THE ASPECT OF LABOUR IN HYBRID AND IN-SITU CONCRETE CONSTRUCTION IN SOUTH AFRICA

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DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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SYNOPSIS

Hybrid concrete construction (HCC) is a construction technique that makes use of both in-situ and pre-fabricated concrete products by making optimum use of the advantages of both these methods in the same project. Although the advantages of this construction method is well recognised throughout the world, and a feasibility study has illustrated that HCC is a suitable construction method in South Africa, it remains under-utilised in this country.

Labour has been identified as one of the aspects of the decision-making process between in-situ and HCC. The construction industry is ranked as the employer with the 5thhighest number of employees in South Africa, which is currently experiencing a 25.4% unemployment rate. This highlights the importance of the construction industry as an employer in South Africa. Labour is considered as one of the areas of highest concern in the South African construction industry. This concern is intensified when the shortage of skilled labour in the industry is taken into account.

In the light of these realities, the objective of this research study was to investigate the utilization of labour in both the in-situ and HCC environments, and the effect of the use of HCC on labour and its *socio-economic aspects.*

The first step of this process necessitated the identification of the most important labour-related concerns in the South African construction industry. A previous investigation into this industry identified low productivity of labourers and the use of unskilled labour as the most significant areas of concern, whilst another study identified *socio-economic issues* as important factors to consider when deciding between in-situ and HCC. These *socio-economic issues* were quantified through literature to be job creation, job security, skills development and a suitable working environment.

Interviews and surveys with experienced managers in different divisions of the South African civil construction industry were used to investigate the effect of the use of HCC on the identified labour-related factors. A case study was used to support the qualitative opinions of the interviewees. Lastly, a risk analysis was conducted, which identified the importance of labour-related risks in both considered environments.

The research study showed that the labour force is applied to greater effect when using HCC than when using the in-situ construction method. The use of HCC also serves as partial mitigation of the shortage of skilled labour in South Africa, due to its ability to effectively utilize low-skilled labour. The construction environment of HCC also proves to be more labour-friendly, and management of labourers are easier and more effective in this environment. However, in-situ construction creates more employment opportunities, whilst HCC has a quicker turnover, thus shortening the employment period. Therefore it should be considered that labourers in the HCC environment are released earlier and could sooner be employed for new projects, countering the effect of less employment opportunities in this environment.

OPSOMMING

Hibriede betonkonstruksie (HBK) is ’n tegniek waarby beide voorafvervaardigde beton-elemente en in-situ beton in dieselfde projek gebruik word ten einde voordeel uit beide metodes te trek. Alhoewel die voordele van dié konstruksietegniek welbekend is in talle lande van die wêreld en ’n uitvoerbaarheidsanalise getoon het dat HBK ’n voordelige konstruksiemetode vir Suid-Afrika is, word dit tans onderbenut in die plaaslike sektor.

Arbeid is geïdentifiseer as een van die faktore in die besluitnemingsproses tussen in-situ en HBK. Die konstruksiebedryf word beskou as die bedryf met die 5^de^ hoogste indiensnemingsyfer in Suid-Afrika, wat tans ‘n 25.4% werkloosheidsyfer ervaar. Dit beklemtoon die belangrikheid van die konstruksiebedryf as 'n werkgewer in Suid-Afrika. Arbeid word ook beskou as grootste probleem-area in die Suid-Afrikaanse konstruksiebedryf. Hierdie probleme word versterk deur die huidige tekort aan geskoolde arbeid in die konstruksiebedryf.

In die lig van hierdie gegewens was die doel van hierdie navorsingstudie om die gebruik van arbeid in beide omgewings te bestudeer, asook die uitwerking van beide konstruksiemetodes op die arbeiders en die *sosio-ekonomiese aspekte* aangaande arbeid.

Die eerste stap van hierdie proses was die identifisering van die belangrikste arbeidsverwante probleme in die Suid-Afrikaanse konstruksiebedryf. In 'n vorige studie aangaande die Suid-Afrikaanse konstruksiebedryf, is lae arbeidsproduktiwiteit en die gebruik van ongeskoolde arbeid geïdentifiseer as die probleem-areas in hierdie bedryf. 'n Ander studie aangaande die gebruik van HBK in Suid-Afrika het *sosio-ekonomiese kwessies* as 'n belangrike faktor beskou om te oorweeg in die keuse tussen in-situ en HBK. Hierdie *sosio-ekonomiese kwessies* is gekwantifiseer deur middel van ‘n literatuurstudie oor: werkskepping, werksekerheid, die ontwikkeling van arbeidsvaardighede en die mees geskikte werksomgewing vir arbeiders.

Onderhoude en opnames met ervare bestuurders van verskillende afdelings in die Suid-Afrikaanse siviele konstruksiebedryf is gebruik om die effek wat die gebruik van HBK op die geïdentifiseerde arbeidsverwante faktore het, te ondersoek en te bepaal. ‘n Gevallestudie is gebruik om hierdie kwalitatiewe menings kwantitatief te ondersteun. ‘n Risiko-analise is ook uitgevoer om die invloed van arbeiders op die produktiwiteit van beide die in-situ konstruksie-omgewing en die voorafvervaardigde omgewing te bepaal.

Hierdie navorsingstudie het getoon dat die arbeidsmag meer effektief gebruik word in HBK as in die in-situ konstruksiemetode. Hierdie metode (HBK) is ook in staat is om laag-geskoolde arbeiders effektief aan te wend. Die konstruksie-omgewing met betrekking tot HBK is ook meer arbeidsvriendelik, en die bestuur van arbeiders in hierdie omgewing is makliker en meer effektief. Alhoewel, wanneer werkskepping oorweeg word, word in-situ konstruksie egter as die doeltreffender metode beskou. Dit moet egter in ag geneem word dat HBK projekte ‘n korter konstruksieperiode het as in-situ konstruksie, dus het arbeiders in die HBK omgewing gouer die geleentheid om met ‘n nuwe projek te begin.

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LIST OF ABBREVIATIONS

CIP	Cast in Place
NDP	National Development Plan
HCC	Hybrid Concrete Construction
RDP	Reconstruction and Development Programme
EPWP	Expanded Public Works Programme
GDS	Growth and Development Summit
NPO	Non-Profit Organisation Programme
CWP	Community Work Programme
NGO	Non-Governmental Organisations
CBO	Community Based Organisations
CMP	Construction Management Programme
HRM	Human Resource Management
PMBOK	Project Management Body of Knowledge
GDP	Gross Domestic Product
CLO	Community Liaison Officer
MPP	Material Procurement Planning
DESCQ	Departmental Ethics Screening Committee Questionnaire
PT	Post-tensioned

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CHAPTER 1

1 INTRODUCTION

1.1 Subject

This investigation aims to provide the civil engineering industry with relevant information regarding the decision between in-situ and hybrid concrete construction, by focussing on the current labour environment of South Africa.

1.2 Background

Hybrid concrete construction (HCC) is a construction technique combining precast concrete elements and in-situ concrete to construct buildings. The precast elements are manufactured in a controlled environment, enabling the production of higher quality products than in the in-situ environment (Elliott, 2002). The controlled environment enables project parties to provide a safer environment for the workforce and to give them better job security (Lombard, 2011). Whilst, within the in-situ construction environment, especially government projects, job security can only be given to a low percentage of labourers due to tender requirements, forcing construction companies to temporarily employ labourers from local communities as far as possible (De Klerk, 2013).

South Africa is regarded as a developing country striving to create 11 million jobs by 2030 (National Planning Commission, 2013). This has a direct influence on the construction industry as it is expected from construction companies and other labour-based industries to provide job opportunities to the unskilled and unemployed labour market. Civil construction projects are ranked amongst the best areas to promote good economic growth and to create job opportunities since it is considered as a labour-intensive environment. Refer to the upper right quadrant of Figure 1.1.

