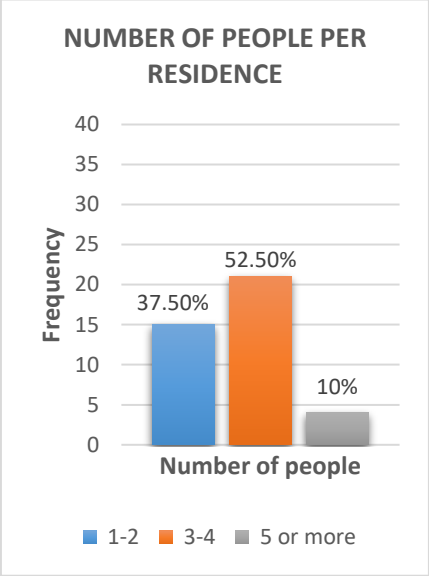


Figure 4.24: Number of People per Residence

4.3.2.5 Perceptions on living in a shipping container construction home

The participants were asked the question 'Would you consider living in a shipping container constructed home?', and the findings of this study reveal that out of the 10 participants currently living in conventional construction houses, 60% said yes, 30% said maybe, while 10% said no. The findings also revealed that out of the 10 participants currently living in social housing (including both RDP and low-cost housing), 40% said yes, 30% said no and the other 30% said maybe. With regards to the 20 participants currently living in shacks, the findings revealed that 70% said yes, 15% said no and the other 15% said maybe (see Table 4.12 and Figure 4.25).

This indicates that out of a total of 40 participants that were surveyed, a significant portion of about 60% of them would consider living in a shipping container constructed home, 22.5% were uncertain and 17.5% indicated that they would not (see Figure 4.25).

Table 4.12: Perceptions on living in a shipping container construction home

No.	Would you consider living in a Shipping Container constructed home?	Frequency of responses			
		Conventional Construction House	Social Housing (RDP)	Social Housing (Low-cost)	Shack (Informal settlement)
1.	Yes	6	1	3	14
2.	No	1	2	1	3
3.	Maybe	3	2	1	3
Total		**10**	**5**	**5**	**20**

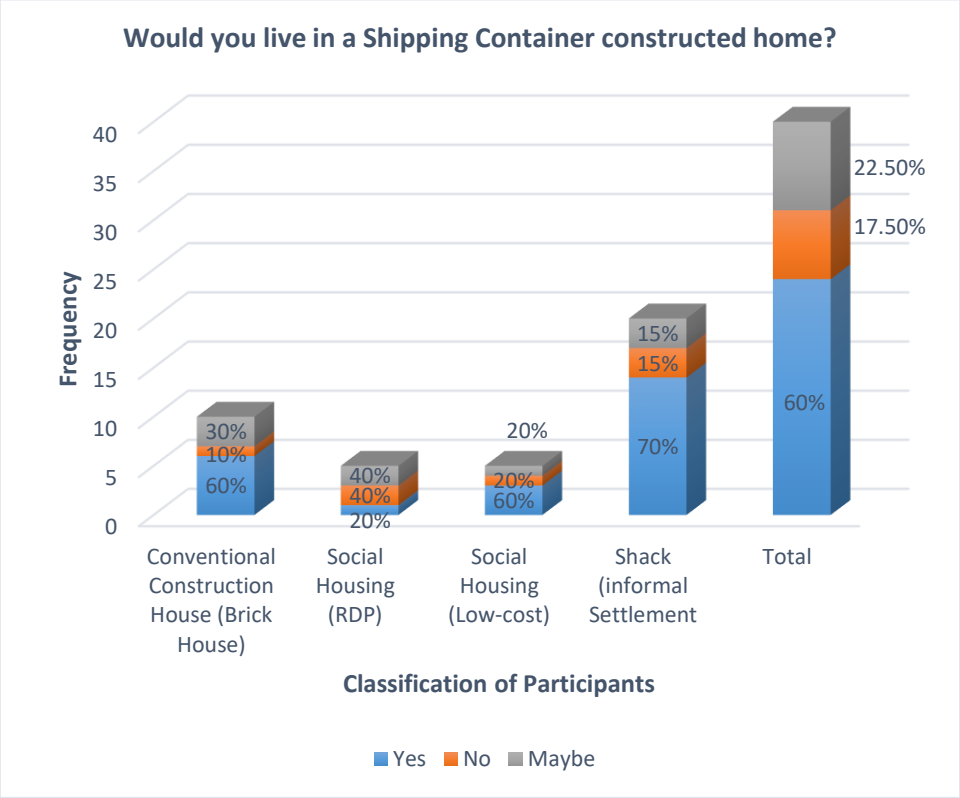


Figure 4.25: Perceptions on living in a Shipping Container home

4.3.2.6 Perceptions on living in a concrete modular construction home

The participants were asked the question 'Would you consider living in a concrete modular construction home?', and the findings of this study reveal that out of the 10 participants currently living in conventional construction houses, 70% said yes, 20% said maybe, while 10% said no. The findings also reveal that out of the 10 participants currently living in social housing (including both RDP and low-cost housing), 80% said yes, 10% said no and the other 10% said maybe. With regards to the 20 participants currently living in shacks, the findings reveal that 95% said yes, while the remaining 5% said maybe (see Table 4.13 and Figure 4.26). This indicates that out of a total of 40 participants that were surveyed, a significantly large portion of about 85% of them would consider living in a concrete modular construction home, 5% were uncertain and the other 5% indicated that they would not (see Figure 4.26).

