Chapter 1: Introduction

1.1 Introduction

The South African construction sector has experienced rapid growth in the past decade in all facets of construction. The buildings construction sector has grown by 5% on average since 2007 according to results published by the Johannesburg Stock Exchange and the trend is set to continue (Johannesburg Stock Exchange, press release 2009).

The commercial sector in particular has experienced growth in its infrastructure development. Companies are comparing leasing property versus purchasing property and developing their own infrastructure. Many companies are beginning to realise the benefits of owning the property from which they operate. Companies are therefore advancing towards property development for the company's business operations. These advancements in business operations together with the lack of available land forces the growth towards high rise developments. Available Land in Johannesburg Central Business District (CBD) is scarce as well as expensive. "High-rise buildings are designated to specific areas where developments are more concentrated and integrated and where there is a need for more efficient use of valuable and expensive land, such as central business districts and mixed-use nodes," said Poulsen (2009). High rise developments pose a solution to this problem of land scarcity. Poulsen (2009) adds that there have been both successful and unsuccessful high-rise developments in the past, from which lessons should be drawn and that the success of the high rise developments depends on its return on its investment and the optimised utilization of resources.

There is a need for more commercial infrastructure to be built at a faster pace according to Poulsen (2009). Current methods of construction of high rise commercial buildings involve mass concrete as a major component of the building process. Components such as steel, brickwork and timber are also used however the extent to which they are used is overshadowed by the quantities of concrete used in the building process (World Business Council for Sustainable Development, 2009). According to an article published by engineering news South Africa in 2011, a typical high rise project in South Africa ranges from 2 years to 5 years in duration. A major cause for the lengthy construction projects can be attributed to concrete, in particular when used in cast-in-situ construction (Poulsen, 2009). At present cast-in-situ construction as a method of building is common practice for many

South African construction companies (Martha, 2006). The technical and economic expansion of the construction industry in the South African market has led engineers searching for new forms and types of construction methods that are efficient and effective, ultimately saving valuable time and money. Total precast construction building systems are becoming the format of choice and preference for many construction companies involved in high rise construction, (Sustainable Precast Concrete, 2012). The precast building system combines the use of pre-stressed, architectural and structural components to form the entire building (Martha, 2006).

Precast concrete as a technique for building high rise commercial structures has created much argument in terms of productivity when compared to cast-in-situ construction methods. Aspects such as skilled labour, installation methods, environmental concerns, transportation and quality all play a role in deciding which method is best suited to a particular project. In a South African context skill labour, transportation and quality may have a significant effect on the productivity of a project. It is therefore important that certain aspects have to be considered in choosing precast or cast-in-situ concrete for a construction project. These aspects can have an effect on productivity and it is important to divulge these issues if they will affect the construction of high rise buildings within a South African context. These aspects are as follows:

1.1.1 Installation Difficulties

Precast concrete panels are extremely heavy and require some sort of hoisting equipment for installation; however, ready mix concrete also requires machinery for handling and placement (Building & Construction Authority, 2006). Precast requires the use of special rigging such as fabric slings which must be used in order to avoid structural damage while handling other materials in a building. Precast products are designed and manufactured for simple connection and many of its components can be installed in a short time. The National Precast Concrete Association (NPCA) (2008) states that it requires less time to install precast compared with other construction methods such as cast-in-situ concrete. Precast concrete members can easily be installed on demand and immediately backfilled, there is no need to wait for the components to cure and for this reason makes precast concrete a very suitable technique that can be used on almost any structure (Gopal, 2005)

1.1.2 Skilled Labour

There is a reduction of overall labour requirements in using precast concrete; this reduction varies from 50% to 80 % of total labour requirements in comparison to cast-in-situ methods (Precast Concrete in Buildings, 2007). Precast concrete installations requires the use of trained and skilled labour as the components are difficult to assemble and training is therefore essential in precast concrete installations to achieve maximum efficiency however the process of training can be time consuming.

A typical precast concrete erection unit comprises of a crane and small crew of about 5-7 skilled labour (Sustainable precast concrete, 2012). Skilled erectors can erect the entire frame, floors, roof and the walls of a building often before any other trades can begin at the site. The following figures below are typical erection times of 2-3 skilled working crews (Precast Concrete in Buildings, 2007).

- Hollow core floor slab installation - 300 m^2 per working day
- Grouting and fixing of joints in floor - 500 m^2 per day
- Column installation - 8 pieces per day
- Beam installation - 15 pieces per day
- Installation of double tee slabs - 25 pieces per day
- Installation of walls - 15 pieces per day
- Installation of stair and elevator shafts - 2 floors per day

According to a publication, Precast Concrete in Buildings, (2007) approximately $100m^2$ of a commercial building project (offices buildings, shopping centres, schools, etc.) can be erected in a day, including the installation of all components and necessary connections.

1.1.3 Quality Control

The quality aspect in considering precast concrete over cast-in-situ is a major deciding factor. Precast concrete products typically are produced in a controlled environment and exhibit high quality and uniformity in their production (Shen et al., 2008). The variables affecting quality, typically found in production as stated by the Concrete Network are as follows:

- Temperature
- Humidity
- Material Quality

- Craftsmanship

These adverse effects by the above said factors are nearly eliminated in a plant environment where each aspect is carefully monitored and controlled. According to the NPCA there are regulations and procedures in which every plant that produces precast concrete has to adhere to.

1.1.4 Environmental Concerns

In the construction industry, it is common that a significant amount of solid waste is produced from construction work (Shen et al., 2009). The increased production of construction waste such as used timber formwork, unused concrete and packaging has caused significant pollution to the environment and given rise to public concern, predominantly in densely populated areas. The reduction of construction waste has therefore become very important in the pursuit towards sustainable construction. Cast-in-situ methods that are currently being used in commercial buildings generate far too much wasted concrete compared to precast in which specific sections are designed according to specifications (Shen et al., 2009). This method leaves almost no wastage which significantly improves the impact on the environment as concrete is one of the most widely used materials in the world after water according to the World Business Council for Sustainable Development, (2009). Lab testing of precast concrete enables future methods for precast production to be more controllable. Precast methods decrease the need for generators and other mechanical equipment that are otherwise needed for ready-mix concrete thus reducing harmful impacts on the environment according to the Cement and Concrete Institute (2010)

1.1.5 Transportation Concerns

Precast concrete manufactures are generally responsible not only for the production but also for the transportation and erection of the units. Consequently the route, traffic, condition of road and weight of the load may all impose negatively on its applicability and productivity of precast concrete construction if not planned carefully (David & William, 1989). David and William (1989) further state that overweight and oversize permits need to be obtained from the local authorities if the precast units are of an abnormal size. With respect to special permissions, cast-in place concrete makes use of site batch mixes of concrete or ready mix concrete trucks which does not require permission from the authorities (Shen et al., 2009). However, the traffic and choice of route may have an adverse effect on the delivery time.

1.1.6 Cost Considerations

According to Alfred (2001) with respect to cast-in-situ, precast and steel structure costs, the cast-in-place concrete was more cost effective than steel, however precast construction remained the most cost effective.

When working with cast-in-situ concrete the formwork into which the concrete is poured contributes significantly to the total cost of the structure. The labour required to assemble formwork is generally one of the most expensive aspects in a cast-in-situ concrete structure, ranging from 35% to 60% of the total structure cost (Hjalti, 2010).

Hjalti (2010) further states that there are several factors that affect the final cost of precast concrete construction projects and the most influential aspects that can affect cost negatively are:

1. *The repetition of elements.*
2. *The size of the elements.*
3. *The geometrical shape of the product.*
4. *The desired quality of the precast products.*
5. *The amount of lead time the precast manufacturer has before the start of the construction project.*
6. *The actual distance of the precast plant to the building site.*
7. *The dimensions of the elements.*

So far the advantages, disadvantages and limitations of both precast and cast-in-place concrete methods used for high rise construction have been reviewed. These aspects may have a profound effect on productivity of both techniques and its usage in South Africa. According to a study conducted by Polat (2009) time savings and increased productivity have been verified in precast concrete structures throughout the world after taking into account the various advantages and disadvantages associated with precast concrete. According to statistics released by Statistics South Africa on labour productivity, labour productivity has fallen into negative territory since early 2000. Negative productivity meaning that for every additional person employed the economy produced less output. Details can be seen in the figure below.

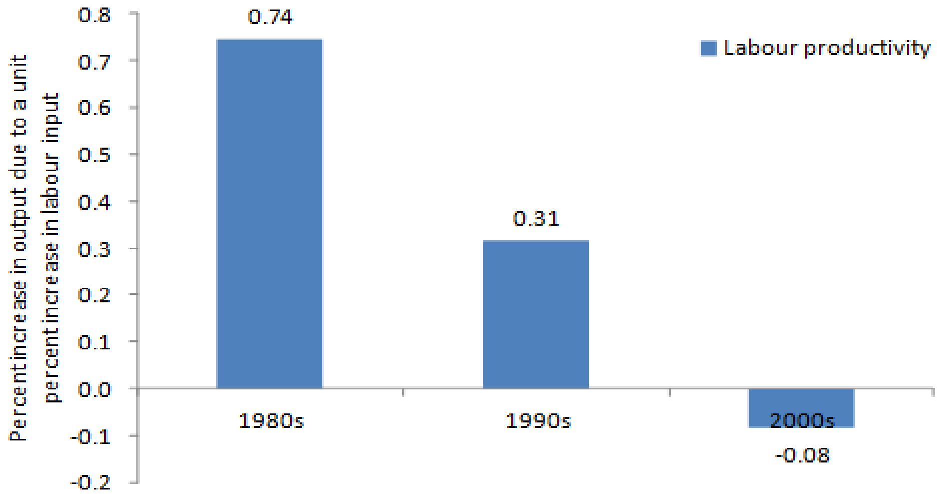

Figure 1.1 South Africa Labour Productivity, 1970-2010; *Statistics SA, South African Reserve Bank, Adcorp Analytics (2011)*

Based on the poor labour productivity in the above diagram it is imperative that a study of this nature be conducted in South African high rise construction to determine if any of the above mentioned advantages and disadvantages of the concrete construction techniques has an effect on productivity and its usage. Little or no research has been done regarding productivity of construction techniques in South Africa and is therefore important to conduct such research.

1.2 Problem Statement

The construction industry in South Africa is faced with shorter lead times to deliver its product in order to maintain the industries economic growth. This requires the industry to adopt innovative construction techniques and methods to deliver the project as early as possible. Precast building methods are one of the methods that can reduce project completion time along with other advantages. However, it requires the skills and resources to make the process more effective and efficient hence there is a need for us to investigate the suitability of precast concrete construction methods in South African high rise building projects. This study focuses on unwinding the above problem relating to productivity and the usage of precast concrete in South Africa.

1.3 Hypothesis

A direct relationship exists between the use of different construction techniques and productivity in South Africa

1.4 Research Questions

- How are the techniques of cast-in-situ and precast concrete different in construction?
- What are all the factors influencing the productivity and utilization of cast-in-situ and precast concrete construction in South Africa?
- Which technique is more productive when analysing cast-in situ and precast concrete construction in South Africa?

1.5 Research Objectives

- To understand the process of cast-in-situ and precast construction in high rise building projects. .
- To identify the factors influencing the utilisation and productivity of precast and cast-in-situ concrete in South Africa.
- To analyse the productivity of cast-in-situ and precast concrete construction in South Africa.

1.6 Scope

The study was conducted within the Johannesburg area. The region and type of projects selected will limit the content and allow an in depth focus to be achieved. The scope of the study was also limited to commercial high rise structures of 5-10 stories in height as this is a common building type and size in South Africa that is experiencing rapid growth. This study does not discuss any issues relating to cost, and focus was given to factors affecting the productivity of precast and cast-in-situ concrete construction techniques. The research is limited to commercial building construction projects and residential projects were not considered in this research.

1.7 Research Limitations

Questions posed in the questionnaire were directed at management as it was felt that issues relating to productivity and technology would be best answered by them, hence, the responses were limited in nature. The research was limited to commercial high rise construction within the Gauteng region in South Africa.

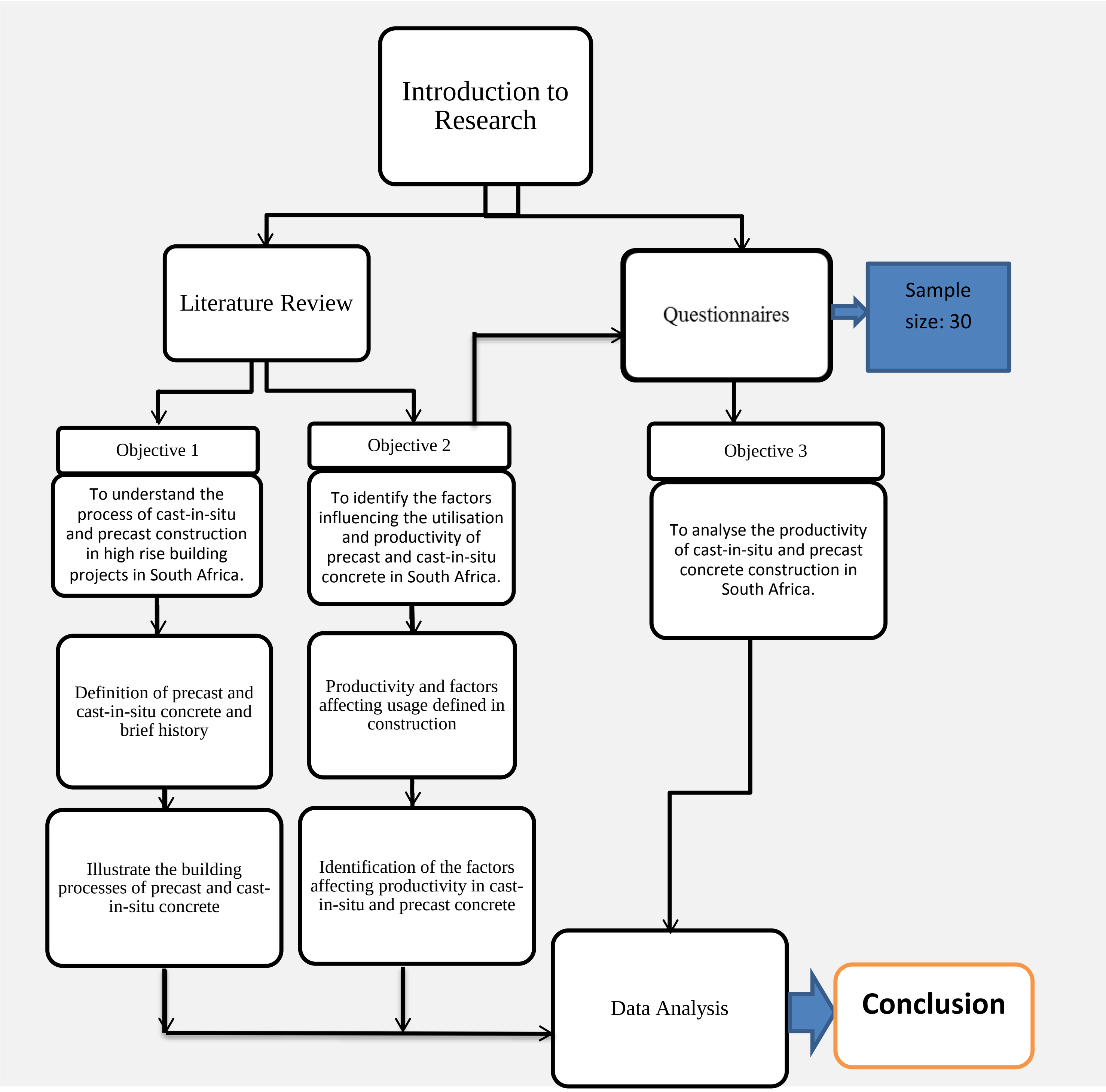

Figure 1.2: Research Design

1.8 Ethics Statement for Proposed Research

The research shall comply with the relevant procedures of ethics as depicted by the University of the Witwatersrand in Johannesburg. Specific care shall be taken in ensuring that there is complete voluntary participation for all the intended respondents. Bearing this in mind, informed consent of all project participants was carried out to ensure respondents understand the risks and procedures involved in conducting the research. The research further guarantees the participants strict confidentiality and anonymity in all aspects of gathering and analysing the data.