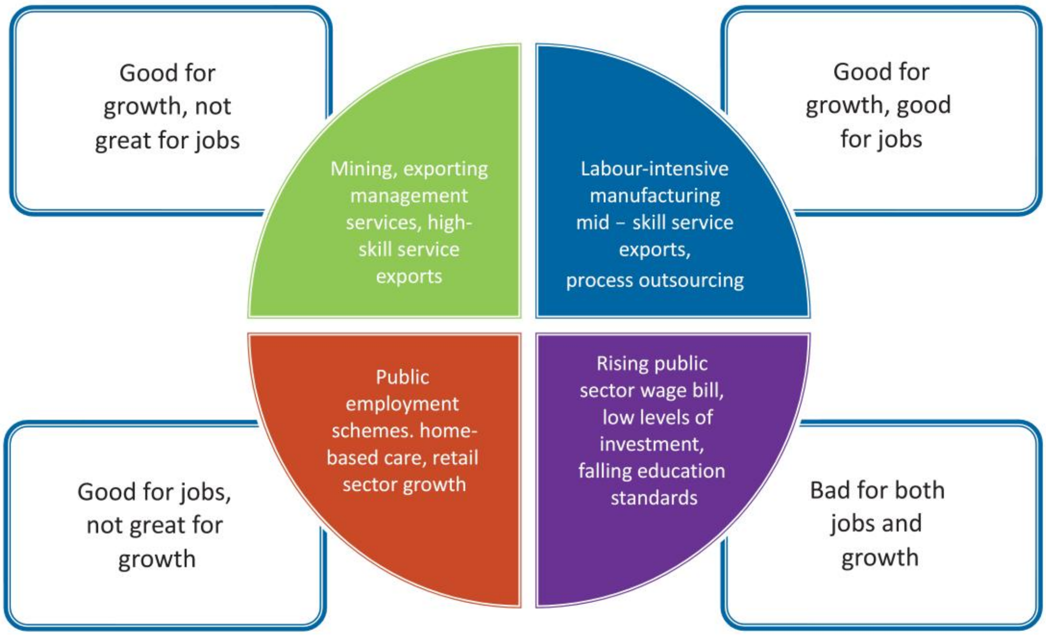


Figure 1.1: The quandary of growth and job creation (National Planning Commission, 2013)

This study investigates aspects of labour and how it affects the choice between in-situ and hybrid concrete construction techniques. Previous investigations suggested that social aspects and labour productivity play an important role in the decision between the two construction techniques in the South African construction environment (De Klerk, 2013; Kriel, 2013; Lombard, 2011). Wells (2003) identified three different groups of society which are affected by an economic activity such as a construction project. The three groups were identified as:

- People involved in the activity itself (labourers)
- The local community where activity takes place
- The wider global community

According to Wells (2003) the wider global community experience little effect in the case of a construction project. However, both the labour force and local communities experience major social impacts (Wells, 2003). This applies to the South African construction industry, as construction companies are forced to employ labourers from the local communities as far as possible (Van Rensburg, 2015). Considering De Klerk's (2013) statement that these local labourers usually have low skill levels, companies appointed by governmental institutions run a risk as they do not always have full control as to whom they employ.

Statements are often made by individuals from the construction industry. This thesis strives to evaluate the validity of these statements by means of adequate qualitative and quantitative research techniques. A statement by Bezuidenhout (2015) which mentioned that the total percentage of unskilled labourers working on an in-situ construction project is expected to be higher than that of an HCC project is an example of such a statement, and will be verified in Chapter 5

Tabassi and Bakar (2009) explained that the workforce used to manufacture precast elements for a HCC project is mainly skilled labourers with the necessary experience. The employment opportunity of a labourer in the prefabricated industry is more secure than that of labourers in the in-situ environment. Thus, taking the *National Development Plan* into consideration, in-situ construction may provide more employment opportunities, but it is of a more temporary nature than that of HCC projects. Also, according to Piek (2014), in-situ concrete construction requires skilled labour, making the use of unskilled temporary labourers a concern for meeting quality requirements.

Jurgens, (2008) investigated the feasibility of HCC for South Africa and concluded that HCC can be feasible for the South African market. However, he stated that further investigation is required to determine and investigate the parameters within which HCC would be the preferable construction technique in South Africa. Lombard, (2011) identified various parameters that should be investigated to guide the decision-making between different construction methods. These include:

- Cost
- Time
- Quality
- Socio-economic aspects (labour)

- Safety (labour)
- Environmental performance
- Client satisfaction

Several of these parameters have and are being investigated at Stellenbosch University (Lombard, 2011; Piek, 2014; Solomons, 2014). This dissertation will investigate labour as a factor in the choice between in-situ and hybrid concrete construction, where another researcher at the same institute is currently investigating labour safety factors regarding both construction techniques. The goal of this dissertation is to provide useful information to form part of a relevant decision making guideline between the two considered construction techniques. This guideline is formulated to help project teams to choose the most appropriate construction technique for a specific situation based on the labour aspects of a project.

1.3 Research objectives

The ultimate goal of the investigation is to determine the effect of labour in the choice of the most appropriate construction method between in-situ and hybrid concrete construction in South Africa. The investigation is done by considering the South African *National Development Plan* (NDP) *2030* as well as the *Expanded Public Works Programme* (EPWP). These programmes aim to produce a plan to reduce the unemployment rate to 6% by 2030 (National Planning Commission, 2013). As mentioned in Section 1.2, the construction industry is important to promote job creation. HCC is known for using fewer on-site labourers than in-situ concrete construction (Piek, 2014). Therefore, it is essential to identify the significance of these programmes considering the implementation of HCC in South Africa. The investigation also strives to provide practical and relevant information with regards to labour productivity in both in-situ construction environment and the precast manufacturing environment, and its influence on these environments. Therefore, the objectives of this study are to:

- Identify and investigate socio-economic factors related to the construction techniques under consideration.
- Investigate the influence of the NDP and the EPWP on the decision-making process between in-situ and hybrid concrete construction.
- Investigate job creation and skills development in both environments and find its relevance considering previous statements.
- Identify factors affecting labour productivity in the construction industry.
- Investigate the effect of the identified productivity-influencing factors on the South African construction environment.

To achieve these objectives, the following set of questions had to be answered:

1) How and to what extent do the NDP and EPWP affect the decision between in-situ and hybrid concrete construction?
2) What construction technique best promotes job creation and skills development?
3) What is the difference between labour hours spent when considering in-situ and hybrid concrete construction?

4) How do labour related productivity-influencing factors affect on-site construction compared to its influence on the precast manufacturing industry?
5) Which of the two considered construction techniques can best mitigate factors affecting labour productivity?

1.4 Scope and limitations

The topic of hybrid concrete construction versus in-situ concrete construction is a broad term and the scope and limitations are therefore introduced to set the boundaries for the study. A project is usually measured by certain critical indicators, such as time, cost, quality, safety, socio-economic aspects (labour), environmental performance and client satisfaction. Although some of these terms may be mentioned, this dissertation primarily focuses on the labour-related aspects of construction projects.

This study largely refers to the structural building industry. Other disciplines within the civil engineering industry which make use of precast concrete elements, such as kerbs or pipes in civil construction or U-beams in bridge construction, may be mentioned but are not investigated.

The interviews with professionals as discussed in Chapter 4, are limited to company representatives from the Western Cape and do not include interviews from across the country or abroad. The primary objectives of these interviews were to facilitate the comparison of job creation and skills development between the two construction methods and to provide an understanding of the NDP's and EPWP's influence on the choice between these construction methods.

The case study conducted in Chapter 5 was limited to structural buildings. Also, the HCC project only made use of one precast element type (hollowcore floor slabs) which was manufactured using the extrusion process which is highly mechanised. Other precast manufacturing techniques make use of techniques similar to the conventional construction techniques which are more labour-intensive. Using such a precast manufacturer would have an effect on the comparison.

A questionnaire survey was used to enable a risk analysis regarding productivity-influencing factors in the construction industry. Although all the survey respondents agreed that they possess the required knowledge to complete the questionnaire, they were from different disciplines, which could influence the accuracy of the survey.

The scope of this study is therefore to identify and quantify labour-related aspects of a construction project and to determine the respective aspects' influences on both in-situ and hybrid concrete construction. With the influences known, relevant suggestions can be made to assist project teams with their choice between in-situ and hybrid concrete construction.

1.5 Research methodology summary

This study made use of several techniques to satisfy the required research objectives. It was decided to divide the study into two sub-divisions (Figure 3.1). These were:

- Socio-economic aspects of labour in both construction techniques.
- Labour productivity and its effect on both construction techniques.

The research process of this study is based on triangulation, which is defined as the use of two or more points of reference to enhance the accuracy of findings. As mentioned, the study was divided into two sub-divisions; a thorough explanation is given in Chapter 3. The following process is a brief description of the research methods applied:

1. A literature study was first conducted, combining international and local information regarding this investigation to gain background knowledge and to guide the remainder of this study.
2. Semi-structured interviews were performed with representatives from various organisations in the South African construction industry. These interviews served as the primary data source regarding socio economic aspects of labour in both construction techniques. It also served as guideline for the set-up of a survey questionnaire regarding labour productivity. Ten individuals were interviewed and were asked similar questions. Asking similar questions to various people provides a good point of reference and gives a better understanding of the topic.
3. Site visits were conducted to enrich the researcher's practical knowledge regarding the two construction methods under consideration. These visits were conducted at the following sites:
    1. In-situ construction sites:
        - New Panorama hospital building - (NMC)
    2. Hybrid Concrete Construction sites:
        - CPUT hostel building - (NMC)
    3. Prefabricated elements manufacturing plants:
        - Cobute
        - Concrete Units
        - Portland Hollowcore
4. A quantitative labour hour comparison between an in-situ and hybrid concrete construction project was done in Chapter 4 to test the hypothesis formed regarding job creation in both the considered construction methods. The hypothesis is based on the opinions of the 10 interviewed individuals. According to the *Fundamentals of quantitative research*, quantitative methods are normally used to test hypothesis and theories (Sukamolson, 2012). This labour hour comparison compares the labour hours of an in-situ building with a similar HCC building. The labour hours spent to manufacture the precast concrete elements used at the HCC project were also considered. Although the case study was conducted to test the hypothesis formed from the 10 interviewees' opinions, more interviews were conducted to help with the setup of the case study. The new interviews were mainly conducted with individuals from the construction company providing the labour execution rates. A representative from the precast manufacturing industry was also interviewed to gain labour hour rates regarding the precast concrete element manufacturing process. This case study is thoroughly discussed in Chapter 5.
5. Finally, a quantitative survey was formulated based on an extensive literature study (Chapter 6) and the guidance of the interviewees. The survey was used to perform a risk analysis regarding the identified factors influencing labour productivity in both the in-situ construction

and the precast manufacturing environments. This was done to provide a better understanding of the extent of labour-related risks in both environments. This risk analysis is discussed in Chapter 7.