Table 4.13: Perceptions on living in a concrete modular construction house

No.	Would you consider living in a Concrete Modular construction home?	Frequency of responses			
		Conventional Construction House	Social Housing (RDP)	Social Housing (Low-cost)	Shack (Informal settlement)
1.	Yes	7	3	5	19
2.	No	1	1	0	0
3.	Maybe	2	1	0	1
Total		**10**	**5**	**5**	**20**

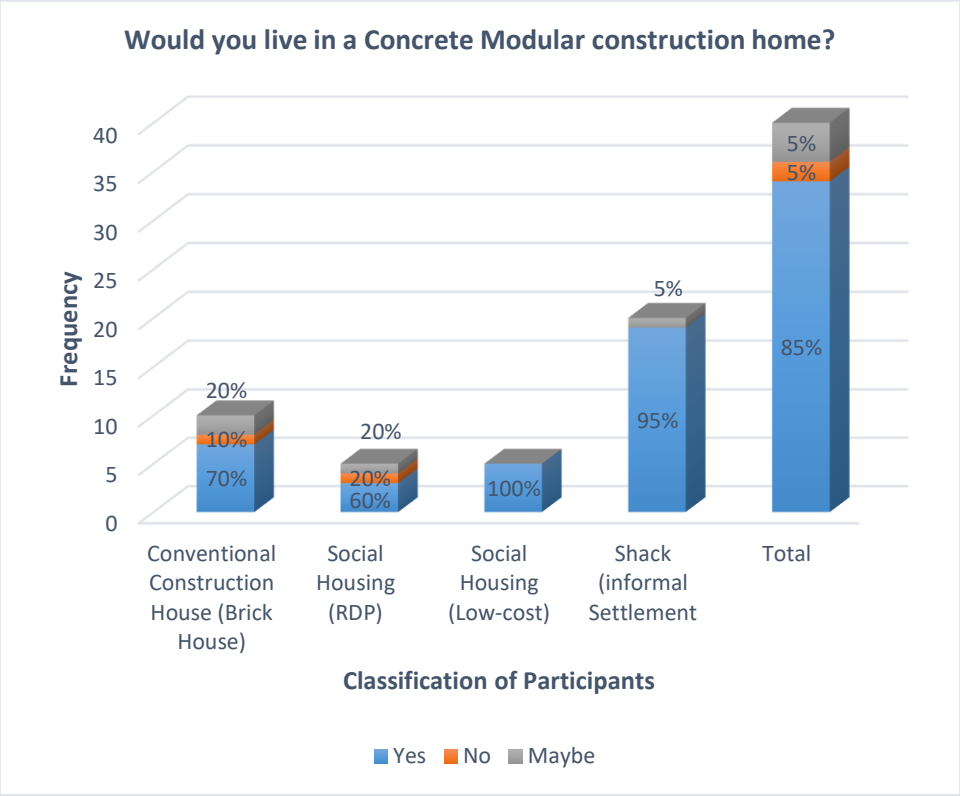


Figure 4.26: Perceptions on living in a Concrete Modular construction home

4.3.2.7 Perceptions on the construction methods

The survey required participants to rate the appearance of the conventional method of construction including the 2 proposed innovative methods of construction. The findings for this study reveal that out of the 40 participants that were surveyed, 85% of the participants rated the appearance of the conventional method of construction as very satisfactory, while the remaining 15% rated it as satisfactory. The findings also reveal that 45% rated the appearance of a shipping container construction as satisfactory, while 35% rated it as very satisfactory, and the remaining 17.5 % rated it as not satisfactory. With regards to the appearance of a concrete modular construction, 57% rated it as very satisfactory, while 37.5% rated it as satisfactory and the remaining 5% rated it as not satisfactory (see Table 4.14 and Figure 4.27).

In Figure 35 it can be seen that the findings indicate that out of a total of 40 participants that were surveyed, the majority of them indicated all the three methods of construction to be very satisfactory. It can also be seen that between the two proposed innovative methods of construction, more participants (57.5%) rated the concrete modular construction to be very satisfactory, while 35% rated the shipping container construction to be very satisfactory, which indicated that between the two proposed

innovative methods of construction, although both of them may be appreciated, the concrete modular construction is the most preferred as the finished building looks more like that of a conventionally constructed building as shown in Figure 4.12.

Table 4.14: Perceptions on the appearance of construction methods

No.	Appearance	Frequency of responses		
		Conventional construction	Shipping Container construction	Concrete Modular construction
1.	Not Satisfactory	0	7	2
2.	Satisfactory	6	18	15
3.	Very Satisfactory	34	15	23
Total		**40**	**40**	**40**