1.9 Methodology

This study used a positivist approach. The data for the study is collected through questionnaires from a sample of 30 contractors who are involved in high rise building construction. The collected data is analysed using hypothesis testing and through simple descriptive statistics.

1.10 Study Design

The structure of the report comprises of five chapters. Following the introductory chapter, which outlines the nature of the study and relevance, chapter 2 presents reviews on related literature on precast and cast-in-situ concrete construction techniques, advantages and disadvantages affecting the usage of each method and a productivity analysis. Chapter 3 is devoted to the methodology of the research explaining the research tools implemented and the analysis of the data followed by chapter 4 that represents the research findings and data analysis. Chapter 5 will conclude the research findings and provide recommendations on the adoption and usage of precast concrete in South Africa. A diagram illustrating the proposed research design can be seen below:

Chapter 2: Literature Review

2.1 Introduction

The literature review begins with a brief history and background of precast and cast-in-situ concrete and will proceed towards illustrating the differences in both techniques. In addition to the background, productivity in construction is defined and rates analysed between precast and cast-in-situ concrete to assess the performance. Much of the remaining focus is to be given to two main aspects. The first aspect are factors which affect the use of precast concrete and the second aspect are factors which affect the productivity of precast concrete construction. In summarising the chapter, time savings of/by using precast concrete over other techniques is discussed despite the many inherent advantages and disadvantages of either technique.

2.2 Precast Concrete

According to David and William (1989) precast concrete is defined as concrete that is cast in a different location other than the concrete's final position in the finished structure. The pre-stressing of a precast component is a process that places a concrete member in a compressive state to prevent the concrete from tension cracking. To do this, the concrete is reinforced by either pre-stressing or post-tensioning. This allows it to maintain a greater load and longer spans than regular cast-in-situ concrete (Alfred, 2001). The idea of casting concrete prior to construction has been around for as long as concrete was used as a building material (Hjalti, 2010) The history dates back to 1886, when P.H Jackson who was a structural engineer in San Francisco obtained a patent for a system of tightening steel rods through voided precast concrete blocks to form slabs (David & William 1989). David and William (1989) further state that in 1908 and 1925 R.C Steiner and R.E Dill of the United States developed a method of pre-tightening and reinforcing high strength steel bars into precast elements.

The modern art of pre-casting structural elements began with the work of John Alexander Brodie, an engineer from Liverpool who began to use precast elements as structural component such as precast concrete slabs in construction (Hjalti, 2010)

2.3 Cast-in-situ Concrete

Cast-in-situ concrete also known as cast-in-place concrete is a building system that requires the placement of temporary forms at the concrete's final position together with reinforcing steel (Garcia, 2010). Fresh concrete is then poured into these removable moulds, by means of a ready mixed concrete supplier or a site-mixed batch. Depending on the application, the concrete is left to harden for a few days after which the removable forms can then be dismantled and taken away.

The earliest forms of cast-in-situ structures were noted over 5000 years ago when the Egyptians were building pyramids (Steiger, 1995). The methods of cast-in-situ structures were further developed after the invention of Portland cement in 1824 by Joseph Aspdin of England (Hjalti, 2010). The concrete was developed from portland cement which was high in compression but weak in tension and therefore the cast-in-situ concrete could not be utilised to its full potential until the invention of incorporating reinforcement into it. At the end of the 18th century Joseph Monier, a French gardener who was not satisfied with materials for making flower pots experimented with concrete. However, the pots were not stable and started cracking. Monier then started experimenting with steel mesh that he embedded into the concrete. These experiments by Joseph Monier led to the first reinforcing related patent which he then used in designing the first ever cast-in-situ reinforced bridge at the Castle of Chazelet(Hjalti, 2010).

2.4 Building Processes of Cast-in-situ and Precast Concrete

2.4.1 Cast-in-situ process overview

There is currently a need for more efficiently produced concrete buildings and more innovative approaches in design and construction. At present, a typical building is made up of a number of standardised components like doors and windows. These are a few of the components that no company would consider manufacturing on site and would prefer to produce these components in a controlled environment such as a factory. The industrialised production unfortunately ends with the production of the standardised components and on the construction site the bulk of the work is still craft based (Lofgren, 2005)

An overview of the activities on a construction site using cast-in-situ concrete techniques can be seen below;

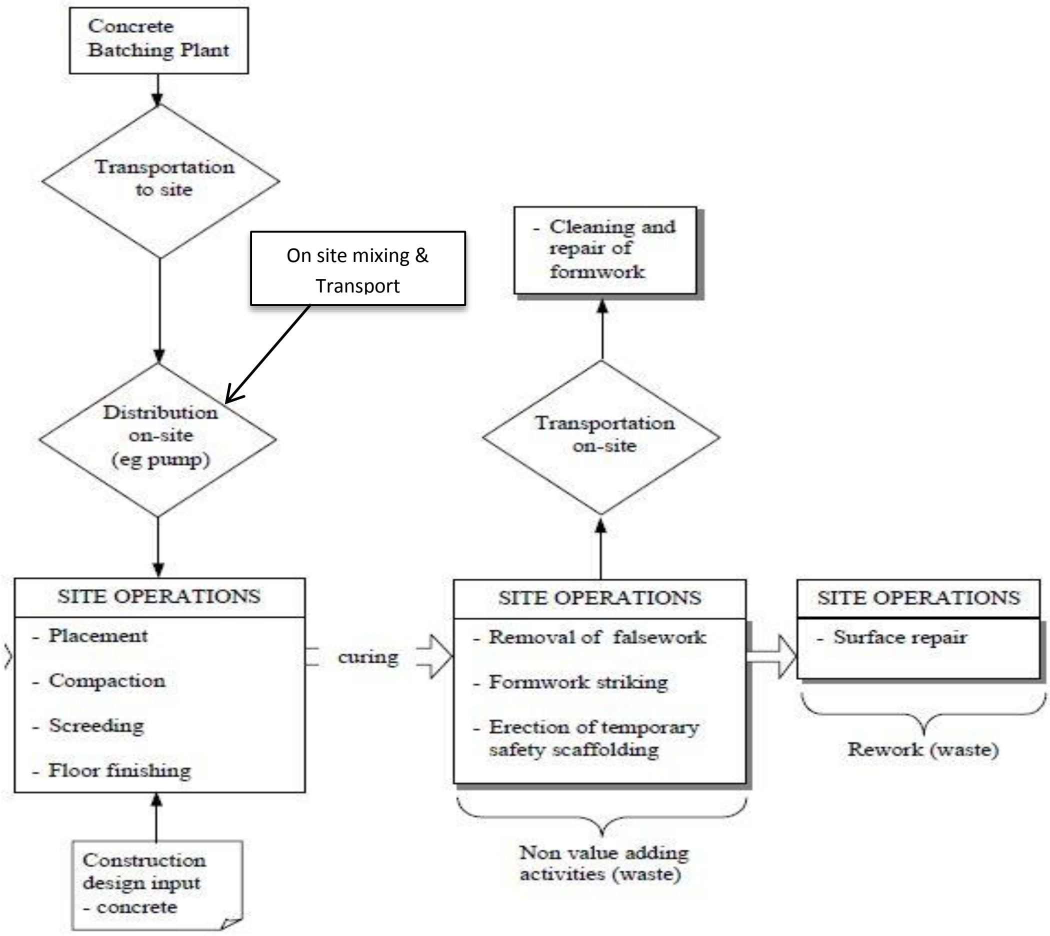

Figure 2.1 Concrete process overview (Lofgren, 2005)

2.4.2 Non-Value Added Work

The following items constitute to work that does not add value to site operations of cast-in-situ concrete (Eastman & Sacks, 2005); removal of false work, formwork striking, erection of temporary safety scaffolding and surface repair. These non-value added work items create a significant delay and reduce productivity greatly in South African cast-in-situ construction; in comparison precast concrete has little or no non-value added items as explained in the sections below.

2.4.3 Precast Process Overview

Precast concrete production is generally referred to as industrialised building (Lofgren, 2005). This term is given to building technologies in which there is a systematic approach to the design, production planning and control. Most importantly, the manufacture and erection is mostly mechanical and automated. An overview of the precast process can be seen below.

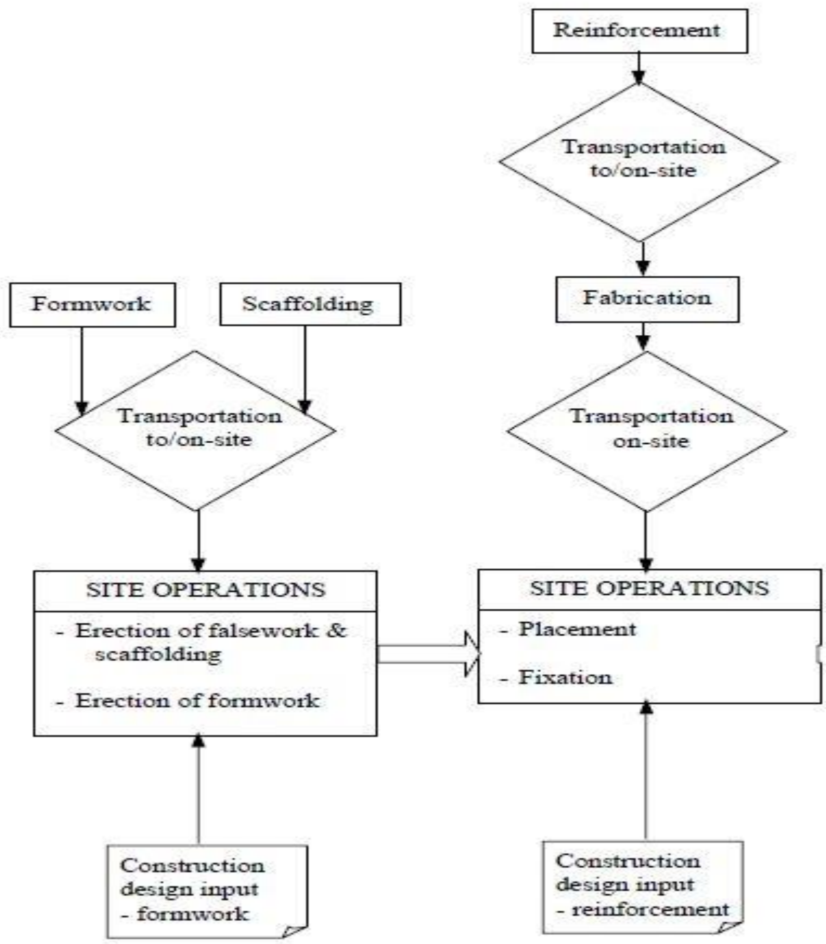

Figure 2.2: Precast concrete process overview (Lofgren, 2005)

2.4.4 Installation Process Overview

In the picture below, precast wall panels are erected using a crane and anchor hooks. These anchor hooks are cast into the concrete and act as lifting mechanisms as well as balancing aids during installation. These wall panels are set into position and grouted using an epoxy.

Figure 2.3: Precast wall installation-wall to slab (CPCI 2012)

Figure 2.4: Precast wall installation-wall to wall (CPCI 2012)

In the picture below, precast floor panels are placed using the same technique with a crane and anchor hooks. The panels are placed spanning the outer edges of the walls in order to distribute the weight evenly across the structure.

Figure 2.5: Precast concrete slab installation (CPCI 2012)

2.4.5 Important Productivity Considerations and Guidelines

Gregory et al. (2012) recommend that monitoring drawings to ensure the proper orientation of structures is vital in reducing any unexpected delays associated with precast concrete installations. Other circumstances if not considered that will impact on productivity are the assembly of multiple section structures by setting levels and positioning the base of each section before beginning with the next component.

Taking into consideration the above guidelines, South African precast contractors represent a building technique that is fairly uncommon in South Africa. The experience and ability of these contractors are minimal which subsequently affects efficiency and productivity negatively. The above guidelines can assist emerging and existing precast concrete contractors in South Africa to improve on their productivity.

2.5 Typical Framing Systems for Cast-In-Situ and Precast Concrete Production

There are a number of different techniques used in construction of precast and cast-in-situ components as stated by Brzev (2007) some of these techniques are listed below;

2.5.1 Cast-in-situ framing systems used for slab production in high-rise construction

A) Solid flat slab

A solid flat slab has the advantage of being flush with the soffit. The slab has a minimum depth that allows for greater flexibility and routing for horizontal services, for spans from 6-10m.

B) Ribbed Slab

A ribbed slab increases the span by reducing the self-weight of the concrete by the use of its structural design, for spans from 8-14m.

C) Band beam and slab

The band beam and slab has a wide shallow cross section, this allows the overall depth to be reduced and the overall span to be increased, for spans from 8-15m.