1.6 Structure of Research

The study is divided into sections as shown in Figure 1.2.

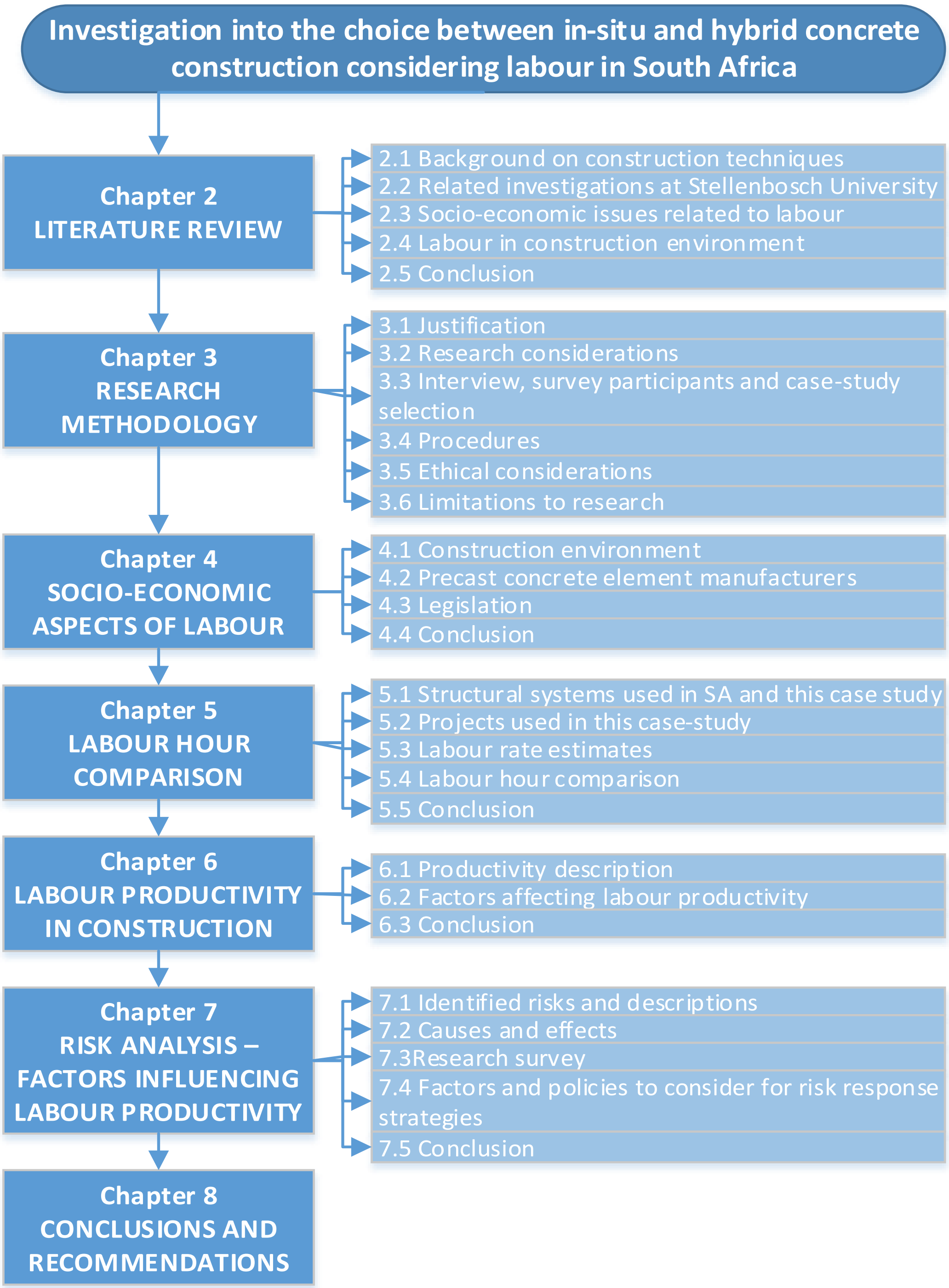


Figure 1.2: Graphical breakdown of research study

Figure 1.2 only shows the thesis layout, whereas the research procedure is described in Section 3.4 (Figure 3.1).

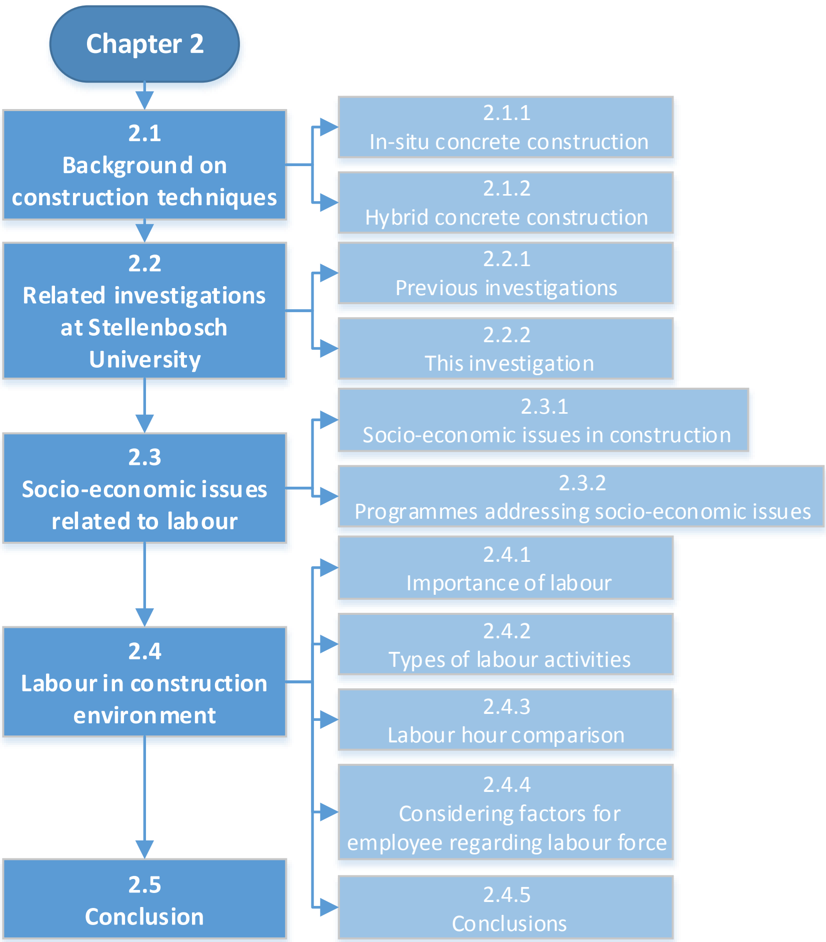
CHAPTER 2

2 LITERATURE STUDY

The literature study provides brief background information on the topic of in-situ and hybrid concrete construction. It also briefly covers previous research in hybrid and modular concrete construction as performed at Stellenbosch University. This provides relevant information regarding the benefits of these findings on construction labour and prevents the repetition of research.

This literature study provides information about the *National Development Plan 2030* and the *Expanded Public Works Programme* to identify the influence of these programmes on the labour of both construction methods under consideration.

The importance of labour in the South African construction environment, considering its influence on the quality, time and cost of a project are also investigated by considering previous studies. In addition, the chapter provides a better understanding of the work environments for labourers in both considered construction techniques by means of identifying tasks executed by labourers in both in-situ and hybrid concrete construction. Productivity levels of South African labourers are also considered and compared to that of countries successfully implementing HCC.