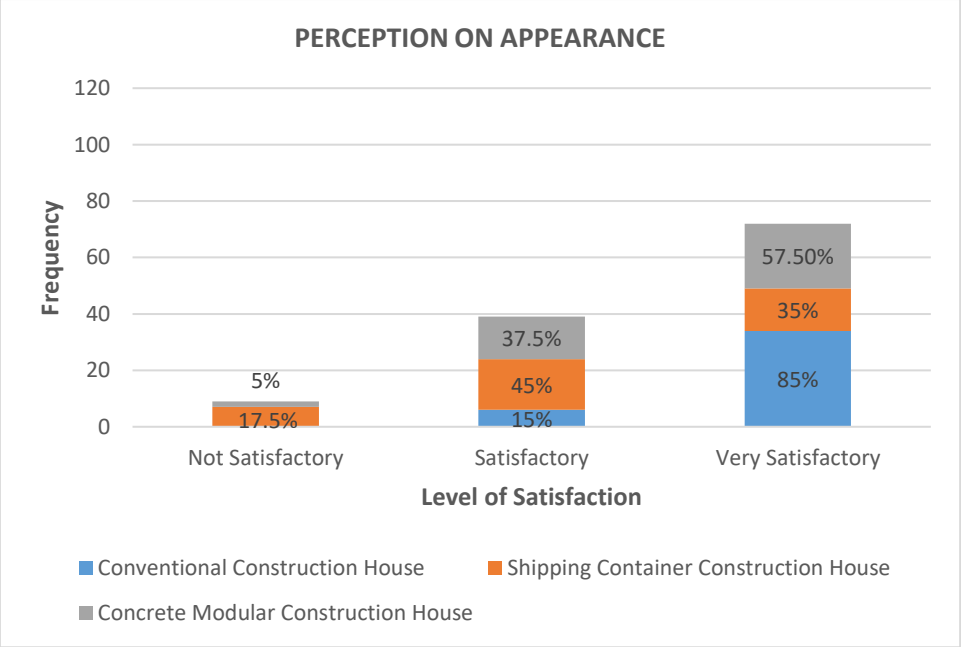


Figure 4.27: Perceptions on the Appearance of Construction Methods

4.3.2.8 Perceptions on social acceptance of proposed innovative methods of construction

The participants were shown the images and drawings illustrated in Fig 4.1, 4.2, 4.5, 4.6, 4.7, 4.10, 4.11 and 4.12, in order for them to be able to answer the following questions:

The participants were asked the question: 'Do you think the appearance of a shipping container construction home, with some bit of architectural flair can be socially acceptable?', and the findings of this study indicate that out of a total of 40 participants that were surveyed, a significant portion (82.5%) of them said yes, and 17.5% said no (see Table 4.15 and Figure 4.28).

The participants were also asked the question: 'Do you think the appearance of a concrete modular construction home, with some bit of architectural flair can be socially acceptable?', and the findings of this study indicate that out of a total of 40 participants that were surveyed, a significant portion (97.5%) of them said yes, and only 2.5% said no (see Table 4.15 and Figure 4.28). These findings indicate that the majority of the participants are happy with the appearance of the two proposed innovative methods of construction, although the concrete modular construction method appears to be the most preferred.

Table 4.15: Perceptions on social acceptance of proposed innovative methods of construction

No.	Social Acceptance	Frequency of responses	
		Shipping Container construction	Concrete Modular construction
1.	Yes	33	39
2.	No	7	1
Total		**40**	**40**

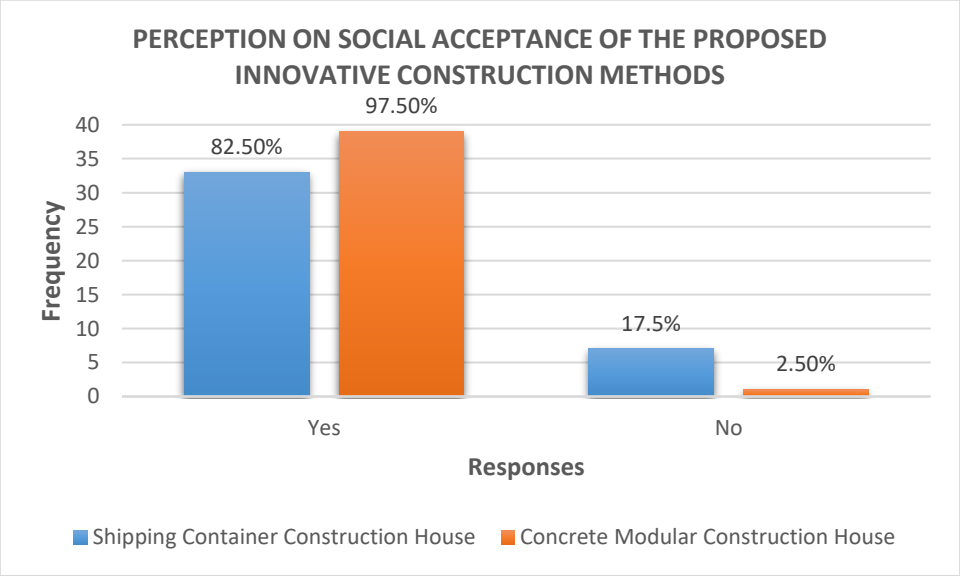


Figure 4.28: Perceptions on the Social Acceptance of Innovative Construction Methods

4.4 COMPARATIVE STUDY

Through both desktop and site survey the research was able to generate the information presented in Table 4.16. It was ascertained that the conventional method of construction is known to be procedural and time consuming, which is due to the various prescribed building materials incorporated in housing construction and the required expertise of labour renders the construction method expensive. The proposed innovative methods of construction were found to have more advantages such as

being cost effective, not time consuming, requiring minimal building materials and highly adaptable to future reuse, relocation, or rearrangement to allow for any desired future extensions.

Based on the findings, the surveyed participants found both the proposed innovative methods of construction to be socially acceptable as shown in Figure 4.28, with the shipping container construction rated as satisfactory and the concrete modular construction rated as very satisfactory as shown in Figure 4.27.

Table 4.16: Comparative study of proposed innovative methods of construction against the existing method.