2.5.2 Precast Framing Systems Used for Slab Production in High-Rise Buildings

Precast floors have the advantage of having controlled manufacturing conditions together with eliminating the need for formwork and labour. These controlled environments promote high quality standards and reduce wastage. There are also options of pre-stressing to increase spans and strength. Typical precast segments are;

A) Hollow core slab

Precast hollow core slabs have minimal concrete in its design. The design allows for spans of 6-11m

B) Composite floor

A composite floor is a combination of precast and cast in situ elements. Spans range from 8-18m

C) T-Beam slab

T –beam slabs offer the highest loading capability and the longest spans but still having the advantage of being light weight. Spans range from 8-20m. Brzev (2007) states that there are various other forms of precast concrete components and designs available for general construction. These other items can be seen in the section below;

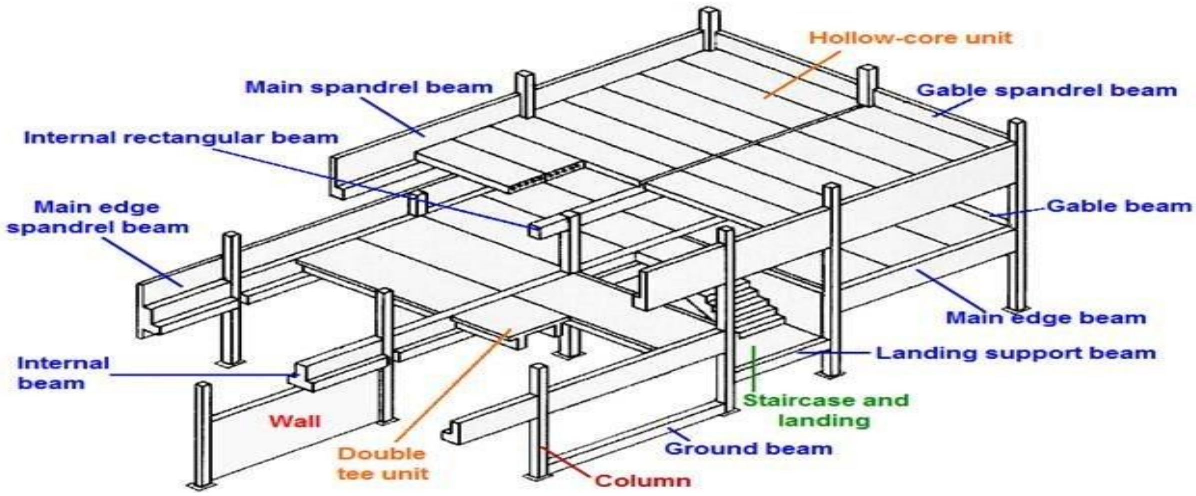

Figure 2.6: Precast concrete components (CPCI 2008)

2.6 Productivity in Construction

James (2006) defines productivity as, "the average direct labour hours to install a unit of material*"*. James (2006*)* further states in a perfect scenario "perfect productivity 1.0 would be accomplished in a standard 40-hour work week with everyone taking all of their holidays and vacation days as planned, all of the engineering drawings would be 100 % complete, there would be no delays of any kind, everyone would work safely, everything would fit perfectly the first time, the weather would be 21 Degrees Celsius, and there would be no litigation at the end of the project." There are many productivity-based definitions, however, the current study is restricted to the definition of labour productivity as a direct measure of industrialised methods, thus productivity can be considered as a ratio of "net production output realised from a quantity of labour input.'' (Eastman & Sacks, 2005)

Eastman & Sacks (2005) further state that one has to study the net production output of a construction activity to be the value of shipments or for site based construction, the value of materials put in place less the value of the activities input resource (fuel, electricity, etc.). Productivity is thus a function of the following, according to Eastman & Sacks (2005);

Productivity *(P_{i})* of a representative construction worker in some defined activity *i* as:

$$P_i = v_{i} / n_i$$

Where v_i = total value added and n_i = total number of workers employed

According to Eastman & Sacks (2005) there is a need to scrutinise the productivity of the off-site precast building components, in relation to similar productions that occur on site. There is also a requisite to examine business data by taking into account labour, wages, product worth and added value generated by these aspects. Wherever possible it is useful to examine industry data for speciality contractors that may exist, so that the economic effects of the activities studied are not weakened by other activities (Eastman & Sacks, 2005). Productivity in construction may be defined by simple formulae and definitions; however the characteristics of the surrounding environment are vital and dictate the final outcome in construction. South Africa is different in many ways to other countries and one has to consider its uniqueness in an attempt to analyse productivity.

As a particular industry grows, the value of this growth can be attributed to two factors:

(1) Increased labour inputs for doing the work.

(2) Increased productivity of each unit of labour.

In order to substantiate any claims, it is imperative to observe and compare a range of different construction work types, some of which are carried out entirely on-site and some of which are carried out in both locations, and other activities that occur mainly off-site in its production (Eastman & Sacks, 2005).

Eastman & Sacks (2005) state that construction activities that are mostly carried out on-site will display low or negative productivity growths were as construction activities that occur partially off-site and partially on-site will show more productivity gain in the off-site section. Eastman & Sacks (2005) further state construction activities that are mostly off-site will have high productivity growth in relation to the construction industry as a whole. Through a South African perspective problems could be encountered in the separation of construction activities being carried on and off site as traffic congestion, location of construction sites and

2.6.1 Productivity Rate Analysis of Precast and Cast-In-Situ Concrete

A comparative case study was done by Idrus et al. (2011) between two projects in Malaysia. One method using precast building technology and the other using cast-in-situ concrete technologies. The labour productivity on these two construction sites was measured of which the focus was based on four structural components which are: beams, columns, walls and slabs. The data collected from the sites were then analysed in terms of productivity as well as factors that affected productivity were noted. The conclusions obtained from the research were that precast concrete is better than cast-in-situ concrete in terms of productivity as the empirical values showed that the number of hours to install structural components was considerably lower. The effect of precast concrete productivity against cast-in-situ concrete productivity has the following reduction times listed in the table below;

Table 2.1 Reduction in construction time due to productivity improvement

Improvement area	Reduction in total cycle time [%]	Reduction in total man-hours [%]
Supply chain management	10.5	15.0
Buildability	3.0	3.5
Resource allocation	6.5	10.5
Operational methods	8.5	13.5
Total	**28.5**	**42.5**

(Lofgren, 2005)

According to Idrus et al. (2009), who documented a study of precast concrete slab construction and cast-in-situ slab construction there was no actual differences recorded in the productivity. The improvement in productivity certainly improves project completion time but the above examples fail to consider outside elements and unique environments. One can expect a slightly different outcome in South Africa. The duration of the two projects above was almost similar and a summary of the results can be seen in the table below.

Table 2.2 Comparative summary of precast against cast-in-situ concrete productivity

Schedule Duration Comparison for Structural Systems	
	Duration (Days)
Precast Planks	14
Composite Slab	14
Difference (Days) :	**0**

(Idrus, 2011)

2.7 Factors Affecting the Use of Precast Concrete

According to Polat (2010), one of the major factors currently affecting precast concrete installations is the availability of specialised precast concrete contractors. Apart from specialised contractors, there are numerous other factors affecting the use of precast concrete, these factors are listed below;

2.7.1 Availability of Labourers Specialised In Precast Concrete Systems

According to Polat (2007), the construction industry is a labour intensive industry especially in the conventional cast-in-situ construction method. Although the precast construction techniques are less labour-intensive, the installation process still requires many labour hours. Consequently, manpower is one of the main factors behind productivity resources in the construction industry. Polat (2008) stated that the lack of qualified and skilled labour in precast building systems brings about poor construction practices that may lead to poor structural performance due to distress in the connections. Precast concrete components are a principally factory-built product, however, they are assembled and installed on-site by construction labours, the expertise level is therefore very important to ensure structural integrity (Polat, 2008). “A shortage of technical skills in the engineering and technology fields is crippling South Africa’s economic growth”, says Cement & Concrete Institute (C&CI) MD Bryan Perrie. These skills shortages possess a significant impact on productivity.

2.7.2 The Availability of Specialised Precast Concrete Contractors and Technological Capacity

According to Polat (2008), the supply process of precast concrete components involves complex and critical resource flow between the project participants including but not limited to the producer, contractor and designer. To manage the entire supply chain process would require a great level of co-ordination amongst the various parties. Polat (2008) further states that contractors are one of the vital project participants as the contractors are responsible for the organisation and installation of precast components in a precast concrete project.

At a convention hosted by the Concrete Manufactures Association (CMA) and the Concrete Society in 2011 the issue of technical capacity and technologies were discussed in relation to precast and cast-in-situ technologies in South Africa. The key purpose of the convention was to promote the use of modern precast technologies which the South African construction sector must embrace should it wish to provide the efficient and dynamic building systems that the industry requires. The vice president of the CMA floor slab division Monique Eggebeen commented that hollow-core precast concrete flooring has been available in South Africa for the past 30 years with a substantial growth potential. According to Eliott (2011), precast building systems in South Africa are particularly suited to residential and apartment blocks as well as medium to high-rise structures. Poulsen (2009) states that precast hollow-core flooring contributes substantially to subsidised housing and there has been several cases where this has been achieved, the latest being the Legacy Housing Project in Cape Town in South Africa, the technology was successfully implemented in the construction of semi-detached double-storey apartments. Contractors specialising in precast concrete are available in South Africa and there are many more contractors pursuing this technique, with time more contractors will participate and compete in the market making it more diverse in nature.

2.7.3 Waste Generation

In any construction activity there are significant amounts of solid waste that are produced. The excessive amounts of construction waste such as used timber formwork, unused concrete and packaging has caused significant pollution to the environment and risen public concern in densely populated areas.

According to a journal published by Martha, (2006), there is not much construction waste to dispose of at a construction site when the structure is composed mainly of precast components. A large research study was carried out in Sweden in 1996 where 400 apartment buildings were constructed. Ten buildings with similar areas were carefully chosen, each containing 11 apartments; 5 were precast and 5 were cast-in-place. Precise records were taken of the intake of energy, materials, productivity, and construction time, working environment, sick leaves, accidents, quality control, erection, waste generation and cost factors. The conclusion from the above research showed a 35% reduction in construction waste when compared to the cast-in-place building techniques.

According to another case study conducted by CPCI (2012), concerning waste generation at a major project in Oslo, Norway. The area of the buildings measured 150 000 m^2. The construction was based on using steel frames with precast hollow core floor and roof slabs components. The delivery and installation of the steel frame and the slabs were combined in the procurement section of the contract. The excess material generated at the site during the erection of these components was only about one kilogram per cubic meter /m^3 of hollow core slab. The excess material comprised mainly of wood, concrete and reinforcing steel from the site. Most of the excess material produced on the site, excluding some epoxy resin, was recycled, and was not considered as wasted material.

Research was conducted by De Silva (2008), on construction waste from data collected from 27 building construction sites, the data was refined into slab, beams and columns of which only these components were considered as construction waste for the study. To compare the wastage accurately precast concrete and cast-in-situ where compared to each other in relation to three main elements found on site namely, cement, sand and metal. The results from the study can be seen below;

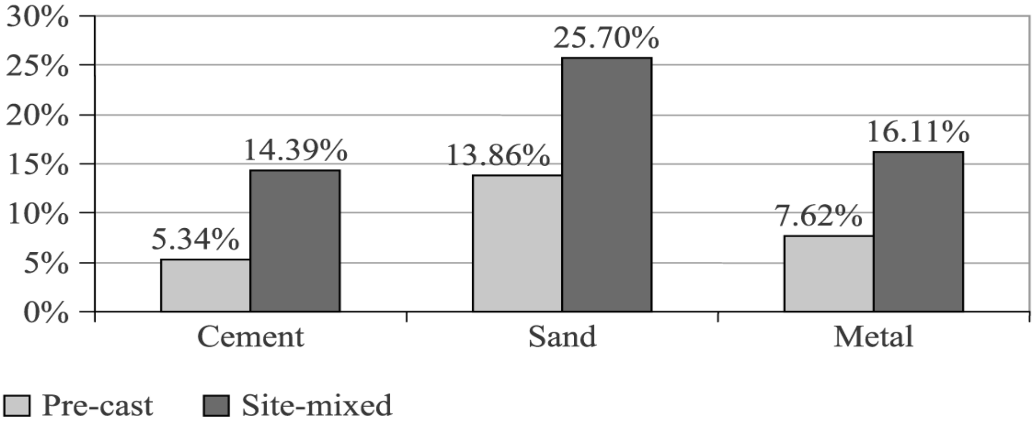

Figure 2.7: Precast and Cast-in-situ materials wastage (De Silva, 2008)

Typical waste generated on a construction site can be seen in the image below provided by CPCI (2012),

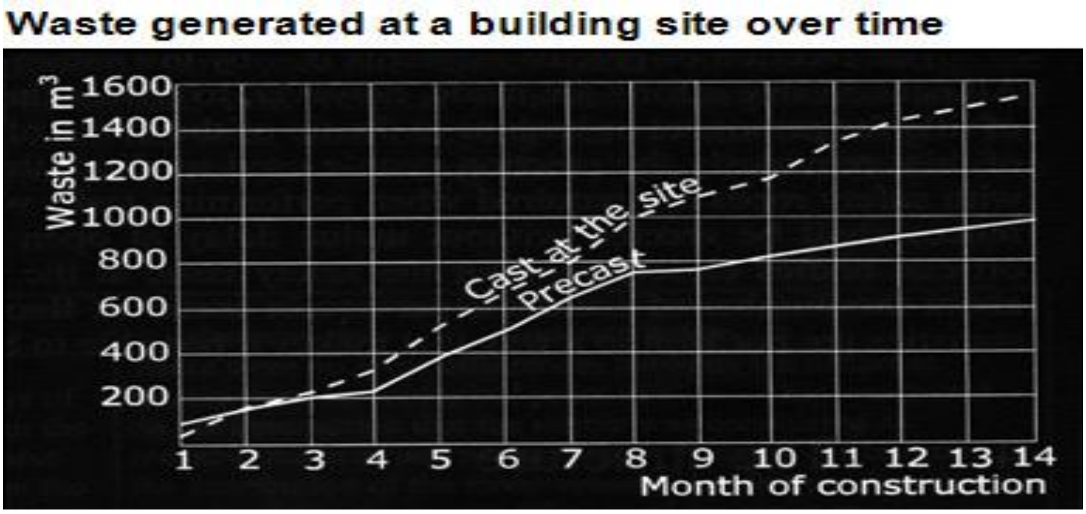

Figure 2.8.Waste generated at a construction site (CPCI, 2012)

2.7.4 Environmental and Social Impacts

- Precast concrete supports excellent air quality indoors and holds no Volatile Organic Compounds (VOC's) to contribute to 'sick building syndrome' As stated by Martha, (2006). Precast concrete is superior in safety and protects againstfire, wind, vibration, and seismic activity. Excellent sound properties are maintained with walls and floors having excellent Sound Transmission Class (STC) ratings to maintain sound levels. The operating energy efficiency and heating & cooling costs are reduced due to the thermal mass of precast concrete. The desired R-value can be attained by stipulating the appropriate type and thickness of incorporated insulation. Martha, (2006) also states that precast concrete requires reduced energy needs for maintenance and renewal that leads to longer lasting structures. Precast concrete structures do not require any additional finishes which makes the process highly productive. The light colour of precast concrete walls also reduces interior lighting requirements while the 'heat island' effect can be reduced with the lighter shades on the exterior (Martha, 2006).