2.1 Background on concrete construction techniques

Concrete plays an important role in modern day living, especially considering its durable, energy-efficient, cost-efficient, and performance-enhanced construction benefits. It is due to these benefits that concrete is the most-used man-made material in the world. It is estimated that an annual average of three tons of concrete are poured for each human on earth. Concrete is used to construct the vast majority of the structures built in society, which include schools, apartment blocks, hospitals, tunnels, bridges, sewerage systems, dams, runways, pavements, roads and more. Concrete is regarded as an irreplaceable material due to its effectiveness, price and performance. (Cement Sustainability Initiative, 2012)

Several concrete construction techniques have been developed to optimize the concrete construction process. This section briefly discusses in-situ concrete construction and HCC, as these two construction techniques are the subject of this investigation.

2.1.1 In-situ concrete construction

Conventional concrete construction date back to the 1850's with the construction of a steel-reinforced two-storey concrete cottage. The cement used during this era was Portland cement, patented in 1824 by Joseph Aspdin from Leeds, England (Shaeffer & Shaeffer, 1992). More than 100 years ago Thomas Edison developed a form of in-situ concrete construction. This technique consisted of casting concrete into removable formworks, similar to in-situ concrete construction of the 20th century (PCA, 2014).

Modern in-situ concrete construction consists of three basic steps (PCA, 2014):

- Installation of temporary formwork (highly labour-intensive).
- Placement of reinforced steel (medium labour-intensive).
- Pouring of fresh concrete into temporary formwork (medium labour-intensive).

A simple example of labourers pouring concrete into temporary formwork is displayed in Figure 2.1.

Figure 2.1: In-situ concrete construction (Concrete wall forms. 2015)

2.1.1.1 Benefits of in-situ concrete construction

Cast in place (CIP) concrete construction is also a familiar term for in-situ concrete construction. CIP is regarded as the conventional construction method for the civil industry due to its high usage and popularity. Its high usage is due to its advantageous attributes which are summarised as:

Familiarity

In-situ concrete construction is considered as one of the oldest and most used ‘modern’ civil construction methods (Goodchild & Glass, 2004), (Shaeffer & Shaeffer, 1992). Designers and contractors have become comfortable and confident with the use of this technique due to the well-developed design codes and guidelines (Goodchild & Glass, 2004).

Monolithic construction

CIP facilitates monolithically construction. This implies that a larger solid structure can be constructed with fewer joints than with HCC. These types of structures are considered reliable in seismic active regions. (Sandt, 2003)

No additional skills & material required

Permanent and local labourers are usually familiar with the use of in-situ concrete construction. In the case where the local labour lacks knowledge or experience they can be given simple jobs, therefore not affecting productivity. Due to this advantage, contractors are confident in hiring local employees. (Sandt, 2003)

Smaller cranes

In-situ concrete construction makes use of cranes to lift and move concrete buckets, reinforcement, and other material and equipment. These cranes are only required when building at heights or when site accessibility is challenging. When compared to cranes used on HCC projects, in-situ construction uses cranes with a much lower lifting capacity (Sandt, 2003).

Insulation

According to Hartman (2015) CIP concrete structures provide high level of insulation due to the absence of gaps between different sections. Thermal insulation is regarded as the most important type of insulation as it prevents moisture from penetrating and damaging the structure. These structures also contain other insulation properties against sound, insects, mold and mildew (Hartman, 2015).

2.1.1.2 Labour-related barriers of in-situ concrete construction

In-situ concrete construction is highly labour-intensive. Usually three separate labour teams are required to proceed with this construction process. After earthworks have been completed, steel fixers proceed with the placement and fixing of the steel reinforcement for foundations. The next team proceeds with setting up the formwork, which requires moderate skill and therefore experienced labourers are required for this construction phase. From here the concrete team proceeds to fill the formwork with the concrete. Projects are usually divided into sub-sections to assure that once a team has finished with their division they can proceed to the next section and repeat similar work. (Illingworth, 2002)

Workers performing steel fixing and formwork placing may find themselves working in awkward positions at great heights, depending on the project. In these cases, in-situ concrete construction proves to be hazardous to the labourers. (Goodchild & Glass, 2004)

Although labour-intensive construction is considered a positive aspect in developing countries due to economic benefits, it could result in lower labour productivity if inadequate supervision is used, ultimately affecting the project schedule (Stofberg, 2015). High labour-intensive construction methods could cause construction sites to be overcrowded, which results in a high-risk environment with lower productivity (Dozzi & AbouRizk, 1993). The extent of these barriers will be investigated as part of Chapter 7 to provide a better understanding of the consequences of high labour-intensive construction on both construction techniques.

2.1.1.3 The use of in-situ concrete construction in South Africa

In-situ concrete construction is a well-recognized term in the South African construction industry and is considered the conventional construction method. Due to its familiarity and well defined design guidelines, consultants and contractors are confident to apply this technique to any given projects within the scope of the design codes (Goodchild & Glass, 2004). In developed countries other construction methods prove to be competitive contenders, if not more widely used than in-situ concrete construction. However, in South Africa construction techniques such as HCC have not yet proven to be more economical than the conventional method, partly due to South Africa's low-cost labour and the skills shortage amongst labourers (Jurgens, 2008).

2.1.2 Hybrid concrete construction

As mentioned in Chapter 1, hybrid concrete construction (HCC) is a combination of precast concrete elements and in-situ concrete construction (Elliott, 2002). Therefore, this technique combines the benefits of precasting (e.g. quality, form, finish, colour, speed, accuracy, pre-stressing) with that of in-situ construction (e.g. economy, flexibility, mouldability, thermal mass, continuity, durability, and robustness) (Goodchild & Glass, 2004).

A simple example of HCC is shown in Figure 2.2. The figure shows the placement of floor slabs which is regarded as precast construction, as well as the finishing of the floor surface which is considered as in-situ construction.

Figure 2.2: Placement of floor slabs and finishing of structural topping

2.1.2.1 Benefits of hybrid concrete construction

HCC was primarily developed to enhance construction time and reduce the cost thereof. The construction technique requires less on-site labour through manufacturing a large number of the elements used for construction at a precast factory (Goodchild & Glass, 2004). There are many other potential advantages, of which the highly ranked advantages are discussed below:

Labour

According to the *Irish Concrete Federation*, site labour is reduced by 50% to 80% with the work following these trades being reduced by 30% to 50%, depending on finishes (Irish Concrete Federation, 2014) . This is an important advantage when considering on-site safety, product quality, and construction performance. Also, not only is it expected to save labour input on site, but especially in skilled trades such as formwork, masonry or plastering, depending on the type of precast element used (Warszawski, Avraham & Carmel, 1984). This can be an advantage in the South African construction environment where skilled labour is scarce and unskilled labour in abundance (De Klerk, 2013; Jurgens, 2008; Piek, 2014).

The reduced labour figures as described by the *Irish Concrete Federation* and the expectancy to save on on-site labour in skilled trades as stated by Warszawski *et al*. (1984) were quantitatively investigated. This was done by means of a labour hour comparison of real projects in the South African construction industry (Chapter 5).

Construction speed

The use of precast elements on an HCC project reduces the duration of activities on-site (Warszawski *et al*., 1984). The manufacturing of the precast elements is not constrained by site progress. Therefore, elements can be produced in advance, optimizing construction time, as concrete work usually occurs on the project’s critical path (Bezuidenhout, 2015). In certain cases, the use of HCC can also eliminate the need for follow-on trades such as ceilings and finishes. These features facilitate even faster construction periods, but require better care and co-ordination regarding detail and protection. (Goodchild & Glass, 2004)

Quality and accuracy

HCC makes use of precast concrete units which are manufactured in a controlled environment. This enables the manufacturer to achieve the optimum design without making simple mistakes such as inaccurate spacing between steel reinforcement and cover distance. Therefore, the client is assured of a high performance product with a quality appearance. (Goodchild & Glass, 2004; Irish Concrete Federation, 2014)

Buildability and reduced temporary work

The buildability of a project depends on the complexity of the design which is subjected to the overall project requirements (Goodchild & Glass, 2004). HCC is a simplified construction technique mostly due to its high precast element usage. Almost the only on-site labour requirement regarding the precast elements is the placement thereof and in some cases connections. Thus, due to reduced need for on-site steel fixing, formwork erection and pouring of concrete, HCC is regarded as a more buildable construction technique than in-situ concrete construction. This increases when constructing high rise buildings, due to the complexity of erecting formwork and pouring concrete at excessive heights (Irish Concrete Federation, 2014).

Safety

HCC has a reduced-risk potential due to a large portion of the work being carried out by experienced and trained labourers in a controlled environment. Thus, less work on site means that the on-site safety-risk exposure is reduced. This technique also provides a cleaner and more organized site with less clutter, contributing to a safer environment. (Goodchild & Glass, 2004)

Earlier return on investment

HCC projects are expected to consume 20% less construction time than in-situ concrete construction projects (Goodchild & Glass, 2004; Irish Concrete Federation, 2014). Piek (2014) also concluded from his case studies that HCC has a higher return rate, which allowed the projects to generate revenue at an earlier stage. Piek (2014) concluded that in some cases the client may pay more for the HCC alternative to benefit from the faster return on investment.