Research attributes (for a 40sqm house)	Existing method	Proposed methods of construction	
	Conventional Method of Construction	Shipping Container construction	Concrete Modular construction
Required building materials	Excessive	Minimal	Minimal
Construction time	4 weeks (1 – 2 months)	2 weeks	2 weeks
Construction cost	R201 000 – R250 000	R100 000 – R150 000	R151 000 – R200 000
Level of execution difficulty	High	Medium	Medium
Level of required skilled labour	High	Medium	Medium
Ease to achieve quality	Not easy	Moderate	Moderate
Adaptability to extensions	Medium	High	High
Level of reusability of materials for renovations	Low	High	High
Social acceptance and Satisfaction	Good	Good	Good

4.5 TESTING THE HYPOTHESES

4.5.1 Introduction

This part of the research discusses and evaluates the hypotheses based on the collected data. According to Fellows and Liu (2015), hypothesis refers to the main statement of uncertainty (assumption) which would therefore, be thoroughly tested (observed) in order to eliminate any element of uncertainty as much as possible, so as to draw true and certain knowledge.

It should be noted and remembered that:

- Data collection methods for this research were through Desktop Survey (literature review) and Site Survey (findings from research questionnaires).

- All the participants that were involved in Site Survey, were strategically selected on the basis of the research attributes which the research endeavoured to investigate.
- The study sample was a mixed group of 60 participants in total. The participants were divided into sample group A participants (20 professionals from the AEC industry) and sample group B participants (40 people currently living in different residence types).

4.5.2 Hypothesis 1:

The sequential method of construction for RDP housing has a restraining effect on the speed of construction.

4.5.2.1 Literature Review Findings

According to Hendry (2001) the conventional method of construction is time consuming. The process of building a house using brick construction (conventional method of construction) is very procedural as it follows a series of stages that must be completed in a specific sequence as recorded by Archid Architecture (2020) and Paula Villoria Sáez, Mercedes del Rio Merino and César Porras-Amores (2011). These stages include i) earth works (i.e. site clearance, setting out and excavation of the foundation trenches, construction of foundations, foundation walls, floor slabs), ii) construction of external and internal walls, iii) roof installation, iv) installation of windows and doors, v) electrical installation, vi) plumbing and drainage installation, vii) plastering and painting of walls, and viii) installation of roof rain-water goods.

Other methods of construction do include a few of the construction stages mentioned above; however, for the purpose of this study, the '*conventional method*' of construction refers to the use of brickwork (any type of brick) also known as masonry to construct a house. Wegeling (2011, p. 113) defines masonry as the assembly of masonry units (i.e. bricks, concrete blocks or stones) with a bonding agent to construct walls. Masonry construction requires each masonry unit to be handled individualy and laid one at a time. One or two persons may be required for the handling of the masonry units, which is dependent on the size and type of the masonry units used (Wegeling, 2011). Due to the procedural and sequatial method involved in the execution of masonry construction (conventional method of construction), more labourers working longer hours may be required to complete a building constructed using this type of

construction, which renders this method of construction labour intensive (Mkhene and Twala, 2009), and time consuming (Hendry, 2001).

Masonry units are laid in courses and bonded together with mortar horizontaly between each course and verticaly between the masonry units so as to form a homogeneous wall structure (Ashcroft, 2013). Masonry construction is usually a wet trade due to the wet mortar that is used (Wegeling, 2011), therefore the height of masonry construction per day should be less than 1.5m (The Constructor, 2019), based on the type and size of the masonry units that are used, to keep the mortar bed intact and to prevent it from being squeezed out by the weight of the masonry courses laid above it (Ashcroft, 2013). Swift, Goobrand and Szymanowski, (2009) affim that the properties of a wall (i.e. durability and stability) are dependent on both the bricks and mortar with which they are constructed.

4.5.2.2 Survey Findings

According to the comparative study presented in Table 4.16, the findings revealed that the overall construction time frame for a standard 40sqm subsidy house can take up to 2 months to complete when using the conventional method of construction. This is considered to be long when compared to the proposed methods of construction in Table 4.16.

4.5.2.3 Test

Based on the above, it can be concluded that both the literature and survey findings support the hypothesis that: ‘The sequential method of construction for RDP housing has a restraining effect on the speed of construction’. It is a known fact that RDP housing construction uses masonry construction, therefore based on the findings discussed in section 4.5.2.1 and 4.5.2.2, it can be concluded that the hypothesis is completely supported.

4.5.3 Hypothesis 2:

The various prescribed building materials incorporated in RDP housing construction and the required expertise of labour render the construction method cost ineffective.

4.5.3.1 Literature Review Findings

The conventional method of construction is the most commonly used method of construction for the construction of residential and commercial buildings, due to some advantages that this method of construction offers (i.e. thermal properties, durable, strong and sturdy structure, etc.). However, this method of construction can increase the construction time, cost and the required labour (Whirlwind Team, 2014). Thus many residential and commercial builders are transitioning from the use of masonry construction to other alternative methods of construction, which offer benefits such as high quality, low maintenance and reduced costs.

The Whirlwind Team (2014), supports the fact that masonry construction materials are expensive and that the execution of this type of construction is labourous as it requires masonry units to be assembled one at a time, which increases the construction time.

Masonry construction is very much dependent on skilled labour (Hendry, 2001), and given the labour involved in this type of construction method, a large number of labourers is required, which increases the construction labour costs (Haron and Rahim, 2013). A research study conducted by Haron and Rahim (2013), confirmed that the construction costs for using the conventional method of construction is more expensive compared to prefabricated modular construction also known as the Industrialised Building System (IBS).

Most steel buildings and other types of modular construction buildings are prefabricated, some may require the use of prefabricated parts (parts are already pre-cut and/or assembled), which can yield the advantages of reducing engineering work, design work, labour required, labour costs and the overall construction costs (Whirlwind Team, 2014).

4.5.3.2 Survey Findings

According to the results shown in the comparative study presented in Table 4.16, the findings revealed that the overall cost for building a standard 40sqm subsidy house using the conventional method of construction, can be between R201 000 – R250 000. This is considered to be expensive compared to the cost of shipping container construction and precast modular construction.