2.7.5 Cost Considerations

The economic advantage of precast concrete is maximised with increased repetition in its production through its design (Alfred, 2001). Careful considerations given to planning can achieve good repetition in the design without compromising any design freedom. Alfred (2001) states that lowering precast concrete unit costs can be achieved by using recommended component sizes and productivity improvement is possible through tooling and design innovations. Production of precast components may continue while foundation and site work have already commenced, this speeds up the construction process ultimately saving costs. Brian (2005) also states that financing costs are reduced due to the overall shorter construction time. According to the CPCA (2012) one of the main economic benefits related to precast concrete is that it is made out of local materials that can be obtained close to its production, thus reducing (additional) transportation costs. The system is low maintenance which requires cleaning only occasionally and the thermal mass characteristics of precast concrete promote lower operating costs to help reduce cooling and heating peaks and lower the need for HVAC equipment. The CPCA (2012) further state that the reflectance abilities of precast concrete surfaces may reduce interior lighting costs and decrease the 'heat island' effect and contribute to lower cooling costs.

The CPCI (2012) state that precast concrete products prices are highly effective as the production process is shorter and more tightly controlled and cost can be more accurately controlled and estimated earlier in the construction process. Changes during design and development can be quickly reassessed to ensure that estimates remain stable.

There are three main factors that make up the cost of cast-in-situ concrete construction which ultimately affects its use over cast-in-situ concrete. According to Hjalti (2010), these factors are:

- Formwork materials & labour
- Reinforcement labour & materials
- Concrete labour & materials

These factors make up the majority of the cost for a cast-in-situ construction project; there are, however, two other factors that may contribute significantly to project costs. The first factor would be the internal and external finishing of the building and the second would be the influence of weather precautions on concrete works and how cold weather affects the workability and properties of concrete. The main factors contributing to concrete labour in cast-in-situ construction as stated by Hjalti (2010) are;

- The method of placing the concrete
- The rate of delivery of ready mixed concrete
- Properties of the concrete to be placed
- Size and shape of concrete structures
- The amount of reinforcement in the formwork

The above items do form part of the major work in South Africa's construction techniques Focus should not only be given through a cost perspective but the items above will also improve on productivity issues.

To demonstrate the cost comparison between precast concrete construction and cast-in-situ concrete construction, two similar projects carried out in Copenhagen were documented. A difference may be observed thorough a South African perspective as labour cost might not be as high as other countries. This could prove to be advantageous with productivity as more labour could be added to a construction site with no major cost impact. After reconciling the accounts for the projects carried out in Copenhagen, the cast-in-situ project had a higher cost than precast concrete which can be seen in the graph below;

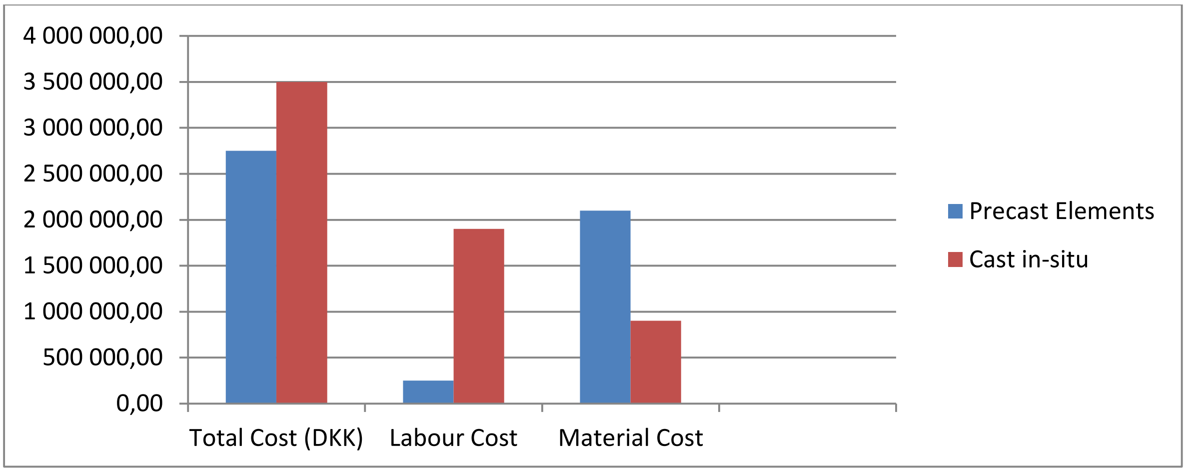

Figure 2.9 Cost comparison of precast and cast-in-situ construction (Hjalti, 2010)

Another similar study which considered three prototypical buildings with similar footprints and resources where compared in terms of actual cost, the results can be seen in the table below;

Table 2.3 Cost comparison of precast, steel and cast-in-situ concrete

COSTS	PRECAST	CAST-IN-PLACE	STEEL
General Conditions	Lowest	Highest	Higher
Structure & Enclosure	Lowest	Highest	Higher
Concrete Decks & Topping	Higher	Lowest	N/A
Shear Walls	Higher	Highest	Highest
Fireproofing	Lowest*	Lowest*	Highest
Caulking	Lowest*	Lowest*	Highest
TOTAL	**Lowest**	**Highest**	**Higher**

(Total Precast Concrete Structures, 2004)

Working with cast-in-situ concrete, the formwork into which the concrete is poured constitutes to a considerable item in the cost of the completed structure. The labour required to assemble formwork is generally the single most expensive aspect in a cast-in-situ concrete structure, ranging from 35% to 60% of the total construction cost (Hjalti, 2010). The pie chart below shows the distribution of construction cost on a cast-in-situ construction project.

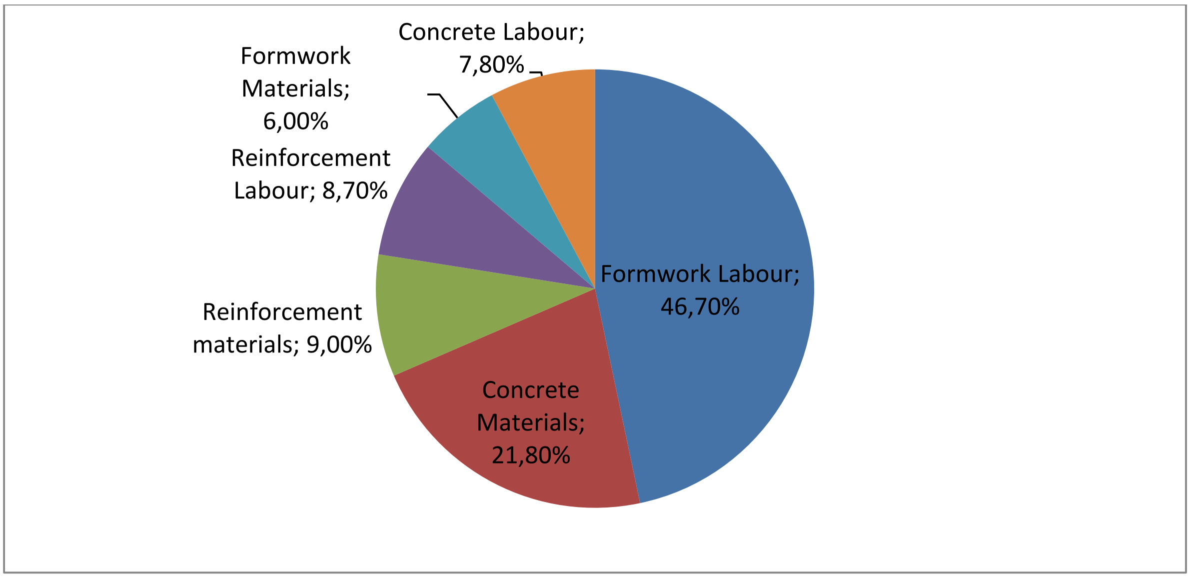

Figure 2.10 Cost breakdown of cast-in-place construction (Lofgren, 2010)

2.7.6 Quality Aspects

An important advantage of precast concrete components is the ability of the pre-casting process to achieve consistently high quality products. The abovementioned shortage of skilled labour has threatened the standard of workmanship in many projects. In precast building projects the process is factory controlled and the manufacturing processes are state of the art enabling precise dimensions, shapes, textures and sizes of concrete panels to be produced much more easily. The precast process also enables the product to be inspected prior to installation. However, the cast-in-situ process has a different set of quality parameters in comparison to precast concrete. According to Hjalti (2010), there are five quality parameters that need to be considered of in cast-in-situ concrete, these parameters are; strength, reinforcement, welding, finished surface, tolerances.

Any pre-stressed concrete member is subject to changes caused by temperature, creep, elastic shortening and shrinkage (Alfred, 2001). Due to these changes, it is essential that the joints are properly designed to allow for any movements without damaging the structure itself. Precast concrete has a significant positive effect with respect to such forces as the forces have already occurred prior to the delivery of the precast product to the site. The movement in precast concrete structures is therefore significantly less than in cast-in-situ structures. By minimising the volume changes together with small joints, precast concrete structures are made both more watertight and aesthetically pleasing. The quality parameters of precast concrete at glance seem to be very demanding however if adhered to strictly the process might be more productive as no rework will have to be done at later stage during construction.

2.8 Factors Affecting Productivity of Precast Concrete

2.8.1 Project Programming

Project programmers working on total precast systems as a method of construction agree that proper project programming saves the project six to eight weeks compared to steel and even more when compared with cast-in-place concrete (Polat, 2008). The total time saved compared to conventional building methods can be critical in meeting a tenant's need for occupancy. The project programming advantages for precast concrete result from several factors that grow through the process (Total Precast Concrete Structures, 2004). These factors are; one-stop shopping secures much of the building's shell in one efficient contractual relationship. The fabrication of units and site work can be done simultaneously. Designers find precast systems easier to design with growing support from new and emerging precast engineers. These systems can also be erected in winter and severe weather conditions, thus maintaining the project's work programme. Finally total precast systems allow the contractor to enclose the building quickly, giving interior finishes an earlier start.

A project delivery timeline between precast concrete and cast-in-situ concrete will differ mainly in the design stage where the time savings achieved are in the region of 25 % faster/shorter (Total Precast Concrete Structures, 2004). Furthermore, the design stage of the project can overlap various phases of the project reducing the overall project timelines. This on-site efficiency of precast concrete provides superior programming flexibility compared to cast-in-place concrete.

2.8.2 Problems Encountered By On Site Managers

According to research conducted by Yannas and Jost (1976), the major problems identified on precast construction sites affecting productivity by on-site mangers are trucks that are frequently delayed, site locations create delivery problems and too many trucks arriving at once

Other problems on site that were significant according to Yannas and Jost (1976) are; technical problems, too many joints, sequencing of erection and deliveries, lack of skilled labour and strikes/sit downs and go-slows. These problems depicted by the study above portray a problem commonly faced in South Africa. The problems are so significant that the process of cast-in-place concrete can be ruled out as an altenative.

2.8.3 Design and Information Processes

Karhu (1997) states that the processes involved in precast design that ultimately influence productivity are; project briefing, programming, global design, detail design, design during construction and design for usage and maintainance.

Typical information flow in traditional building design goes from architect to structural engineer and finally to manufacture. Usually a break in the information pattern is the return of information from the structural engineer back to the architect. There are many different building packages available in South Africa that could eliminate problems faced in communication by various parties. A result in major delays due to communication can be seen in the figure below;

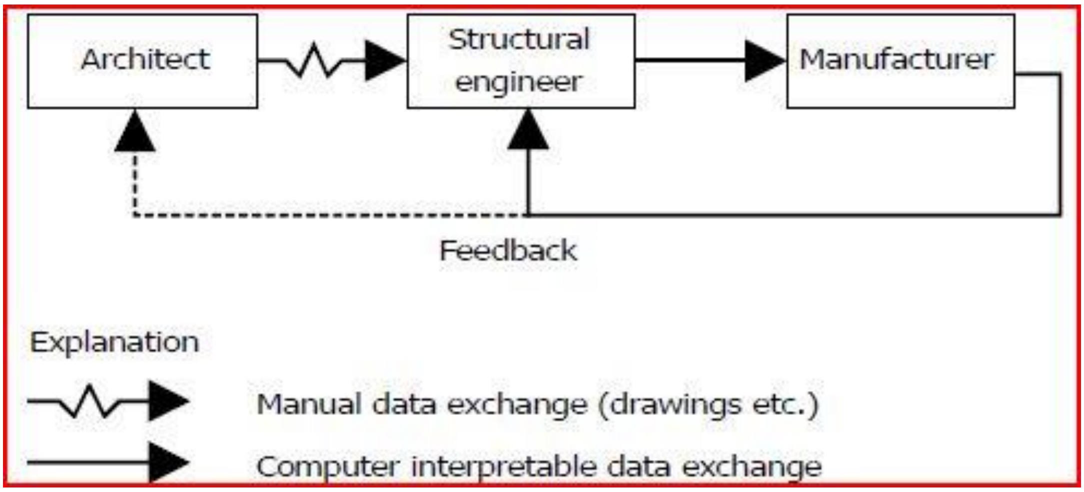

Figure 2.11: Information Sequence (Karhu, 1997)

2.8.4 Business Constraints

The Grant Thornton International Report (2012) of over 11 500 companies in 40 economies focused primarily/mostly on the constraints of doing business in the South African construction and property sectors. This report highlighted three aspects that have proven to be significant constraints, these are; regulations and red tape (49%), the lack of available skilled work force (40%) and a shortage of demand (36%). The lack of available skilled labor is concerning as this is an important component in the productivity of precast concrete and cast-in-situ concrete. Much attention has to be given to skilled labor in order to make an informed decision about which technique will be suitable. A detailed breakdown of the constraints can be seen below;