The earlier return on investment also implies that temporary labourers will be available for new projects at an earlier stage. If these labourers are immediately employed, it counters the effect of job loss when using HCC.

Larger clear spans

Pre-stressing or post-tensioning is easy to apply to precast concrete elements as they are manufactured at ground level using permanent formwork. Large elements can thus be manufactured with minimum effort. This enables longer spans to be covered with less vertical supports (Goodchild & Glass, 2004). Structures such as sport stadia and car parks require long span decks with minimum columns. Therefore, considering these types of structures, HCC can be very beneficial (Irish Concrete Federation, 2014).

2.1.2.2 Overview of benefits

These HCC related benefits provide that HCC projects can be constructed more efficiently by means of time and quality as it utilizes less on-site labour with an earlier return rate than a similar in-situ construction project. It is also considered to be a more labour friendly environment due to the reduction in safety related risks.

These benefits however should be validated in the South African construction environment as the majority of investigations were conducted abroad. Some of these benefits have been addressed in South African related investigations and are discussed in Section 2.2. The labour hour comparison conducted in Chapter CHAPTER 5 will also provide relevant information regarding the productivity of labourers, labour hours required and the buildability of the respective construction techniques. The risk analysis conducted in Chapter 7 also provides relevant information regarding environment related benefits of HCC.

2.1.2.3 Labour related barriers of hybrid concrete construction

Referring to South Africa's *National Development Plan* and the EPWP, the government promotes a large percentage of the overall job creation through construction projects (Department of Public

Works, 2013b; National Planning Commission, 2013). Thus, the government expects that more labourers should be employed. Reviewing previous investigations it seems that HCC will possibly reduce the number of employees when compared to in-situ concrete construction (Goodchild & Glass, 2004; Hanekom, 2011; Irish Concrete Federation, 2014; Piek, 2014). However, none of these studies investigated the total number of labourers used in HCC, including both on-site labourers and those manufacturing the precast elements, but rather considered only the on-site labourers. This study will consider both on-site and off-site labour when conducting the labour hour comparison in Chapter 5.

As mentioned earlier, replacing in-situ concrete construction with HCC can result in an on-site labour reduction of 50% to 80% (Irish Concrete Federation, 2014). However, this excludes the labourers at the precast factory. It is hard to measure the exact number of factory labourers working on a specific project, as they operate as a factory, simultaneously manufacturing various concrete elements for several projects.

Lombard (2011) concluded from a personal interview with a design engineer from *Arcus Gibb* that job creation was regarded as a common barrier for implementing HCC in South Africa. This opinion was collective, considering the investigations done at Stellenbosch University with regards to HCC in South Africa (Hanekom, 2011; Jurgens, 2008; Lombard, 2011). Therefore, further investigation will be done to find a better understanding of the influence of job creation in the choice between in-situ concrete construction and HCC.

2.1.2.4 The use of hybrid concrete construction in South Africa

Jurgens (2008) investigated the feasibility of HCC in South Africa. The investigation performed a theoretical cost exercise comparing material and erection costs of HCC and other construction techniques. Jurgens (2008) concluded that HCC can be feasible in South Africa. However, he suggested that further investigation is required to determine the parameters for which HCC would be the preferred construction method. (Jurgens, 2008)

Hybrid concrete construction (HCC) is not considered a popular construction method in South Africa. Nevertheless, this method has been implemented in several projects in South Africa. The different precast elements used in South Africa are listed below, together with a few South African project examples:

Slabs

There are three basic precast floor systems available in South Africa. The three systems are briefly discussed in the following paragraphs.

Hollow core – The slabs typically contain circular or elliptical hollow cores, reducing its self-weight by at least 30% compared to solid slabs of the same depth. These slabs may be pre-stressed or reinforced and are designed as ribbed slabs. After the slabs have been placed it is covered by an in-situ topping.(Concrete Manufacturers Association, 1999)

Rib and block – This system consist of precast concrete rectangular shaped beams (“lintels”) placed at a standard spacing of 560, 600 or 650mm apart. Non-structural hollow concrete rebated filler blocks are used as floor panels, placed on the beams. After placement the system requires an in-situ topping. (Concrete Manufacturers Association, 1999)

Panel and topping – The panels are used as permanent floor shuttering and still require an in-situ topping. (Concrete Manufacturers Association, 1999)

Some example projects where precast concrete slabs have been implemented in construction are given below (Hanekom, 2011):

- Steenberg social housing project (Cape Town, 2010)
- Oakfields shopping centre (Benoni, 2009)
- Orlando station upgrade (Soweto, 2009)
- King Shaka International Airport (Kwazulu Natal, 2010)
- Protea Hotel (Kwazulu Natal)
- Eikestad Mall (Stellenbosch, 2014)
- CPUT residence building (Cape Town, 2015)
- Numerous other low rise residential facilities using load bearing masonry walls.

Walls

Single leaf, collar-jointed, cavity and diaphragm walls are suitable structural walls which are often used on HCC projects in South Africa (Concrete Manufacturers Association, 2015). Project examples where some of these precast concrete walls have been implemented are listed below (Hanekom, 2011):

- Gautrain sound insulation wall (Gauteng, 2009)
- The Houghton luxury hotel and apartment retaining wall (Johannesburg ,2010)
- Dora Nginza Hospital and Greenbushes business estate security walls (Port Elizabeth, 2009)
- Cosmo City (Gauteng)

Beams and columns

Precast concrete beams and columns are often used when applying the HCC method. In South Africa these elements have been used on numerous construction projects. Some of the South African construction projects using these elements are (Hanekom, 2011; Piek, 2014):

- Volkswagen paint shop (Uithenhage, 2006)
- Honda showroom (Polokwane)
- Orlando Stadium (Soweto)
- Linley reservoir (2008)
- Polokwane reservoir (Polokwane, 2009)
- Longridge reservoir (Bloemfontein, 2012)

Reviewing these construction projects it is evident that HCC is used in the South African construction industry. This investigation will aim to find labour related reasons why this technique is not used more often and whether it is worthwhile to consider HCC within the current situation of the South African socio-economic environment.

2.2 Related investigations at Stellenbosch University

Since 2006, modular construction has been investigated at the Chair in Construction Engineering and Management of Stellenbosch University's Department of Civil Engineering. These investigations mainly focussed on the implementation of HCC in South Africa.

The question identified by researchers is why, if developed countries achieve such great success with HCC, the South African construction industry still prefers to use in-situ as the conventional construction technique. Nevertheless, several projects in South Africa have made use of HCC techniques, with some being a success, and others being less successful (Hanekom, 2011). These investigations identified research topics on the utilization of HCC in South Africa.

This section provides a brief summary of previous and current investigations on precast modular construction, and their contribution to this topic where the effect of labour is investigated.

2.2.1 Previous investigations

2.2.1.1 An investigation into the feasibility of hybrid concrete construction in South Africa (Jurgens, 2008)

Brief summary

Jurgens (2008) identified through literature that the high usage of HCC in developed countries is due to its ability to enhance product quality, reduce life-cycle project cost and to achieve faster project-delivery time. This motivated Jurgens to investigate and identify the obstacles that prevent the utilization of HCC in South Africa. Jurgens investigated whether HCC is feasible in the South African construction environment.

Jurgens (2008) interviewed professionals from the South African construction industry as the main method of research regarding the use of HCC in South Africa. He verified the information through a case study on an HCC project.

The investigation identified three relevant areas of importance, i.e. management aspects, technical aspects and contractual aspects.

Labour-related findings

The research revealed the following aspects regarding labour in South Africa:

- Labour costs are a large part of a project's overall cost. With a potential increase in labour cost, it will be playing an ever bigger role in final project costs.
- Intensive labour construction methods may be the reason for slow construction.
- HCC requires competent crane operators and riggers of which there is a shortage in South Africa.

2.2.1.2 Decision-making between hybrid and in-situ concrete construction in South Africa (Lombard, 2011)

Brief summary

This dissertation provides project teams from the South African construction environment with information to assist them in their choice between in-situ and hybrid concrete construction. The investigation identified the following parameters as playing an important role in the decision between construction techniques: time, cost, quality, labour, logistics, safety, environmental performance, and client satisfaction. The study discussed each parameter and its contribution to projects in the South African construction environment.

Labour was identified as one of the key factors in the choice between in-situ and hybrid concrete construction in South Africa.

Labour-related findings

Interviews conducted by Lombard (2011) revealed that precast manufacturing requires highly skilled labourers. The extension of this statement should however be compared to the technicality of the in-situ construction technique to find its relevance to this study. Lombard (2011) also suggested that job creation should be one of the considerations in the decision-making process between in-situ and hybrid concrete construction. To quantitatively determine and compare job creation between the construction techniques, Lombard (2011) suggested a labour hour comparison case study. Both these labour related findings partially contributed to the decision to conduct a labour hour comparison (Chapter 5).