4.5.3.3 Test

Based on the above, it can be concluded that both the literature and survey findings support the hypothesis that: 'The various prescribed building materials incorporated in RDP housing construction and the required expertise of labour renders the construction method cost ineffective'. Therefore, in light of the findings discussed in section 4.5.3.1 and 4.5.3.2, it can be concluded that the hypothesis is completely supported.

4.5.4 Hypothesis 3:

Construction work executed by unskilled labour results in poor workmanship, which usually leads to the need for restoration projects.

4.5.4.1 Literature Review Findings

Mkhene and Twala (2009) reported that shortage of technically skilled labour is a critical problem that the construction industry is facing today, resulting in poor workmanship, which is costing most contractors tremendous time and money. In addition, the construction industry has been criticized for slow productivity and low quality of products (Yusof *et al*., 2014), therefore skilled labour and productivity in construction are much needed to ensure survival of the construction industry.

The nature of masonry construction requires skilled labour (Hendry, 2001), in order to achieve the required construction quality. Therefore skilled labour is necessary in construction, as skilled labourers or bricklayers with years of experience behind them are guaranteed to produce high quality work (Burdfield, Fearn, Jones and Rudman, 2013), which will prevent poor workmanship that would later need to be repaired.

Employing unskilled labour is one of the causes of poor labour productivity (Doloi, Sawhney, Iyer and Rentala, 2012), poor workmanship (Cotney Construction Law, 2019) and delays in construction projects (Fugar and Agyakwah-Baah, 2010).

According to Cotney Construction Law, (2019), some of the factors that may lead to poor workmanship include instances whereby labourers are careless, fail to follow project specifications or even lack the required skills to carry out construction work. Furthermore, in some cases, labourers encounter complex construction work details that may be difficult for them to build (Hendry, 2001), which may give rise to poor workmanship.

Cotney Construction Law (2019) defines workmanship as the degree of skill or the quality with which a product is made or a job is executed. Cotney Construction Law (2019) emphasises that missteps in a construction project due to unskilled labour can result in construction defects, expensive repairs and even lawsuits.

Doloi *et al.* (2012) advise that, if hiring unskilled labourers is inevitable due to unavailability of labourers with the required skill set, it is essential that they are first properly trained before being put to work. Participating in training would allow the labourers with no experience in construction to learn specific technical skills required in construction (Mkhene and Twala, 2009).

4.5.4.2 Survey Findings

According to the results shown in the comparative study presented in Table 4.16, the findings revealed that the conventional method of construction requires a high level of skilled labour even for small construction projects such as the construction of a standard 40sqm subsidy house, whereas the proposed shipping container construction and precast modular construction methods only require a medium level of skilled labour.

4.5.4.3 Test

Based on the above, it can be concluded that both the literature and survey findings support the hypothesis that: ‘Construction work executed by unskilled labour results in poor workmanship, which usually leads to the need for restoration projects’. Therefore, on the basis of the findings discussed in section 4.5.4.1 and 4.5.4.2, it can be concluded that the hypothesis is completely supported.

Chapter 5 : CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

The previous chapter analysed and interpreted the findings of the collected data. This chapter presents the general summary of the study, the conclusions and recommendations for future construction considerations with regard to the implementation of innovative construction methods in construction industry based on literature review findings and the site survey findings.

5.2 SUMMARY OF THE RESEARCH

As it was stated in chapter 1, that there is a high demand for housing in SA, however, there is a prolonged waiting period for the needy to receive government subsidy housing. This has resulted in housing delivery delay and the fast-paced establishment of informal settlements. The increasing housing backlog including the scale and fast-paced spread of informal settlements has pressured the government towards upgrading of physical infrastructure, housing units and service connections and greater social and economic integration of informal settlements (Shortt and Hammett, 2013).

Some of the factors contributing to housing delivery delay include government budgetary constraints, lengthy supply-chain and procurement processes, corruption, tender irregularities, lengthy construction periods, poor construction workmanship and inadequate construction management resources from the government departments.

The focus of this study was on the construction aspect of the factors that contribute to the delay/problem. The construction of government subsidy housing uses the conventional method of construction otherwise known as masonry construction. This is considered to be labour intensive and time consuming.

In pursuit of the aims and objectives of this study, the research methodology that was adopted was a triangulation of both the quantitative and qualitative methods of inquiry, to enable the research to gain in-depth information on the potential use of the proposed innovative methods of construction for subsidy housing. The aims and objectives of this study, discussed in section 1.6 were fulfilled by the findings gathered from the data analysis.

5.2.1 Fulfilment of the Research Aims and Objectives

This primary aim of this research study aimed to explore innovative construction methods that could be implemented in the construction of government subsidy housing in order to fast track delivery. In addition this study aimed to explore the possibility for integration of the proposed innovative methods (prefabricated modular construction) of construction fully into other architectural applications in the building industry, in the future. The aims of this study were complemented by the objectives discussed in sections 5.2.1.1, 5.2.1.2 and 5.2.1.3.

5.2.1.1 Objective 1:

To establish innovative construction methods that could be implemented in the construction of government subsidy housing, in order to fast track the construction and delivery of subsidy housing.