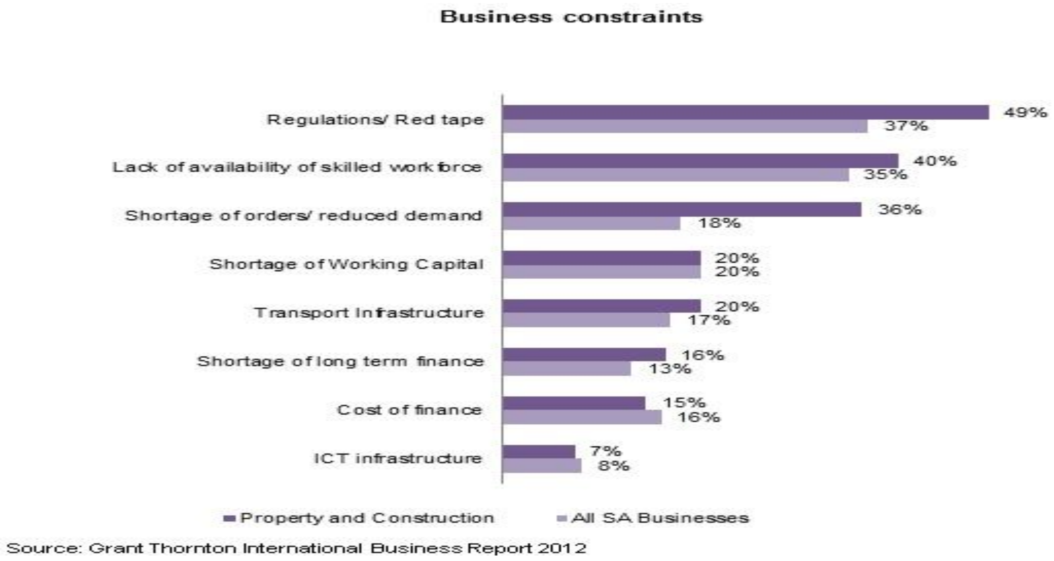

Figure 2.12: Business constraints in property and construction, (Grant Thornton International Business Report, 2012)

2.8.5 Transportation Restrictions

Delivery of precast concrete components from manufactures is generally met with delays. The main problem encountered is when the construction site is located in the city centre where factors such as traffic, overcrowding, loading restrictions and restricted space cause severe problems and effect the productivity of a construction project (Polat, 2008). The allowable weights and sizes of loads are restricted severely as dictated by the carrying capacity of on-route bridges, pavements, tunnels, etc. (Arditi et al., 2000). Furthermore, there are other limitations imposed by government and road agencies such as lane restrictions and parking availability. These restrictions can have a severe impact on the delivery on precast components to the construction site which in turn significantly reduces the overall productivity while workers have to wait for precast panels to be delivered if they are not already on site otherwise known as idle time.

2.8.5.1 City of Johannesburg's Managed Lanes Policy

According to the latest publication of traffic regulations published by the Johannesburg Department of Transportation (2012) factors that may contribute to issues relating to productivity are the use of exclusive lanes; further information relating to exclusive lanes can be seen in the paragraph below;

Exclusive Lanes

The exclusive lane regulation offers certain vehicles, generally designated by vehicle class an exclusive functioning lane. The most common types of vehicles selected for this policy are buses and large trucks. Buses are often given exclusive lanes to provide an incentive for commuters by decreasing delays associated with traffic, whereas trucks are separated in an effort to decrease the effects of trucks on safety operations and minimise struggles by the physical split-up of truck traffic from passenger car traffic. Various forms of truck lanes in South Africa serve to improve traffic operations, productivity, and safety and aid the flow of goods. Truck lanes involve lane restrictions on existing mixed lanes, separated, dedicated roadways, and interchange bypass lanes, these special allocations contribute to faster traffic flow rates especially in the city centre. The use of exclusive lanes may be both of an advantage and disadvantage, if problems are faced with these exclusive lanes there are possibilities that delays could be inevitable. A well designed system with good interface and operational plans should be an ideal solution to the use of exclusive lanes.

2.8.6 Resource Allocation Problems in the Precast Industry

According to Al-Bazi & Nashwan (2009), there is a need for logical dependencies and resources for items such as worker crews, plant and equipment. The formation of a crew may contain shared work which is involved in more than one process, whereby an individual or resource may be a part of various sequences of the work and is not dedicated to a specific activity. An individual resource allocation allows activities to start as soon as the logical dependencies are available without any delays. Idle times of resources are still not carefully considered and the overall output time or total costs maybe longer or higher than expected. This problem becomes more pronounced when there is significant idle time for a process because of shared workers allocated at more than one process and needed at each of the allocated crews amongst different or similar precast operations (Al-Bazi & Nashwan, 2009).

Precast operations are labour intensive and the workers involved in this industry are highly skilled and therefore costly. Thus, optimisation of crews is essential to improve productivity and minimise idle time (Al-Bazi & Nashwan, 2009).

2.9 Time Savings Despite Surrounding Circumstances

The Precast Concrete Institute (2004) offers a comparison of project tracking for two similar office buildings. The comparative analysis was carried out by a nationally recognized estimating company. The research subject comprised of a 4 story high, 100 000 square-foot building and an 8-story, 200 000-square-foot building, each with an area of 113 feet x 227 feet. The total precast structure was ready for occupancy in 21% less time than the steel & brick, 16% less than the steel & precast and 29% less than the cast-in-place framing method. The time savings can be seen in the graph below.

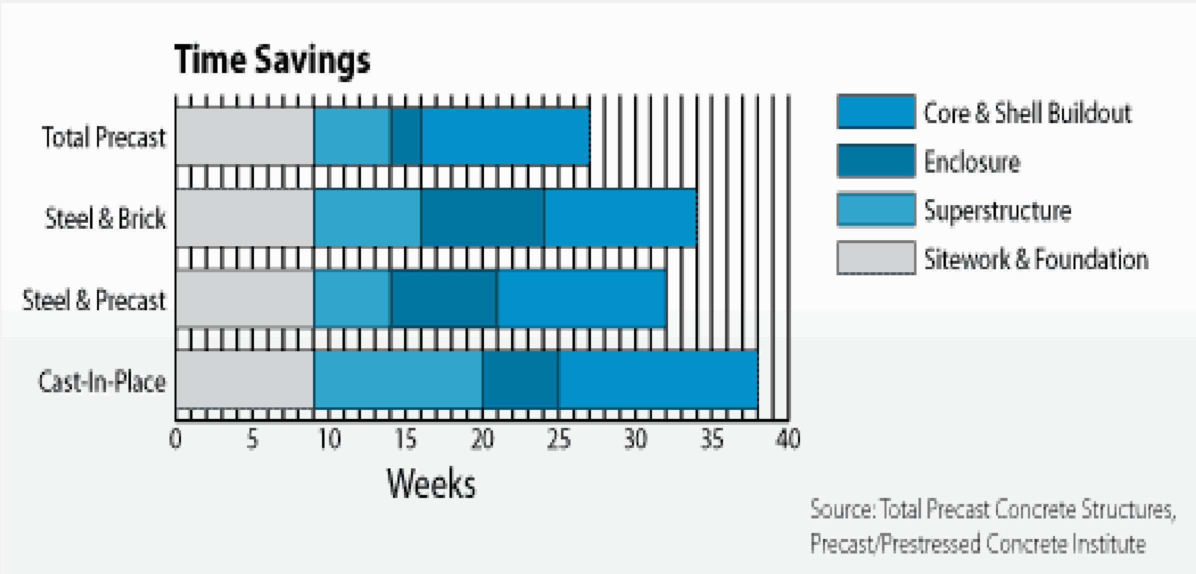

Figure 2.13 **Time savings with the use of precast concrete techniques (Total precast concrete structures, 2004)**

2.10 Conclusion

Precast building techniques are very different to cast-in-situ methods as precast concrete components are primarily factory built. In comparison, cast-in-situ concrete is a method of building in which most of the activities occur on the construction site. There are various advantages and disadvantages of precast concrete. However, there are similar experiences with cast-in-situ concrete construction. The major advantages associated with precast concrete are increased productivity, reduction of total project duration and environmental impacts. Disadvantages of precast include availability of specialised contractors, skilled labour and costs. In contrast/ by way of comparison with cast-in-situ concrete construction has the advantage of being cost-effective, easy to build with design freedom and a large variety of capable contractors. The disadvantages of cast-in-situ are poor productivity, extended contract durations and environmental concerns. These advantages and disadvantages promote a strong justification for this study to be conducted in South Africa which will highlight the major issues affecting productivity and usage of building techniques.

Chapter 3: Research Methodology

3.1 Introduction

The main aim of research is to pursue knowledge and not merely to gather information, and in the process achieve to answer the “unanswered” questions (Goddard & Melville, 2001). Leedy & Ormand, (2005) state that research is a systematic process of collecting, analysing and interpreting data for the purpose of increasing ones understanding of the phenomenon about which one is interested in. The main purpose should be to seek answers to a problem or problems in the light of the data that relates to these problems incurred. The method used to achieve this can be divided into two separate fields of work, the first part being the ‘deskwork’ and the second part which is the ‘fieldwork’. The deskwork takes the form of a literature review and the questionnaires produce the data required for the field work. A brief overview is given at the beginning on the type of research, which is followed by population and sampling methods used in this study. The research tools selected is described in detail and finally the method of analysis of the data and its justification is explained.

3.2 Type of Research

Qualitative research is associated with the social constructivist paradigm which emphasises the socially constructed nature of reality. Qualitative research is based on recording, analysing and attempting to uncover the deeper meaning and significance of human behaviour and experience, including contradictory beliefs, behaviours and emotions (Goddard & Melville, 2001). Quantitative data is represented by empirical values that require mathematical computation to conclude the research, Leedy & Ormand, (2005). The data in this research is therefore of a qualitative nature as opinions and theories will be used to conclude the findings.

3.3 Population

The population was chosen from the South African construction sector involved in precast and cast-in-situ concrete construction as this is a group that is the subject of interest and defines a population (Goddard & Melville, 2001). The population was further limited to Gauteng, as this population would be more manageable and samples would be easier to extract. Other parties responsible during construction such as design firms and consultants were not considered as contractor employees will be the most familiar with labour productivity of construction techniques. Approximately 40 contractors involved in buildings construction were discovered during a physical verification on different construction sites in Gauteng.

3.4 Sampling

When studying a particular population it is not practical or possible to study every single member of the population. It is therefore imperative that sample groups serve as representatives for the entire group selected of which general observations about the population are then made from the selected group (Goddard & Melville, 2001).

A convenient sampling approach was used as participants targeted in the survey were reduced to management, this technique was useful as larger groups had to be filtered and refined into more meaningful samples. This sampling method was also used as building techniques, decisions and knowledge of precast and cast-in-situ concrete are left to various levels of management and the concentration of these samples had to be around these management levels. A final sample size of 30 companies were selected at 75% of the total population, These 30 companies were chosen as a result of these companies being involved directly with high rise buildings. Blaxter et al., (2006) states that probability sampling in a stratified natured when sampling certain groups and knowledge areas of a population is the most effective way of sampling, this method was hence used as it fulfilled the above criteria The sample size was significant as it represented approximately 75% of the total population. The internal validity of the sample portrays a strong generalisation over the entire population of the South African construction precast and cast-in-situ building sector.

3.5 Validity

Research is deemed to be valid after a cause and effect relationship has been established (Riege, 2003). Internal validity is based on results that are due only to the manipulated independent variable and external validity is the applicability to groups, environments and contexts outside of the research environment (Riege, 2003). Therefore it is vital that all research is assessed for internal and external validity. The internal validity of this research is assessed through the questionnaire and the external validly assessed through a literature review. The questionnaire aims to answer the research questions by receiving information from local participants in a South African context to justify the internal validity. To test externally validity information is obtained from other countries outside the research environment that implement precast and cast-in-situ concrete techniques, this information is analysed in the literature review. The strength of the internal and external validity will be justified in the conclusion

3.6 Research Tools

The research tool used for collecting data is the survey. The data in this study is of a qualitative nature and therefore the best approach would be to use a questionnaire survey to collect qualitative data (Blaxter et al., 2006). Empirical collection of data would be difficult to collect as the process would have to be strictly controlled and the samples would have to be exact or similar in nature. The opinions of respondents can be explored in greater detail and a non-bias response can be expected due to the discrete responses and routing of a questionnaire based survey. The importance of a survey relevant to the study and the main instrument to be used is explained below:

3.6.1 Questionnaires

Questionnaires are a process of gathering information through written questions, where the researcher has a fixed list of questions to be answered by a sample of the population (Walliman, 2006). Goddard & Melville (2001) state that questionnaires should be planned so that the data can be easily and effectively analysed. Furthermore, there are two different types of questionnaires which are; open-ended questionnaires and structured questionnaires. Open-ended questionnaires allow respondents to answer the question in their own words and structured questionnaires allow respondents to choose from a collection of alternatives. For the purpose of this research a structured questionnaire was chosen as it will make the analysis of the data much easier. The questionnaire is divided into three parts that reflects the profile of the respondent, the factors affecting the use of precast concrete and the factors affecting productivity of precast concrete. According to Walliman (2006), there are important aspects to consider in the development of a questionnaire such as; establishing the variables in which data needs to be collected, using language that is clear and unambiguous, keeping the questionnaires as short and simple as possible and to present the questionnaires in a format that is clear and professional.

For the purpose of this research a structured questionnaire was chosen for the following benefits according to Eiselen et al., (2005).

- *They are more cost effective to administer than personal (face-to-face) interviews*
- *They are relatively easy to administer and analyse*
- *Most people are familiar with the concept of a questionnaire*
- *They reduce the possibility of interviewer bias*
- *They are perceived to be less intrusive than telephone or face-to-face surveys and hence, respondents will more readily respond truthfully to sensitive questions*
- *They are convenient since respondents can complete it at a time and place that is convenient for them*

The Likert scale is commonly used in survey research. It is often used to measure respondent's attitudes by asking the extent to which they agree or disagree with a particular question or statement (Miller & Salkind, 1991). The questionnaire developed would rely on the respondent's knowledge and experience related to precast and cast-in-situ concrete construction. Respondent's opinions will have to be relied upon as there is no other way of preparing numerical data and site observations and interviews are time-consuming. Hence, a five-point Likert scale questionnaire was selected for carrying out the research. Certain considerations were given in the development of the five-point Likert scale used in this study as shown below.