Lombard (2011) mentioned that in some instances labour is considered as the key driving-force of the decision-making process between different construction methods, thus contributing to the importance of this investigation.

2.2.1.3 Increasing the utilisation of hybrid concrete construction in South Africa (Hanekom, 2011)

Brief summary

Following the investigation by Jurgens (2008) which stated that HCC was feasible in South Africa, Hanekom, (2011) investigated how to increase the utilisation of HCC in South Africa. The investigation identified possible barriers that prevented the utilisation of HCC in South Africa and suggested relevant solutions which addressed the identified barriers. Hanekom (2011) also covered the importance of collaborative contract procurement strategies, such as design build, to improve the application rates of HCC in South Africa.

Labour-related findings

Hanekom (2011) stated that project requirements for construction practice in South Africa differ between public and private clients, especially regarding labour, procurement procedures and construction methods. This contributed to the decision to focus the investigation on public projects, as this is the industry mostly influenced by labour related legislation and programmes such as the NDP and EPWP.

According to Hanekom (2011) HCC is promoted worldwide, as it requires less labour compared to the conventional method (CIP construction). However, in South Africa labour-intensive construction is encouraged by the NDP and the EPWP, as discussed in Section 2.3.2. Interviews with managers from precast firms revealed that some precast manufacturers in South Africa do implement labour-intensive construction methods within their factories due to these programmes (Hanekom, 2011).

2.2.1.4 Precast modular construction of schools in South Africa (De Klerk, 2013)

Brief summary

De Klerk (2013) conducted an investigation into the use of precast concrete construction as an alternative for constructing schools in South Africa. This investigation was based on the barriers identified by Hanekom (2011) together with the framework proposed by Lombard (2011).

De Klerk (2013) performed a feasibility study on the implementation of precast concrete construction as an alternative, based on the following criteria:

- Time
- Cost
- Quality
- Socio-economic (labour)
- Logistics
- Health & safety
- Procurement strategies

The study concluded that implementing precast concrete construction for multiple schools proves to be advantageous considering cost and time. Repetition and standardization in the implementation of HCC proved to be important to obtain the construction technique's full potential.

Labour-related findings

De Klerk (2013) mentioned that the use of precast concrete elements can reduce on-site labour by up to 43%. This coincides with the *Irish Concrete Federation* which stated that on-site labour is reduced by 30-50% depending on the finishes. The chief engineer at the Department of Transport and Public Works stated during an interview that the use of precast elements during construction indirectly implicates job loss. However, considering that the reduction of on-site labour, only considers one point of view. Therefore, this investigation considers the bigger picture, including the precast manufacturing plant. From this, the two construction methods are broken down and compared from various angles (Chapters 4, 5 and 7).

According to his findings De Klerk suggested that working at a precast factory will provide better job security and enhance the skill of labourers. South Africa's construction labour environment is in a position where skilled labour is scarce but unskilled labour is abundant (Murtaza, Fisher & Skibniewski, 1993). It is important to identify the validity of this statement as this can contribute to the decision between which construction technique is most appropriate to the South African construction environment.

De Klerk (2013) stated that although the decrease in labourers on site (HCC advantage) is seen as an advantage in developed countries, it is considered a disadvantage in South Africa. However, De Klerk (2013) found that the faster rate of construction when using HCC will counter the effect of reduced site labour, as the labourers are able to start with a next project. This is an important factor to consider when deciding between the two construction techniques based on job creation.

2.2.1.5 A process to assist technology investment decisions in construction – A case study on labour productivity (Kriel, 2013)

Brief summary

This investigation aimed to provide construction companies with a process which will support them in informed decision-making. Kriel (2008) studied the application of technology in order to address areas of concern in the construction industry. Kriel (2008) concluded from a survey that low labour productivity and the employment of unskilled labour are the most influential areas of concern in terms of impact on construction projects.

Labour related findings

Kriel (2013) identified the management of labour productivity on site as a big problem in the South African construction environment. According to the Construction Management Program delegates of 2012, low labour productivity and the employment of an unqualified workforce are ranked as the top two areas of construction project concerns in South Africa. Thus, it was considered worthy to conduct a risk analysis, ranking labour related productivity influencing factors from high priority to low priority risks in both construction environments (Chapter 7).

2.2.1.6 Investigating the impact of site activities and conditions on concrete quality of in-situ and precast construction methods (Solomons, 2014)

Brief summary

Solomons (2014) proposed a risk model which could be used to identify the areas with the major risk and to weigh the precast option against an in-situ option. The external/secondary factors considered in this study were management, the working environment, safety, labour and subcontractors.

Labour related findings

HCC is considered to provide a safer environment, as fewer labourers is needed on site. This statement together with the labour environment benefits mentioned earlier contributed to the decision to conduct the risk analysis.

Solomons (2014) identified the following labour related attributes influencing the quality of concrete:

- Training of labourers
- Level of skills
- Amount of casual labour
- Motivation/human attitude
- Non-conformance

Solomons concluded that with regards to in-situ construction, labour plays an important role in achieving durable concrete, while labour is considered important in the aesthetics of the precast product.

2.2.1.7 An investigation into the time and cost factors for a decision between in-situ and hybrid concrete construction (Piek, 2014)

Brief summary

Piek (2014) identified factors that have an influence on the time and cost of in-situ concrete construction and HCC in South Africa. These identified factors were then used to provide a framework that can assist project teams in their decision between in-situ concrete construction and HCC.

Labour related findings

Local case studies conducted by Piek (2014) revealed that in all cases less labour and skills were required on site when implementing HCC, compared to in-situ concrete construction. However, for these case studies no complex precast connections were required, which would have increased the required number of skilled labourers.

Interviews with two consultant engineers concluded that skilled labour is of shortage for the implementation of in-situ concrete construction in South Africa and the training of labourers is both expensive and time consuming. Also, they stated that in-situ concrete construction requires more skills and skills development than HCC.

2.2.2 Summary of previous investigations

Previous investigations at Stellenbosch University covered three important aspects regarding labour. They were:

- Importance of labour in construction
- Skills requirements in both in-situ and hybrid concrete construction
- Labour related socio-economic factors, i.e. job creation and skill development

Labour is considered as an important, if not the most important, factor in the construction industry. Labour cost forms a large part of the overall project cost, and if inadequate numbers of labourers are used it can result in extra costs, time delays and insufficient product quality. Thus, the success of a project is amongst other factors directly dependant on the labour force. Therefore, it is understandable that Lombard (2011) made the statement that in some instances labour is the primary factor to consider in the decision-making between different construction methods, in this case in-situ and HCC. The extent of the labour force's importance in construction will be tested by means of a risk analysis, Chapter 7.

All of these previous investigations had one communal factor: they all were related to the South African construction environment. From these investigations it was evident that labour skills in South Africa are sub-standard, therefore either construction companies should invest in skills development programmes or adjust their construction techniques to best suit the low-skilled labourers. For construction companies to invest in skills development programmes is highly unlikely as the labourers with low skill levels are usually temporary labourers. Thus, adjusting the construction technique seems to be the solution, but it will pose some challenges.

HCC requires less skilled labour on-site than in-situ concrete construction. This is due to the substitution of skilled activities with the placement of precast concrete elements. However, skilled labour is required at the precast manufacturing plant. The extent of skilled labour used at the manufacturing plants is determined by the manufacturing method used and is also dependant on the type of element manufactured. However, it should be considered that labourers at a manufacturing plant are usually permanently employed, therefore it is sensible to invest in skills development.

Job creation was also a communal area of discussion, as it is known that HCC uses less on-site labour than in-situ concrete construction. Due to this, many of these investigation stated that the use of HCC indirectly implicates job losses. However, to accurately verify such a statement, the labour hours spent off-site at the precast manufacturing plant should also be considered. This contributed to the decision to conduct a labour hour comparison between projects using in-situ and HCC, with consideration of the off-site labour hours (Chapter 5).

2.2.3 This investigation

This investigation follows on previous investigations discussed in Section 2.2.1. As mentioned, Lombard (2011) identified a framework to assist project teams in their choice between in-situ and hybrid concrete construction. Lombard's proposed framework is shown in Figure 2.3

Figure 2.3: Criteria for a decision between construction methods (Lombard, 2011)

Others have investigated some of these factors which influence the decision between in-situ construction and HCC. The focus of this dissertation as highlighted in Figure 2.3 is the labour aspects affecting the choice between in-situ and hybrid concrete construction. This was concluded to be a sufficient research field based on the importance of labour in the construction environment as mentioned in Section 2.2.2.