To fulfil this objective, a comprehensive investigation through literature review (desktop survey) of innovative construction methods was conducted. Then the researcher analysed literature based on existing innovative construction methods that could be proposed as alternative construction methods for implementation in the construction of RDP housing, such as the concept of using prefabricated modular construction technologies/systems whereby the researcher discovered the following:

i) The researcher discovered that innovative construction methods such as the use of prefabricated modular construction specifically in the form of Shipping Container construction and Precast Concrete Modular construction, have already been introduced in the construction industry, however only a few buildings have been built using such methods (i.e. classrooms, clinics, small offices, emergency shelters, etc.).

ii) The most crucial discovery by the researcher was that the idea of implementing such innovative methods has not been considered, explored or introduced in SA for implementation as alternative solutions specifically for RDP housing construction for the sole purpose of fast tracking the construction and delivery of RDP housing which would result in the reduced demand for housing and the reduced proliferation of informal settlements in the long run.

iii) The current social housing seeks to deliver other housing methods to be implemented as alternatives for RDP housing construction, on a fully serviced property with free hold title.

iv) Another interesting discovery in literature was that the involvement of the community members of an informal settlement (as subsidy housing beneficiaries) must be considered, in the process of determining how their settlement should be upgraded.

Further investigations were conducted through interviews and administration of structured questionnaires (site survey) in pursuit of the fulfilment of the fourth discovery listed above. The following questions were posed to the participants (informal settlement residents), in order to obtain in-depth information on their thoughts on the proposed innovative construction methods that could be implemented as alternatives for the construction of RDP housing:

- *"Would you consider living in a shipping container constructed home?"*
- *"Would you consider living in a concrete modular construction home?"*
- *"Do you think the appearance a shipping container construction home, with some bit of architectural flair can be socially acceptable?"*
- *"Do you think the appearance a concrete modular construction home, with some bit of architectural flair can be socially acceptable?"*

Other participants who currently live in conventional construction houses located in suburban areas, were also asked the above questions, to get a broad perspective from the general public on the overall appearance and social acceptance of proposed innovative construction methods. The study revealed that significantly high numbers of the participants would consider living in shipping container and precast concrete construction homes and these innovative construction methods' appearance was considered to be satisfactory and socially acceptable.

5.2.1.2 Objective 2:

To establish cost effective construction methods/materials that could be used in the construction of government subsidy housing, in order to reduce construction costs.

To fulfil this objective, the professionals in the AEC industry were asked to provide estimated costs based on their expert knowledge, for a typical 40m^2 government subsidy house constructed using the conventional method of construction, shipping container construction and precast concrete modular construction, in order to compare the cost of a conventional method of construction against the costs of the innovative

methods of construction, and determine as to which of the methods is more cost effective. The study revealed that the cost of using the conventional method of construction was estimated to be very high (R201 000 - R250 000) when compared to using the concrete modular construction (R151 000 – R200 000) or shipping container construction (R100 000 – R150 000). This indicates that out of the three methods of construction, the two proposed innovative methods of construction could significantly reduce construction costs per unit for government subsidy housing as their costs were estimated to be relatively lower than that of the currently used conventional method of construction.

5.2.1.3 Objective 3:

To establish and introduce innovative construction methods that require a medium level of labour skills, that could be implemented in the construction of government subsidy housing, in order to ensure quality construction and prevent poor workmanship.

To fulfil this objective, through the administration of questionnaires, the professionals were asked for their expert input on rating the level of execution difficulty, labour skills required and ease to achieve quality for the conventional method of construction, shipping container construction and precast concrete modular construction. The study revealed the following:

- The level of execution difficulty and the level of labour skills required for the conventional method of construction is perceived to be high, while the level of execution difficulty and level of labour skills required of the proposed innovative methods of construction is perceived to be comparatively medium.
- The level of ease to achieve quality of all the above-mentioned methods of construction differ. However the level of ease to achieve quality for the conventional method of construction is perceived to be not easy, compared to the proposed innovative methods of construction, which are perceived to be comparatively moderate in terms of ease to achieve quality.

Through literature review, the researcher discovered that the use of prefabricated modular construction methods can reduce construction costs, time, and execution difficulty and even provide the convenience of fast housing delivery, which allows houses to be habitable much sooner compared to the conventional method of construction.

5.3 CONCLUSIONS

The benefits of prefabricated modular construction methods highlighted in literature review are supported by the research findings. As the research findings indicate that the proposed innovative prefabricated modular construction methods are more cost effective compared to the conventional method of construction, which is a major advantage as cost is a driving factor to any construction project. The reduction in construction cost could result in additional dwellings being provided for the same government annual housing budget compared to conventional construction methods.

The second major advantage confirmed by the research findings is the reduction in construction time offered by prefabricated modular construction methods. The research findings indicate that the building industry professionals view the proposed innovative methods of construction as time saving, which would allow for the delivery of housing to be fast tracked; this would reduce the effects of rapid proliferation of informal settlements as highlighted in the problem statement. As the research problem was based on reducing the prolonged delivery time for subsidy housing, therefore this advantage of modular construction methods addresses this problem.

The research findings also indicate that the modular construction methods offer other benefits such as reduced level of required labour skill, improved building quality, and reduced building construction difficulty. The overall sentiments from sample group A – which are the AEC industry professionals, favoured the innovative solutions proposed in this research. The results from the sample group B – which are participants living in different types of residences, proved to be in favour of the proposed methods of construction to be implemented in the construction of subsidy housing. Even though most participants would consider staying in any type of the proposed modular construction homes, the majority of the participants showed more preference towards the precast concrete modular construction home over the shipping container home, as it looks very similar to the conventional brick and mortar home. The group that most appreciated the modular constructed buildings was the participants that are currently residing in shacks located in informal settlement as the proposed methods would improve the living conditions and improve people’s dignity. The results indicate that participants that currently reside in brick and mortar buildings accepted the alternate solution with a bit of scepticism as the idea is new.