- **Number of responses categories**

  The number of responses can vary from a three point system to a nine or even ten point category, and the researcher has to consider how 'finely' he/she wants the respondents to express their views (Eiselen et al., 2005). When more than seven categories are selected the respondents tend to get confused and the responses become unreliable (Eiselen et al., 2005). Therefore, the conclusion was that a five-point system would be ideal for the purpose of this research.

- **Odd or even number categories**

  A middle or neutral category supports the decision for an odd number category scale. Not including a middle or neutral category may force respondents to take a side despite the fact that they could feel neutral about the situation (Eiselen et al., 2005). A five-point scale was thus chosen for the questionnaire to illuminate such decision making in responses.

The questions posed in the questionnaire are based on the objectives of the study and assisted in answering the research questions. This provides an ideal opportunity for the information obtained in the literature to be tested.

A pilot survey was conducted to test participants understanding and willingness to participate after which a final distribution of questionnaires was conducted. Ethical issues were avoided by using the pilot survey as a means to assess respondent's opinions. The type of questions portrayed dealt purely with aspects relating to construction productivity and no questions were included that would affect ethical concerns.

3.7 Data Analysis

Qualitative data would fall under categorical values that are non-numeric (Blaxter et al., 1996). An arithmetic mean would have no significance alone and therefore a mode would have to be used, the mode value assists in finding the most frequent answer however this cannot be the only means of analysing the data. The data will have to be further simplified by combining the four original categories into two nominal categories, "agree/disagree". This offers other analysis possibilities such as a chi-square test that can be used to statistically analyse the data further (Miller & Salkind, 1991). This is done by combining the "agree" and "strongly agree" responses into one category and the "disagree" and "strongly disagree" into another. The purpose of a chi-squared test is to compares respondent's actual responses with expected answers. This technique will be ideal for interpreting respondents opinions as the data received will be tested against expected values, a hypothesis. As no empirical data will be collected this method of data analysis will be the most suitable technique available. The chi-square test assesses the statistical significance of a given hypothesis (Miller & Salkind, 1991). The greater the level of deviation between actual and expected responses, the higher the chi-square statistic, and thus the less well the data fits the hypothesis (Miller & Salkind, 1991).

3.8 Question Design

The following table below will show the link in the information obtained through the literature review to show how the survey questions were developed to test its validity.

	Literature Review	Survey Questions
1	2.7.5 Cost considerations	The cost of precast concrete components
2	2.8.5 Transportation Restrictions	The size and load restrictions on transportation
3	2.7.2 The Availability of Specialised Precast Concrete Contractors and Technological Capacity.	The lack of qualified structural engineers specialized in precast concrete
4	2.7.2 The Availability of Specialised Precast Concrete Contractors and Technological Capacity	The lack of contractors specialized in precast concrete
5	2.7.1 Availability of Labourers Specialised In Precast Concrete Systems	The lack of labour specialized in precast concrete
6	2.8.2 Problems Encountered By On Site Managers	The involvement of labour unions
7	2.7.4 Environmental and Social Impacts	The clients level of satisfaction with precast concrete structures
8	2.7.4 Environmental and Social Impacts	The waste generated from precast concrete
9	2.7.4 Environmental and Social Impacts	The noise generated from precast concrete
10	2.7.4 Environmental and Social Impacts	The dust produced from precast concrete
11		The safety of precast concrete installations
12	2.7.2 The Availability of Specialised Precast Concrete Contractors and Technological Capacity	The lack of technology used to manufacture precast concrete
13	2.7.6 Quality Aspects	The aesthetics of precast concrete structures
14		The complexity of projects
15	2.7.6 Quality Aspects	The quality of precast concrete elements

1	2.8.5 Transportation Restrictions	The traffic congestion on national roads
2	2.8.5 Transportation Restrictions	The route taken during transportation to the construction site of precast concrete
3	2.8.2 Problems Encountered By On Site Managers	The complexity of precast technology building systems
4	2.7.1 Availability of Labourers Specialised In Precast Concrete Systems	Skilled crane operators
5	2.2 Precast Concrete	Precast concrete assembly
6	2.7.2 The Availability of Specialised Precast Concrete Contractors and Technological Capacity	The availability of contractors specialized in precast concrete systems
7		Inclement weather
8	2.8.3 Design and Information Processes	Design changes in precast concrete structures
9	2.8.2 Problems Encountered By On Site Managers	Delays in resource supplies
10	2.7.1 Availability of Labourers Specialised In Precast Concrete Systems	The availability of labour specialized in precast concrete systems
11	2.7.6 Quality Aspects	Remedial and repair work
12	2.8.3 Design and Information Processes	Information supply between various parties involved in the construction process

3.9 Overall Research Design

The diagram below illustrates the overall research design implemented;

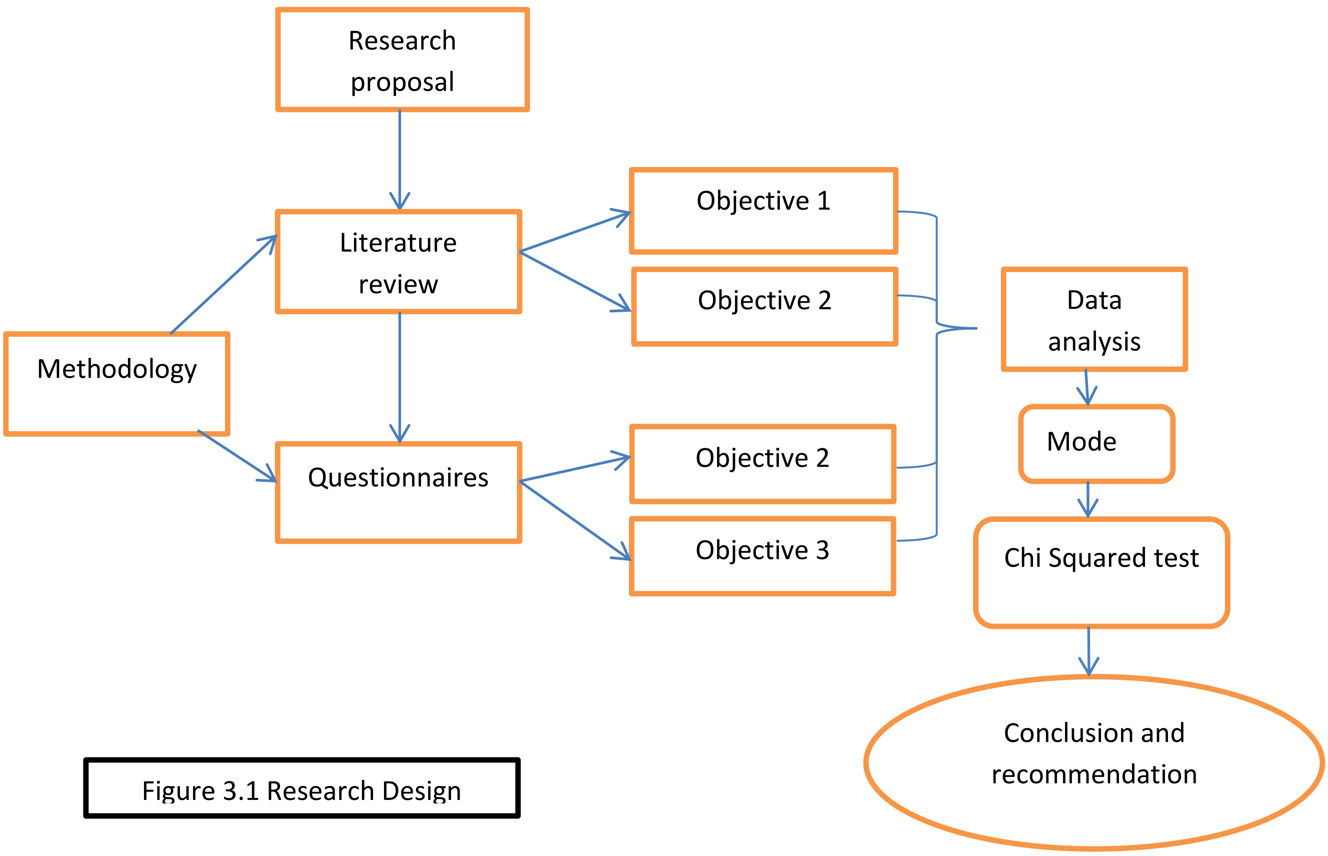

Figure 3.1 Research Design

3.10 Conclusion

The description of the research methodology is important in providing an understanding to how the research was conducted. The finalisation of the research tools provides an effective way in answering the research questions appropriate to the study. The statistical data analysis finally provides the desired solution for providing a conclusion.

Chapter 4: Research Findings and Analysis

4.1 Introduction

This chapter deals with the data collected from the questionnaire survey and its analysis. The questionnaire analysis is divided into three parts that reflects the profile of the respondent, the factors affecting the use of precast concrete and the factors affecting productivity of precast concrete. The data from each question is graphically represented by means of a pie-chart or graph so that the reader may interpret the results with ease. The statistical analysis of the data can then follow. This first part of the analysis involves the calculation of a mode value after which a chi-square analysis is done to portray the differences between the expected and the actual values. This provides a better understanding in the context of the South African precast and cast-in-situ construction sector.

4.2 Survey Response and Sample Size

A total number of thirty three questionnaires were sent out to thirty contracting companies involved in the South African precast and cast-in-situ concrete construction sector. The total population in Gauteng is approximately 40 contractors. Six questionnaires were declared spoilt as no information could be extracted. Twenty seven questionnaires were hence used for the data analysis.

Part I. Profile of the Respondent

This section of the questionnaire aims to obtain personal information relating to the participant and their field of work.

I Number of years in the company

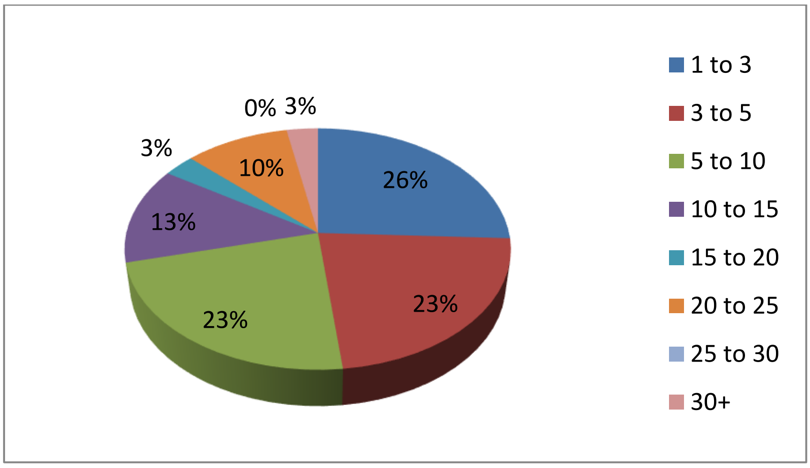

Figure 4.1 Experience of respondents

The experience of the participants in the questionnaire fell mostly in the category of three to ten years, while a very few participants had more than thirty years' experience in a company.

II Current Position in the company

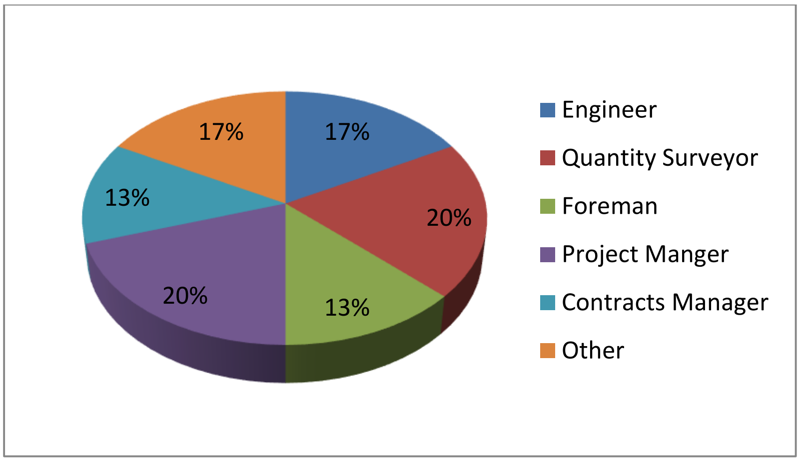

Figure 4.2 Positions held by respondents

The array of positions held by the various respondents was evenly distributed amongst the various trades in construction as a general consensus was aimed to be achieved.

III Number of years involved in the industry

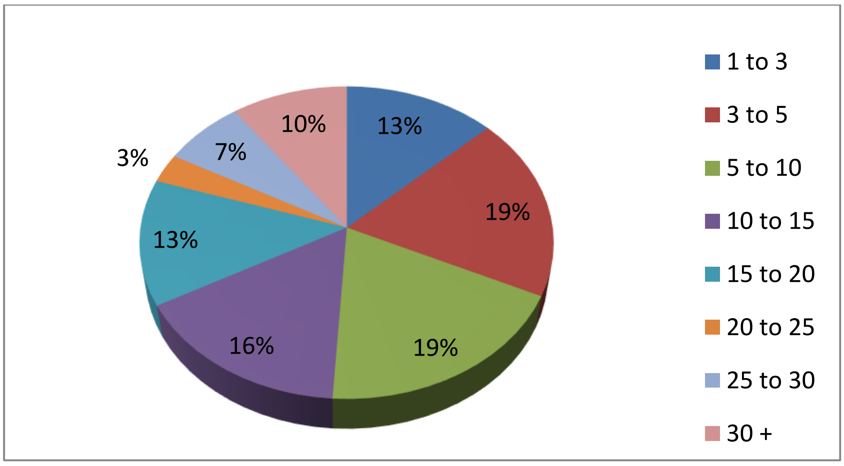

Figure 4.3 Years of experience within the industry

Nineteen percent of the respondents had an average experience of three to five years which equalled the respondents that had experience between five and ten years while ten percent had an average of over thirty years' experience.

IV Type of company

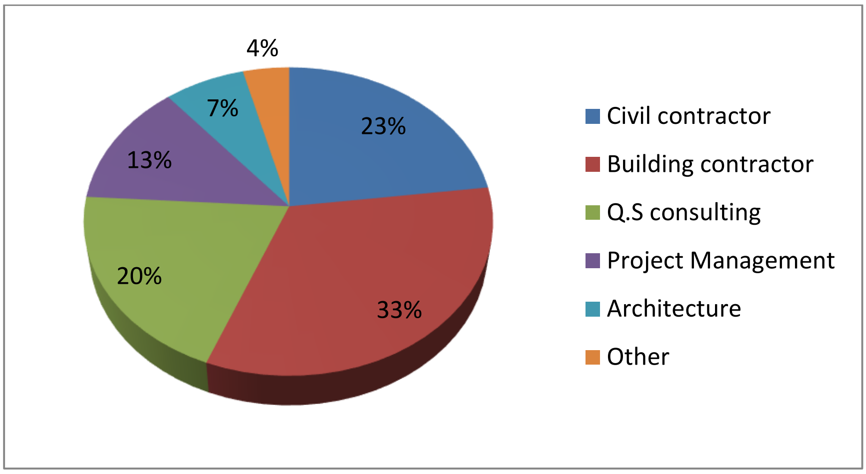

Figure 4.4 Types of company's respondents are employed

Just over half of the respondents worked in building contracting and Q.S consulting companies. Respondents from a civil background were also found to be common.