Several of the investigations reviewed in Section 2.2.1 mentioned *socio-economic concerns* such as job creation and skills development related to HCC (De Klerk, 2013; Hanekom, 2011; Lombard, 2011; Piek, 2014). For the purpose of this investigation labour is divided into two sub-divisions, identified as socio-economic aspects of labour and labour productivity in construction. The comparison between in-situ and HCC of these two sub-divisions will provide sufficient information with regards to the best construction technique considering labour. Other factors also play a role in the productivity and cost effectiveness of a project, but for the purpose of this dissertation only labour-related factors are investigated. The identified labour-related parameters which will be addressed in this investigation are:

- Job creation
- Labour skills and skills development
- Job security
- Labour environment
- Labour productivity

By addressing these parameters identified in this literature study, it will provide sufficient information to adequately address the main research objective.

2.3 Socio-economic aspect of labour

South Africa is considered as a Third World developing country experiencing economic pressure, partly due to key socio-economic challenges. Pillay (2001) identified six key *socio-economic issues* that South Africa faces. From these six issues, the labour market and poverty were identified as relevant considering this investigation. Poverty is considered to be a concern in South Africa, largely due to the country’s high unemployment rate.

2.3.1 Socio-economic issues in the construction environment

2.3.1.1 Identification and description of issues

Recent unemployment results were released in October, 2014. At that time the unemployment rate was 25.4%, with 4.88 million people unemployed in South Africa. According to *Statistics South Africa*, in 2014 a total number of 1.28 million people were employed in the construction industry. This is high, considering that the maximum South African labour force is 19.92 million, with only 15.03 million employed. The construction industry is ranked 5th, considering industries with the highest employment figures (Statistics South Africa, 2014). During 2008, 1.11 million people were employed in the construction industry (Statistics South Africa, 2008). Therefore, a construction employment increase of 15.3% occurred from 2008 to 2014.

Programmes addressing *socio-economic issues* in South Africa have been published and are discussed in Section 2.3.2. These programmes partially expect of the construction industry to enhance job creation and to provide training to unskilled individuals. The NDP expects unemployment in South Africa to be neutralised by 2030 (National Planning Commission, 2013).

In the process of creating job opportunities through implementing labour-intensive construction methods, poverty will automatically be reduced as more people will exceed the poverty level (Lombard, 2011). However, a concern regarding job creation in the construction industry, especially when implementing in-situ concrete construction, is job security. It is not cost-effective for construction companies to employ all labourers on a permanent basis, as they do not always have the same amount of work. However, this becomes a risk during public projects as the contractor has little control over the temporary workforce due to tender requirements. These requirements expect of the contractor to employing local labour, as a governmental job creation scheme (Stofberg, 2015; Van Rensburg, 2015).

Job security, job creation and skills development are therefore socio-economic obstacles worth investigating when considering labour in in-situ concrete construction and in HCC.

2.3.1.2 Relevance of socio-economic issues for this investigation

The influence of implementing HCC on the identified *socio-economic labour issues* was found to be worth investigating, considering South Africa's current labour environment. The reason for this is that a small change in the construction environment can have a considerable effect on South Africa's unemployment rate, as construction labour covers 8.52% of the country's labour force (Statistics South Africa, 2014). Therefore, implementing labour-intensive construction techniques can have a positive influence on the country's employment rate.

HCC is not considered a labour-intensive construction technique; in fact, one of the advantages of this construction method is that it makes use of less on-site labour than in-situ construction. Thus, considering the unemployment rates, in-situ is considered the better construction technique with regards to the country's high unemployment rate. However, as mentioned earlier, the labour hours required at the precast manufacturing plant should not be discarded when investigating the best construction technique to promote job creation. Also, HCC could be considered as more beneficial for the employed labourers as the manufacturing plant provides labourers with better job security and relevant training. The validity and importance of these issues in the decision-making process between in-situ concrete construction and HCC are investigated and discussed in Chapter 4 and Chapter 5.

2.3.2 Programmes addressing socio-economic issues in South Africa

2.3.2.1 South Africa's National Development Plan (NDP)

The Reconstruction and Development Program (RDP) formed the basis of the government's attempt to attack poverty deprivation and to build a united, non-sexist and non-racial South Africa. The *National Development Plan* (NDP) was developed to translate the RDP into policies, programmes and budgets to set achievable goals for 2030. The NDP defined a minimum poverty level of R418 (in 2009 prices) per person per month. In the publication year, 39% of people were living below the poverty level. The goal of the NDP is to reduce this poverty level to 0% by 2030 (National Planning Commission, 2013).

Nine main challenges were identified as the reasons for South Africa's current socio-economic situation. The following two challenges were identified as critical: not enough people are employed, and the availability of quality education to the poor (National Planning Commission, 2013). These challenges relate to the construction industry as this industry serves as a labour-absorbing industry as shown in Figure 1.1, Section 1.2.

The NDP strives to create job opportunities, expand infrastructure, improve education, provide quality health care, fight corruption, transform society, and unite the nation as part of reaching the set goals. The aim regarding job creation is to promote employment by labour-absorbing industries. Thus, reducing the amount of labour used in construction as anticipated when replacing in-situ construction with HCC will be contradictory to the goal of the NDP. The importance of the NDP regarding the decision between HCC and in-situ concrete construction is therefore investigated through an interactive study with relevant people from the construction industry. The results of these interviews are discussed in Chapter 4.

2.3.2.2 Expanded Public Works Programme (EPWP)

The *Expanded Public Works Programme* (EPWP) originated at the Growth and Development Summit (GDS) of 2003. One of the themes discussed at the Summit was *'More jobs, better jobs, decent work for all'*. The GDS agreed that the EPWP can provide relief to societies in poverty. This initiated the development of the EPWP, which was then launched in 2004 (Department of Public Works, 2013a).

The EPWP goes hand-in-hand with the *National Development Plan* and is a key governmental programme regarding the creation of decent employment opportunities and sustainable livelihoods, the improvement of health and education, rural development, food security and land reform, and the fight against corruption and crime. The EPWP is a nationwide initiative which strives to draw high numbers of the unemployed into productive work, to enable the labourers to gain skills and knowledge while they work, and also to increase their capacity to earn an income. EPWP projects employ labourers on both a temporary and permanent basis.

EPWP's goals and achievements

The EPWP promotes job creation in four main sectors namely, Infrastructure, Non-State, Environment and Culture, and Social, through (Department of Public Works, 2013a):

- Increasing the labour intensity of government-funded infrastructure projects under the Infrastructure sector
- Creating job opportunities through the Non-Profit Organisation Programme (NPO) and Community Work Programme (CWP) under the Non-State sector
- Creating job opportunities in public environment and culture programmes under the Environment and Culture sector
- Creating work opportunities in public social programmes under the Social sector

The EPWP also includes Training and Enterprise Development support at a sub-programme level. Another skills development initiative performed by the EPWP is the *National Youth Service* (NYS) which is discussed in Section 4.1.2.

Only the infrastructure sector is considered relevant to this investigation as it involves the use of labour-intensive methods in the construction and maintenance of public sector-funded infrastructure projects. Labour intensive infrastructure projects under the EPWP entail: (Department of Public Works, 2013c)

- The use of labour intensive construction methods to provide work opportunities to local unemployed people
- Provide training and skills development to the local unemployed people
- Build cost effective and quality assets

During the first phase of implementation of the EPWP which extended from April 2004 to March 2009, the EPWP's goal was to provide 1 million job opportunities. This goal was reached one year earlier than envisaged, which set a guideline for the planning and implementation of Phase 2 (Department of Public Works, 2012).

Phase 2 extended from April 2009 to March 2014. The objective of this phase was to create 4.5 million job opportunities for unemployed and poor people in South Africa (or 2 million full-time jobs), which will contribute to halving the country's unemployment by 2014. (Department of Public Works, 2013b). This is done through the delivery of community services and public works. The intention thereof is to ensure that the EPWP enables the government to act as an employer of last resort as part of the Anti-Poverty Strategy.

Unfortunately, the results of phase 2 have not been released at the date of this publication.

EPWP eligibility

Employment is done by the government, by contractors, or by other non-governmental organisations under the Ministerial Conditions of Employment for the EPWP (Department of Public Works, 2013a). Non-governmental organisations under the Ministerial Conditions of Employment for the EPWP are defined in the Basic Conditions of Employment Act, 1997. The Act describes the following construction-related programmes as part of the EPWP (Oliphant, 2012):

Projects as well as Infrastructure Sector Programmes that are declared part of the EPWP include the construction, rehabilitation and maintenance of: rural and low-volume roads, storm-water drains, basic sanitation, water reticulation, sidewalks, footpaths, bicycle paths, schools and clinics.

The type of activities subjected to the EPWP as experienced in the construction industry will be investigated in Chapter 4.