5.4 RECOMMENDATIONS

For the success of government subsidy housing delivery, with the aim of alleviating the housing need problem and to eradicate informal settlements, the research makes the following recommendations.

5.4.1 Recommendations for the SA government

i) The SA government needs to be proactive in its commitment to address the subsidy housing delivery backlog problem by exploring other available housing solutions that could be implemented to resolve this problem.

ii) This research addresses the need for alternative housing methods as per the government's current social housing policy which seeks to deliver alternative housing methods that could be implemented for the construction of subsidy housing. The use of modular construction methods (MCMs) is one such alternative, as it could play a significant part in the speedy delivery of housing, thereby alleviating the housing need and assist in eradicating the proliferation of informal settlement in the long run.

iii) Government should, invest in the future development and adaptation of the proposed alternative methods in this study. Government should also allocate funding towards further experimental investigations to be conducted to test end-user (informal settlement dwellers) comfortability, level of security, habitability and suitability to climate conditions.

iv) The consideration of these alternative construction methods in the form of shipping containers and precast concrete modules/panels would empower the manufacturers of these systems, resulting in more research and development for speedy housing delivery.

v) This research has demonstrated that MCMs can be used as an alternative to address some of the subsidy housing delivery problems. The challenge of any new innovative solution is to overcome end-user scepticism as the new solution is out of the norm.

vi) The government should devote itself to carefully educating and bringing awareness to the potential end-users about alternative housing methods such as the use of MCMs that could be implemented for the construction of subsidy housing. According to literature, it is very crucial for the government to involve and enlighten the community of an informal settlement in the process of upgrading their settlement.

vii) Government should update the latest building codes to include the proposed building construction methods in a more standardised and regulated manner.

5.4.2 Recommendations for subsidy housing end-users

i) The end-users must be open to new alternative construction methods/technologies, and they must understand that a house that is not of masonry construction is not at all inferior.

ii) End-users must understand that the only difference between the conventional method of construction and the proposed MCMs is that the material composition of these methods may be different, however they are similar in terms of the physical properties that a habitable home should poses.

iii) Although the proposed alternative methods of construction do not have a long proven record of existence and use like the conventional method of construction, the end-users must understand that they would not compromise the comfort, safety, security and reliability that a typical habitable home should have.

iv) The most important benefit to the end-users is the speedy delivery of social housing and dignified living conditions.

v) End-users must be open to the idea that these proposed alternative construction solutions, can be adapted to be aesthetically appealing, trendy and socially acceptable, with the addition of minor architectural enhancements.

5.4.3 Recommendations to the built environment professionals

i) Although the use of MCMs have been introduced in the construction of medium scale building projects (e.g. small dwellings, clinics, classrooms, offices, garages, emergency shelters, including the construction of affordable housing), these methods have not been fully explored in the construction industry, for the construction of large scale building projects. Therefore, the professionals within this industry must take advantage of the benefits that these alternative methods of construction offer, such as fast delivery of the end product to clients and reduced construction costs, time and labour.

ii) The built environment professionals must work closely with the manufacturers of these MCMs in order to ensure that these systems are designed and built to comply with the National Building Regulations (NBR).

iii) The built environment professionals must be open to developing new systems and technologies that can be used to enhance construction methods for the long term benefit and survival of the construction industry.

iv) The built environment professionals need to integrate the use of these proposed MCMs fully into other architectural applications, to ensure that these proposed MCMs do not define the image of informal settlements or government subsidy housing, instead these methods of construction should define a form of architectural design approach.

5.4.4 Recommendations to manufacturers of MCMs

i) Manufacturers should develop their modular construction systems to adapt to building requirements and to meet NBR.

ii) Manufacturers should invest in research and development for these MCMs in order to deliver large scale projects cost effectively and have streamlined manufacturing processes.

iii) The success of these MCMs would directly benefit the manufacturers, therefore manufacturers should assist government in end-user education about these MCMs, and provide scalable solutions for testing purposes.

5.4.5 Recommendations for future research

i) The main research recommendation is for this research work to be taken to the next phase which would involve life size experimental models of these proposed innovative methods of construction. This would involve physically constructing a sample of each solution to allow for evaluation or testing of the challenges, aesthetic enhancements, end-user comfort, and ease of integrating services. These life size experimental models are essential, as they would allow potential end-users to get the look and feel of the proposed solutions in real life scale. Two experimental end-users can be nominated to live in the two life size experimental models with their families in order to provide the research with in-depth feedback with regards to their overall experience.

ii) Further studies should involve scientific measures to assess suitability to climate conditions, durability, security, acoustics and others.

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7. ANNEXURE A: RESEARCH COVER LETTER

NELSON MANDELA
UNIVERSITY

11 July 2019

Dear Dr. / Madam / Prof. / Sir

Re: Evaluation of innovative construction methods to address housing demand

Dear Respondent

You are cordially invited to participate in completing a survey which forms part of a research study on **"INNOVATIVE CONSTRUCTION METHODS TO ADDRESS HOUSING DEMAND".** This study aims to explore other innovative construction methods that can be used as alternatives for the construction of government subsidy housing in order to fast track delivery.

The undersigned researcher, has identified two innovative prefabricated modular construction methods e.g. (i) shipping container construction and (ii) precast concrete modular construction. The researcher thus proposes that these construction methods be applied as alternatives for the construction of government subsidy housing which would require additional architectural flair in order to achieve an aesthetically appealing appearance that is socially acceptable. Therefore this questionnaire will access the two identified innovative construction methods by conducting a comparative study of these two construction methods against the currently used conventional method of construction (brick & mortar) in SA.