V Do you use precast concrete in construction?

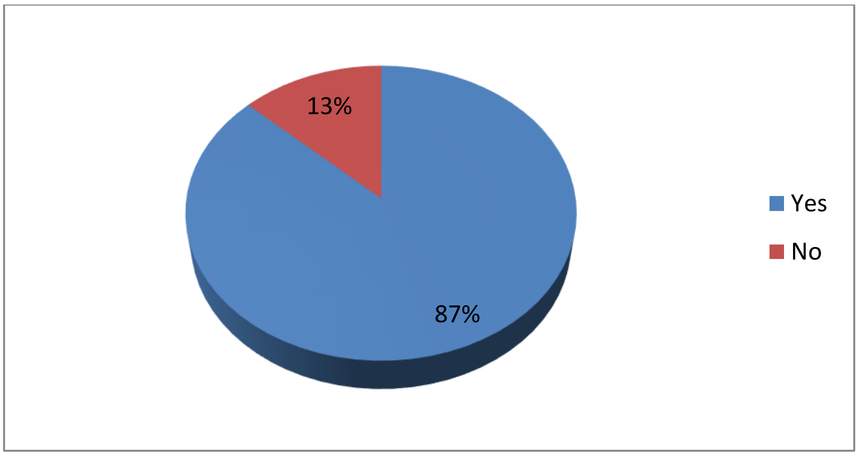

Figure 4.5 Respondents use of precast concrete in construction

A significant amount (87%) of participants had used precast concrete components in construction while only 13% had not used precast concrete in construction.

Part II. Factors Affecting the Use of Precast Concrete

Part II of the questionnaire required participants to provide their opinion on factors they considered that affected the use of precast concrete construction in South Africa.

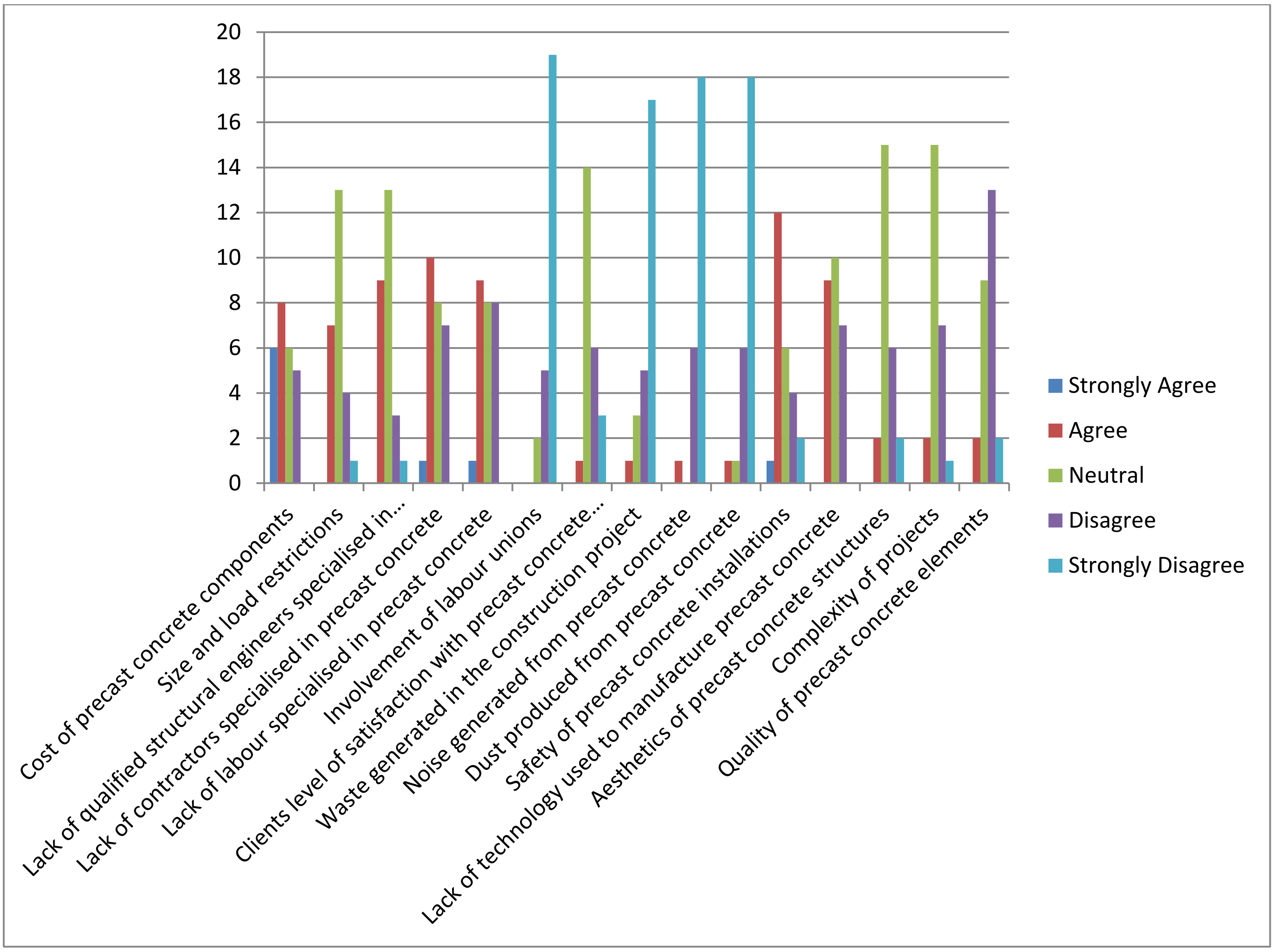

Figure 4.6 **Factors affecting the use of precast concrete**

Part III. Factors Affecting Productivity of Precast Concrete

Part III of the questionnaire required participants to provide their opinion on factors they considered that affected productivity of precast concrete construction in South Africa.

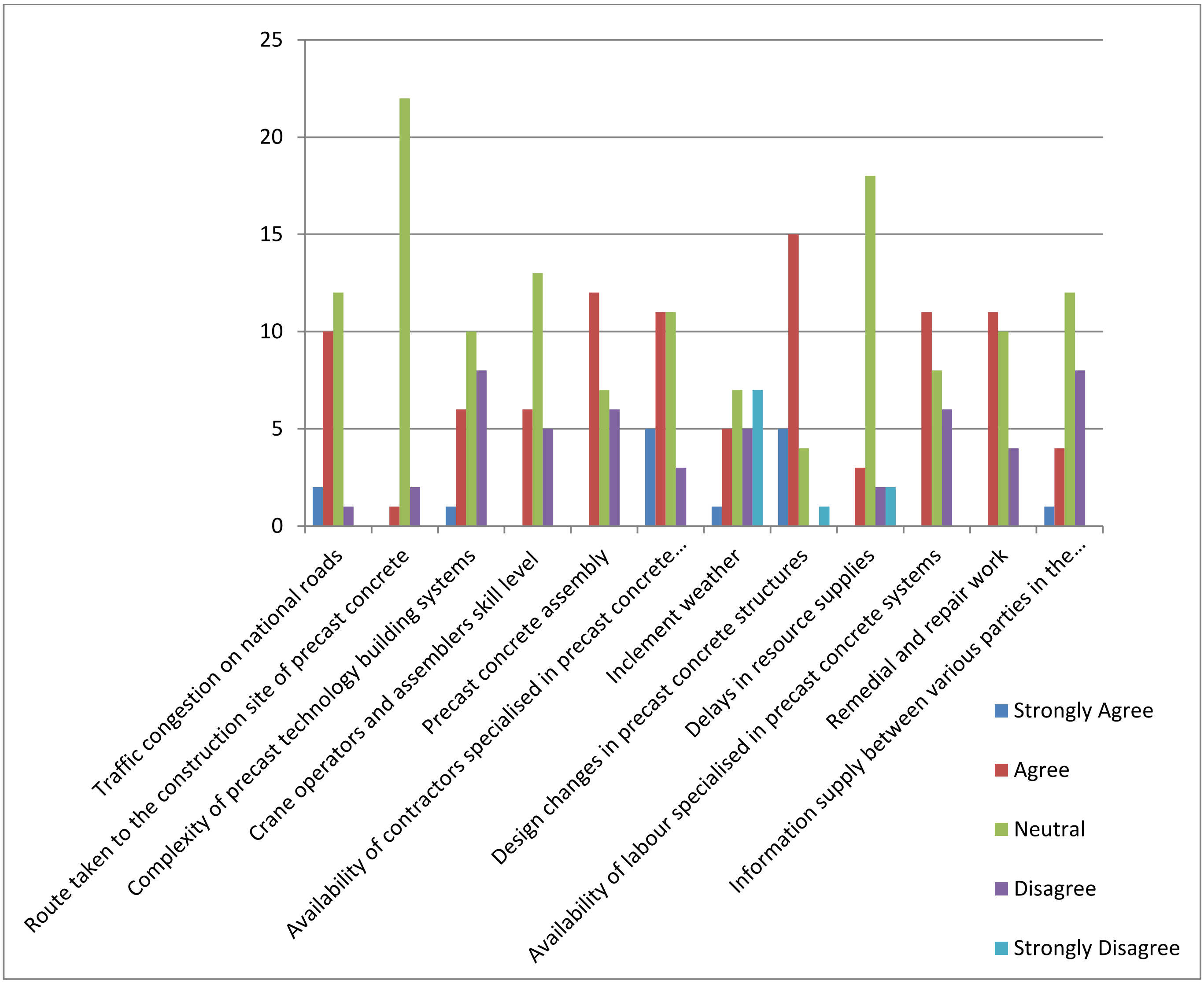

Figure 4.7 **Factors affecting productivity of precast concrete**

4.3 Data Analysis

The results from the data support the literature review in essence however some of the data suggest that there is indeed a dislike for the use of precast concrete technologies in South Africa. Common findings in the literature review and data suggest that skilled labour, precast concrete technology and infrastructure relating to traffic all impact negatively on precast concrete productivity and affects it usage. To delve deeper into the significance and deduct further reasoning a more scientific approach was used to analyse the data. The chi-squared analysis was used and will be explained further in this chapter.

The chi-squared analysis was used to test the hypothesis. The result can be seen in the table below. Mean values were not calculated as this data would provide no substance in its meaning, a mode value was hence computed as this will establish the most frequent value in a data set. This will help us understand which answer is most frequent amongst various respondents on a particular question. The data is not of a continuous nature and therefore the mode will be the best way of measuring central tendency (Eiselen, 2005). The data is further simplified by combining the four original categories into two nominal categories, “agree/disagree”. This offers other analysis possibilities such as a chi-square test that can be used to statistically analyse the data further (Miller & Salkind, 1991). This is done by combining the “agree” and “strongly agree” responses into one category and the “disagree” and “strongly disagree” into another.

4.3.1 Chi - Square Test

The main purpose of the chi-squared test is to test the validity of a distribution assumed for a random phenomenon (Eiselen, 2005). The test evaluates the null hypotheses H_0, which is the data that is governed by the assumed distribution against the alternative, which is the data that is not drawn from the assumed distribution. The chi-squared test is best inclined towards research that involves the testing of opinions and theories. With a good representation of the sample population, the results will allow reasonable deductions to be made (Eiselen, 2005) the formula for Chi Squared is;

$$X^2 = \sum \frac{(\text{observed - expected})^2}{\text{expected}}$$

No. of categories = 3

DF = No. of categories –1

Significance = 95%

The critical value is obtained from the Statistics Table 4.1 which was chosen at a 95% significance range, this range provides a significant statistical acceptance (Eiselen, 2005). The Degree of Freedom was calculated to be 2 and the corresponding value of **5.991** was thus chosen as the critical value for acceptance from the statistics table below. Chi square values that are greater than the critical value are rejected and Chi square values that are lower than the critical value are accepted.

Table 4.1 Statistics Table

DF	0.995	0.975	0.20	0.10	0.05	0.025	0.02	0.01	0.005	0.002	0.001
1	0.0000393	0.000982	1.642	2.706	3.841	5.024	5.412	6.635	7.879	9.550	10.828
2	0.0100	0.0506	3.219	4.605	5.991	7.378	7.824	9.210	10.597	12.429	13.816
3	0.0717	0.216	4.642	6.251	7.815	9.348	9.837	11.345	12.838	14.796	16.266
4	0.207	0.484	5.989	7.779	9.488	11.143	11.668	13.277	14.860	16.924	18.467
5	0.412	0.831	7.289	9.236	11.070	12.833	13.388	15.086	16.750	18.907	20.515

The Table 4.2 summarises the different hypotheses from the second part of the questionnaire based on the various factors affecting productivity of precast concrete in high rise construction in South Africa. Values obtained from the calculations that are below the critical value are accepted and values above the critical value are rejected (Eiselen, 2005).

4.3.2 Chi – Square Analysis

Table 4.2 Chi Square Analysis (factors affecting the use of precast concrete)

No.	Null Hypothesis statement	Chi Square(x^2)	Critical Value	Decision
1	Ho = The cost of precast concrete components affects its use in precast concrete construction	4	5.99	Accept
2	Ho = The size and load restrictions in South Africa affects precast concrete usage	4	5.99	Accept
3	Ho = The Lack of qualified structural engineers specialised in precast concrete affects its use	5	5.99	Accept
4	Ho = The lack of contractors specialized in precast concrete affects its usage	2	5.99	Accept
5	Ho = The lack of labour specialized in precast concrete affects its usage	1	5.99	Accept
6	Ho = The involvement of labour unions affects precast concrete usage in South Africa	41	5.99	Reject
7	Ho = The clients level of satisfaction with precast concrete structures affects its usage	11	5.99	Reject
8	Ho = The waste generated from precast concrete affects its use in South Africa	31	5.99	Reject
9	Ho = The noise generated from precast concrete affects its use in precast concrete structures	44	5.99	Reject
10	Ho = The dust produced from precast concrete affects it usage in precast concrete structures	41	5.99	Reject
11	Ho = The safety of precast concrete installations affects its usage in South Africa	4	5.99	Accept
12	Ho = The lack of technology used to manufacture precast concrete affects its usage	1	5.99	Accept
13	Ho = The aesthetics of precast concrete structures affects its use in South Africa	10	5.99	Reject
14	Ho = The complexity of projects in South Africa affects precast concrete use	10	5.99	Reject
15	Ho = The quality of precast concrete elements affects it use in South Africa	10	5.99	Reject

The Table 4.3 summarises the different hypotheses from the second part of the questionnaire based on the various factors affecting productivity of precast concrete in high rise construction in South Africa.

Table 4.3 Chi Square Analysis (factors affecting productivity of precast concrete)

No.	Null Hypothesis statement	Chi Square(x^2)	Critical Value	Decision
1	Ho = The traffic congestion on national roads affects productivity	10	5.99	Reject
2	Ho = The route taken during transportation to the construction site of precast concrete project affects productivity	34	5.99	Reject
3	Ho = The complexity of precast technology building systems in South Africa affects productivity	1	5.99	Accept
4	Ho = Skilled crane operators affect precast concrete productivity	5	5.99	Accept
5	Ho = Precast concrete assembly affects productivity	3	5.99	Accept
6	Ho = The availability of contractors specialized in precast concrete systems affects productivity	5	5.99	Accept
7	Ho = Inclement weather affects productivity in precast concrete installations	3	5.99	Accept
8	Ho = Design changes in precast concrete structures affects productivity	25	5.99	Reject
9	Ho = Delays in resource supplies affects precast concrete productivity	17	5.99	Reject
10	Ho = The availability of labour specialized in precast concrete systems affects productivity	2	5.99	Accept
11	Ho = Remedial and repair work affects precast concrete productivity	4	5.99	Accept
12	Ho = Information supply between various parties involved in the construction process affects productivity	3	5.99	Accept

4.3.3 Calculation of Mode Values

The mode analysis provided a clear choice for the values that are most frequently occurring amongst the participant and provided a general consensus of the situation.

Formula for calculation, Mode = L + [(fm-f1) / (fm-f1) + (fm-f2)] x h

where:

L = the lower class boundary of modal class

fm = the Frequency of the model class

f1= is the previous frequency of the model class

f2 = is the next frequency of the model class

h = the size of model class i.e. difference between upper and lower class boundaries of model class.

Model class is a class with the maximum frequency.

Table 4.4 Mode Analysis (factors affecting the use of precast concrete)

	Factors affecting the use of precast concrete in high rise construction in South Africa	**Mode Value** **(most frequent occurring value)**
1	The cost of precast concrete components	2
2	The size and load restrictions on transportation	3
3	The lack of qualified structural engineers specialized in precast concrete	3
4	The lack of contractors specialized in precast concrete	2
5	The lack of labour specialized in precast concrete	2
6	The involvement of labour unions	5
7	The clients level of satisfaction with precast concrete structures	3
8	The waste generated from precast concrete	5
9	The noise generated from precast concrete	5
10	The dust produced from precast concrete	5
11	The safety of precast concrete installations	2
12	The lack of technology used to manufacture precast concrete	3
13	The aesthetics of precast concrete structures	3
14	The complexity of projects	3
15	The quality of precast concrete elements	4

Table 4.5 Mode Analysis (factors affecting the productivity of precast concrete)

	Factors affecting productivity of precast concrete in high rise construction in South Africa	**Mode Value** (most frequent occurring value)
1	The traffic congestion on national roads	3
2	The route taken during transportation to the construction site of precast concrete	3
3	The complexity of precast technology building systems	3
4	Skilled crane operators	3
5	Precast concrete assembly	2
6	The availability of contractors specialized in precast concrete systems	2
7	Inclement weather	5
8	Design changes in precast concrete structures	2
9	Delays in resource supplies	3
10	The availability of labour specialized in precast concrete systems	2
11	Remedial and repair work	2
12	Information supply between various parties involved in the construction process	3

4.4 Conclusion

After conducting the chi-square analysis as well as a mode analysis, the results portrayed similar signs to what was documented in the literature review. The analysis concluded that the following factors affecting the use of precast concrete building systems negatively in South Africa are;

- Skilled Labour
- Cost
- Complexity
- Safety
- Technology

These negative aspects support current methods of cast-in-situ construction and are the reasons for its continued existence. The productivity statistical analysis portrayed the following information that negatively affected the productivity of precast concrete;

- Skilled Labour
- Lack of qualified contractors
- Inclement weather
- Design

These limitations that prevent the use of precast concrete as well as affect productivity outweigh much of the negative aspects portrayed in the literature review about cast-in-situ concrete.

Chapter 5: Conclusions and Recommendations

5.1 Introduction

This chapter compares the information obtained through the literature review to the data collected through the questionnaires. This is required in order for us to reach a conclusion on the original research problems after which recommendations and ideas for future research can be drawn. The chapter will begin with the presentation of the hypothesis and its result, Next would be the objectives and research findings followed by; problems encountered conducting the research, limitations, recommendations and ending with a conclusion.

5.2 General Hypothesis

A direct relationship exists between the use of different construction techniques and productivity in South Africa

5.2.1 Result of Overall Hypothesis

The above hypothesis serves to be correct as the statistical analysis of the data justifies the relationship. The data suggests that there are many factors affecting productivity of precast concrete and its usage in South Africa.

5.3 Research Questions, Objectives and Research Findings

Research Question 1

How are the techniques of cast-in-situ and precast concrete different in construction?

Research Findings 1

Precast concrete and cast-in-situ concrete construction were found to be very different in their process and procedure. Differences in the process were mainly related to the on-site and off-site activities. Precast concrete construction focused on the production of precast concrete units that were manufactured off site in a controlled environment. These precast modular units are then transported to site ready for assembly. The assembly of the precast units required skilled labour and cranes to facilitate the process. The process of cast-in-situ concrete construction related to operations that were mostly construction site based with respect to the concrete works. The concrete in some cases is produced off-site and then delivered to site ready to be placed in its final position. This method of construction is widely used and does not require much skilled labour and equipment.

Research Question 2

What are all the factors influencing the productivity and utilization of cast-in-situ and precast concrete construction in South Africa?

Research Findings 2

According to the literature review many of the factors affecting productivity and the usage of precast concrete construction were deemed to be true as the results in the questionnaires portrayed a strong sense of negativity towards the precast construction method. Factors that were identified and pertinent in a South African context of construction were related largely to skilled labour, lack of available contractors and lack of suitable technology. Bad weather had also contributed to some extent and affected productivity negatively. Much of these underling issues are affecting the use of precast concrete in South Africa and therefore the full benefits of precast concrete cannot be realised.

Research Question 3

Which technique is more productive when analysing cast-in situ and precast concrete construction in South Africa?

Research Findings 3

In South Africa, productivity of precast concrete is compromised as a lack of skilled labour, equipment and technology affects precast concrete negatively. The literature reviewed represents different results in the comparison of productivity compared to the data in the questionnaire representing a South African perspective. Productivity of precast concrete construction in an international context is considerably better than cast-in-situ methods of construction. In various international projects where both techniques have been compared against each other, precast concrete has shown mostly positive gains in productivity over cast in-situ concrete. However, in South Africa there are far too many aspects that may have a negative effect on the productivity of precast building methods, and therefore cause an actual reduction in productivity.

5.4 Recommendations

5.4.1 Recommendations on Adopting Precast Concrete Techniques

Availability of Skilled Labour

The adoption of labour recruiters in the procurement of labour may provide a bigger pool of skilled labour for contractors to use. If there is still a shortage, outsourcing labour from surrounding areas could be implemented. Training institutes should provide more opportunities for skilled trades to be learnt and more practical experience gained. These aspects will slowly increase the available quantity of skilled labour available to precast concrete contractors.

Cost Viability

Much of the negativity surrounding precast concrete lies in the perception that it costs more than cast-in-situ methods. To justify any reasoning in the adoption of a particular method a feasibility study between cast-in-situ concrete and precast concrete should be done at the design stage of a project. This process will have a small cost but will provide a good indication of the savings that can be incurred in the adoption of a specific technique.

Project Programming

To understand the advantages pertinent to project duration, an estimate of the project programme should be done at the design stage. Any advantages or disadvantages projected may influence the adoption of one particular technique over the other; in addition any time savings highlighted may provide a strong desire in choosing a particular construction method.

Specialist Precast Contractors

Green building initiatives should be more recognised and incentives should become more available. These green building initiatives will persuade more contractors to adopt precast concrete techniques as it has been recognised as a greener alternative to cast-in-situ concrete. Organisations such as the Masters Builders Association of South Africa should be educating contractors on specialist technologies and methods of construction. This education will empower clients to select precast concrete contractors more often.

Environmental Impacts

To promote a green building society, government should impose fines or taxes on non-environmentally friendly building techniques. This will persuade contractors to develop and adopt new methods of construction such as precast concrete that will help to achieve a more environmentally friendly and sustainable product.

5.4.2 Recommendations on the Improvement of Precast Concrete Productivity

Skills Development

In order to adopt techniques using precast concrete in South Africa much focus has to be given to skills development. Without having the necessary skills, productivity of precast construction is significantly reduced. Workshops have to be set up to train individuals on specialist precast concrete works. Learning these processes should not start on site and should be done at a training institute. Crane operators are one of the most important components of a precast installation, and these operators should be given regular training to ensure the efficient operation of their equipment.

Pursuit of Technology

Precast concrete productivity can be greatly improved by introducing more technology into the manufacture and assembly process. Technology used to create the formwork and casting process should be streamlined to create an efficient and effective product. For onsite operations technology can be used to eliminate some manual labour operations and thereby create greater efficiency. Lifting equipment such as mobile cranes, cherry pickers and forklifts can be used to assist during the installation process in order to aid tower cranes when possible. Special precast concrete contractors should be at the forefront investing in new technologies that will assist them in their operations.

Precast concrete manufactures

These production factories should be situated closer to the construction site to prevent delays and reduce any risks. If this is not possible, then smaller production factories can temporarily be made on site, where at least some components can be made in-situ. This can significantly improve productivity on site.

5.5 Summary and Conclusions

The advantages of precast concrete construction on high rise establishments were reported in many studies; however its utilization when compared to cast-in-place concrete is very minimal throughout the world. There are many factors reported around the world for its underutilization. The current results also portrayed similar conclusions as it was documented in past studies. However, the relative importance of these influencing factors is different in South Africa. Based on this study, it is evident that the availability of the specialized precast concrete contractors, qualified and experienced labour along with the precast concrete installation and safety arrangements influences much on the selection of the precast concrete construction in commercial high rise establishments. Further, the client's lack of awareness and their perception on the durability and performance of the precast concrete structure affects their willingness to utilize the system. Awareness of the precast concrete construction methods and understanding its utilization benefits may improve the share of precast concrete construction in the overall industry. The productivity of precast concrete construction was greatly affected by design changes because of a lack of experienced structural engineers/contractors along with less skilled labour and their poor assembly procedure. Though many studies around the world concluded that precast methods productivity is much higher than cast-in-place methods, the above said influencing factors can change the project outcome dramatically. Training the qualified crane operators with the riggers and integrating precast concrete design in the curriculum may influence the awareness and utilization in future.

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Visible Research Output

Venkatachalam Senthilkumar & Buckus Shafee, “A study on the factors influencing precast concrete construction in Gauteng’s high rise commercial building projects”, 2nd International Conference on Infrastructure Development in Africa (ICIDA) 2013 17-19 March 2013, University of Johannesburg, Johannesburg, South Africa held by the Department of Construction Management and Quantity Surveying - University of Johannesburg, South Africa in collaboration with the College of Architecture and Planning - Kwame Nkrumah University of Science and Technology- Ghana. (**Accepted for Presentation**).

APPENDIX A:

Questionnaire

Part I. Profile of the Respondent

i. Number of years in the company

1-3		15-20	
3-5		20-25	
5-10		25-30	
10-15		30+	

ii. Current Position in the company

Engineer	
Quantity surveyor	
Foreman	
Project Manager	
Contracts Manager	
Other	

iii. Number of years involved in the industry

1-3		15-20	
3-5		20-25	
5-10		25-30	
10-15		30+	

iv. Type of company

Civil contractor	
Building contractor	
Q.S consulting	
Project management	
Architecture	
Other	

Part II. Factors affecting the use of precast concrete in high rise construction in South Africa

Do you use precast concrete in construction?

YES		NO	

If you have answered **yes** please continue with the questions below, if **no** please disregard

		Strongly Agree				Strongly Disagree
1	The cost of precast concrete components	1	2	3	4	5
2	The size and load restrictions on transportation	1	2	3	4	5
3	The lack of qualified structural engineers specialized in precast concrete	1	2	3	4	5
4	The lack of contractors specialized in precast concrete	1	2	3	4	5
5	The lack of labour specialized in precast concrete	1	2	3	4	5
6	The involvement of labour unions	1	2	3	4	5
7	The clients level of satisfaction with precast concrete structures	1	2	3	4	5
8	The waste generated from precast concrete	1	2	3	4	5
9	The noise generated from precast concrete	1	2	3	4	5
10	The dust produced from precast concrete	1	2	3	4	5
11	The safety of precast concrete installations	1	2	3	4	5
12	The lack of technology used to manufacture precast concrete	1	2	3	4	5
13	The aesthetics of precast concrete structures	1	2	3	4	5
14	The complexity of projects	1	2	3	4	5
15	The quality of precast concrete elements	1	2	3	4	5

Part III. Factors affecting productivity of precast concrete in high rise construction in South Africa

Do you use precast concrete in construction?

YES		**NO**	

If you have answered **yes** please continue with the questions below, if **no** please disregard.

		Strongly Agree				Strongly Disagree
1	The traffic congestion on national roads	1	2	3	4	5
2	The route taken during transportation to the construction site of precast concrete	1	2	3	4	5
3	The complexity of precast technology building systems	1	2	3	4	5
4	Skilled crane operators	1	2	3	4	5
5	Precast concrete assembly	1	2	3	4	5
6	The availability of contractors specialized in precast concrete systems	1	2	3	4	5
7	Inclement weather	1	2	3	4	5
8	Design changes in precast concrete structures	1	2	3	4	5
9	Delays in resource supplies	1	2	3	4	5
10	The availability of labour specialized in precast concrete systems	1	2	3	4	5
11	Remedial and repair work	1	2	3	4	5
12	Information supply between various parties involved in the construction process	1	2	3	4	5

Thank you for you co-operation