Your participation in this research is crucial and will be highly appreciate. The feedback provided will be used in the abovementioned research study conducted under the MSc Built Environment Programme of the Nelson Mandela University. **Please note that your anonymity is assured,** and that the questionnaire should **not take more than 5-8 minutes** to complete.

Please don't hesitate contact me, should you have any queries or require any clarity.
Thank you in advance for your cooperation.

Mosa B Tsosane
MSc Built Environment (Construction Management) candidate.
Faculty of Engineering, Built Environment and Information Technology

Nelson Mandela University | s209069658@mandela.ac.za | 073 3054 713

8. ANNEXURE B: RESEARCH QUESTIONNAIRE A

NELSON MANDELA UNIVERSITY

RESEARCH QUESTIONNAIRE (A)

(To be completed by professionals in the building industry)

Please provide information for the sections below:

1. Occupation (tick the relevant box below):

Occupation	(Tick)
Architect	
Structural Engineer	
Contractor	
Manufacturer / Supplier	
Quantity Surveyor	
Other:	

2. Please provide your company details:
(Please note, these details will not be disclosed in the research document, it is just to allow easy identification of all data received from the different participants in the building industry).

Company Name: _____

Company Address: _____

_____

_____

_____

3. Provide an **estimated cost** for a 40m^2 government subsidy house constructed using the CONVENTIONAL METHOD OF CONSTRUCTION (Brick & Mortar).

Conventional Construction	(Tick)
R 100 000 – R 150 000	
R 151 000 – R 200 000	
R 201 000 – R 250 000	
R 251 000 – R 300 000	
Other:	

4. Provide an **estimated cost** for a 40m^2 government subsidy house constructed using the SHIPPING CONTAINER CONSTRUCTION.

Shipping Container Construction	(Tick)
R 100 000 – R 150 000	
R 151 000 – R 200 000	
R 201 000 – R 250 000	
R 251 000 – R 300 000	
Other:	

5. Provide an **estimated cost** for a 40m^2 government subsidy house constructed using the CONCRETE MODULAR CONSTRUCTION.

Concrete Modular Construction	(Tick)
R 100 000 – R 150 000	
R 151 000 – R 200 000	
R 201 000 – R 250 000	
R 251 000 – R 300 000	
Other:	

6. Provide an **estimated time frame** of construction for a 40m^2 government subsidy house constructed using the following construction methods:

Conventional Construction	(Tick)
1 week	
2 weeks	
1 – 2 months (4 – 8 weeks)	
3 – 4 months (12 – 16 weeks)	
5 – 6 months (20 – 24 weeks)	

Shipping Container Construction	(Tick)
1 week	
2 weeks	
1 – 2 months (4 – 8 weeks)	
3 – 4 months (12 – 16 weeks)	
5 – 6 months (20 – 24 weeks)	

Concrete Modular Construction	(Tick)
1 week	
2 weeks	
1 – 2 months (4 – 8 weeks)	
3 – 4 months (12 – 16 weeks)	
5 – 6 months (20 – 24 weeks)	

7. Rate the level of **execution difficulty** for the following construction methods.

	Low	Medium	High
Conventional Construction			
Shipping Container Construction			
Concrete Modular Construction			

8. Rate the level of **labour skills required** for following construction methods.

	Low	Medium	High
Conventional Construction			
Shipping Container Construction			
Concrete Modular Construction			

9. Rate the level of **ease to achieve quality** for following construction methods.

	Not easy	Moderate	Very Easy
Conventional Construction			
Shipping Container Construction			
Concrete Modular Construction			

10. What is your opinion on the use of modular construction methods (e.g. shipping containers, precast concrete panels) in all government subsidy housing types (i.e. RDP housing, multi-storey low-cost housing, cluster housing etc.)?

_____

_____

_____

_____

11. Do you think that modular construction methods can also be implemented/integrated in other Architectural applications (i.e. single/double storey residential houses, hospitals, schools etc.)?

Yes	No

9. ANNEXURE C: RESEARCH QUESTIONNAIRE B

NELSON MANDELA UNIVERSITY

APPENDIX C: RESEARCH QUESTIONNAIRE (B)

(To be completed by residents)

Please provide information for the sections below:

1. Indicate the type of residence you currently reside in (tick the relevant box below):

	(Tick)
Conventional Construction House (Brick House)	
Social Housing (RDP)	
Social Housing (Low-cost)	
Shack (Informal settlement)	

2. Which area in Port Elizabeth/Bloemfontein is your residence located?

_____

3. Indicate your job status (tick the relevant box below):

	(Tick)
Employed	
Unemployed	
Casual / Part time worker	
Self employed	
Other:	

4. Indicate your age group (tick the relevant box below):

	(Tick)
25 – 30 years	
31 – 40 years	
41 – 50 years	
51 – 60 years	
61 – 70 years	

Over 70 years	

5. Indicate the number of people living in your house including you (tick the relevant box below):

	(Tick)
1 - 2	
3 - 4	
5 or more	

6. Would you consider living in a **shipping container constructed** home?

Yes	No	Maybe

7. Would you consider living in a **concrete modular construction** home?

Yes	No	Maybe

8. Rate the **appearance** of the following construction methods.

	Not satisfactory	Satisfactory	Very satisfactory
Conventional Construction			
Shipping Container Construction			
Concrete Modular Construction			

9. Do you think the appearance a SHIPPING CONTAINER construction home, with some bit of architectural flair can be **socially acceptable**?

Yes	No

10. Do you think the appearance a CONCRETE MODULAR construction home, with some bit of architectural flair can be **socially acceptable**?

Yes	No