Grant allocation

Only public bodies or projects financed by public bodies can qualify to receive a grant if they satisfy the EPWP requirements. The base amount payable to the participating body is formulated as: *The* *amount of person days of work created in a year ×minimum EPWP wage (R63.18 per person day of work in 2012).* An additional adjustment factor is considered based on the status of each public body in terms of the following variables (Department of Public Works, 2013b):

a) Potential
b) Need in terms of unemployment and poverty
c) Sector coverage
d) Institutional support of vulnerable municipalities and capacity support for provincial departments

The adjustment factors for both provincial departments and municipalities are determined through comparing the body's performance against the minimum targets for a full time equivalent job (FTE) considering the four variables. Additional adjustments are added to the adjustment factor in certain cases but for the purpose of this dissertation these adjustments are irrelevant. Finally, the grant allocation is determined through the multiplication of the base amount with the adjustment factor (Department of Public Works, 2013b).

EPWP in large projects

A guideline has been set up for the implementation of the EPWP in large projects. According to the guideline large projects are defined as projects exceeding a R30 million (including VAT) budget with components that can be conceptualised, designed, planned, tendered, implemented and managed, using labour-intensive construction. The success of this strategy requires of the public bodies to implement strategic schemes to attract medium and large-sized contractors, while being more developmental for small enterprises. There are two principle methods of implementing this strategy (Department of Public Works, 2012).

The first approach is known as the "carrot approach", whereby public bodies offer incentives to contractors for implementing labour-intensive construction. This is done through providing contractors with additional preference points during the tender evaluation stage, considering the highest labour content (Department of Public Works, 2012).

Another proposed method is the "stick approach", whereby the tender documents specify the project's minimum labour requirements. In the case where contractors fail to meet the required labour content a prescribed amount could be deducted from the payment (Department of Public Works, 2012).

The implementation of this model requires that the public bodies stipulate the required labour content, skills required, and capabilities of labourers to the contractor (Department of Public Works, 2012).

2.3.2.3 Relevance of the NDP and EPWP to this investigation

With consideration to this study, the EPWP is a programme that aims to reduce unemployment in the construction industry. It also provides a platform to carry out the projected milestones of the NDP.

Previous researchers at Stellenbosch University identified job creation as a restriction to use HCC in South Africa (De Klerk, 2013; Hanekom, 2011; Lombard, 2011). Some of these opinions were based on interviews with individuals from the South African civil construction industry. The interviewees considered the use of HCC and other labour minimizing technologies to reduce their tender competitiveness. The EPWP implements the job creation schemes in the South African construction industry and are therefore considered relevant to this investigation.

The extent of the application of the EPWP on construction projects, especially HCC compatible construction projects, requires further investigation. Interviews with individuals from the construction industry, with sufficient experience, will be used to address this issue (Chapter 4).

2.4 Labour in the construction environment

In South Africa, labour is regarded as the most influential area of concern considering its possible impact on construction projects. This statement was made by Kriel (2013) after thorough investigation was done by means of interviews and surveys with senior managers from different divisions of the South African civil construction industry (Section 2.4.2.2).

2.4.1 Types of labour activities

In-situ and hybrid concrete construction require to some extent labourers with different types of skills. This is due to the different nature of construction between these two techniques under consideration. This section provides the different activities performed by labourers within each respective construction method. Therefore, it supplements the investigation by providing a better understanding of the responsibilities and required skills of labourers from both environments.

2.4.1.1 In-situ concrete construction

In-situ concrete construction consists of five main activities and makes use of three dominant labour teams. The three separate teams are responsible for steel fixing and positioning of steel, erection of formwork, and placement of concrete. Each team usually involves different labourers and requires exclusive skills. Unskilled labourers are either trained to become part of the three mentioned teams or are employed to do the informal work of the project (Illingworth, 2002). In-situ concrete construction mainly consists of the following five activities:

Site preparation

Earthworks are done to prepare the site according to the designed requirements. This is usually done with the use of equipment such as excavators which require skilled operators.

Erection of shuttering and scaffolding

The formwork and required supports for the structure’s elements are set up using manual labour. This is a labour-intensive and time-consuming activity (Illingworth, 2002; PCA, 2014). The labourers erecting the formwork need moderate to high skills which they obtain through training and short courses at temporary formwork plants (Burgess, 2014).

Installation and fixing of reinforcement steel

The required steel reinforcement should be placed and fixed according to the proposed designs. This can be done before or after the formwork is erected, depending on the element type. This process is considered as medium labour-intensive and requires labourers with specific skills (PCA, 2014).

Pour concrete

Construction projects usually make use of ready-mixed concrete which is poured into the temporary formwork. Additional tests are conducted after concrete placement to verify that the concrete consists of all the required properties. These tests usually consist of a slump test, air content test, unit weight test and a compressive-strength test. Labourers with special skills and knowledge are required to perform these tests. The placement and finishing of the concrete are medium labour intensive. Both skilled and unskilled labour are used during this process. (PCA, 2014)

Remove formwork

As soon as the concrete has reached the designed setting time the shutters are removed and prepared for reuse. Labourers with limited skill are required for this activity.

2.4.1.2 Hybrid concrete construction

Hybrid concrete construction partially uses precast concrete elements in conjunction with the conventional cast-in-place (in-situ) construction (Elliott, 2002). Precast concrete elements are readily available if standard size elements are ordered. Various elements such as slabs, beams, columns, stairs, culverts and modular units are manufactured in South Africa. Other architectural elements are also manufactured on request, but will not be manufactured as fast as the standard elements (Hanekom, 2011).

Hybrid concrete construction consists of two individual processes, known as:

1. Manufacturing of precast concrete elements at the manufacturing plant.
2. On-site placement and construction

A brief summary of the respective processes within the HCC environment is given below:

Precast elements manufactured at the precast manufacturing plant

The manufacturing of precast concrete elements can be done by using two distinctive techniques. The first technique makes use of conventional moulds, with conventional steel reinforcement and concrete placement. The other technique is known as the extrusion or slip-form method where concrete is mechanically placed on a long pre-stressing line (Only applies to hollow-core slabs). Independent of the manufacturing technique used the manufacturing process takes place in a controlled environment which tends to be advantageous compared to elements manufactured in-situ due to the reasons as discussed below.

The production methods promote the prolonged use of pre-set forms and shutters, with only minor repairs when needed. Furthermore, the manufacturing processes do not involve temporary supports and scaffolding due to ground level production (Precast/Prestressed Concrete Institute, 2010). Thus, precast manufacturing plants are able to manufacture fully cured elements from the placement of steel reinforcement to finished elements from the beds in a 24-hour cycle (De Klerk, 2013).

High strength elements by means of pre-stressed tendons enable element weight reduction by inducing hollow-core sections. This is especially used when manufacturing slab elements (Smith, 2011). Precast plants mostly manufacture precast concrete elements according to standard dimensions and shapes.

This promotes a high degree of reputational work, which simplifies and speeds up the manufacturing process.

The use of pre-set forms and standardised formwork reduces the technicality of formwork erection compared to that of in-situ formwork, thus not requiring high skilled labour. Also, with the absence of temporary supports and scaffolding, fewer labourers are required for the manufacturing of these elements' formwork, compared to a similar in-situ process. Due to the high degree of repetition, labourers with lower skills are required in a precast factory (Piek, 2014). Labourers in this environment are not often challenged with new circumstances or different construction environments such as for in-situ labourers.

On-site construction
As mentioned, HCC replaces certain elements of the conventional in-situ construction method with precast concrete elements. The type and extent of precast element usage on a project are dependent on the design and client requirements. The on-site labour can consist of up to four types of labour teams compared to in-situ concrete construction's three teams. This is due to the addition of an element placement team. However, it should be remembered that an HCC project as a whole will entail four types of labour teams, but when considering the structural section replaced with precast elements in isolation, then only two teams are a required: the element placement team, and the team responsible for the finishing, depending on the type of elements replaced.

The placement team usually entails six people but it differs, depending on the element types used and the working height. The team consists of a crane operator, a navigator, two labourers to attach elements, and two labourers to place and detach elements. The only team member that requires special skills is the crane operator (Piek, 2014).

The other three teams are responsible for steel fixing and positioning of steel, erection of formwork, and placement of concrete as mentioned in Section 2.4.1.1. Although HCC makes use of four types of teams compared to in-situ's three, it makes use of less on-site labour overall. This is because, considering the section replaced with precast elements, one precast element placement team substitutes three labour teams as required during the conventional construction method (Irish Concrete Federation, 2014).

2.4.2 Importance of labour in the construction environment

2.4.2.1 The iron triangle

The iron triangle was originally developed to assist project managers with the cost, time and quality estimates of a project (Atkinson, 1999). Eventually, the triangle became a method for measuring project success. The triangle is known as the iron triangle, as each of the parameters is directly dependant on one another (Ebbesen & Hope, 2013). For instance, if the performance or quality of a project needs to be increased, the cost will increase accordingly, or if the project cost needs to be lowered, the construction period will increase or product quality will decrease. The iron triangle is shown in Figure 2.4.

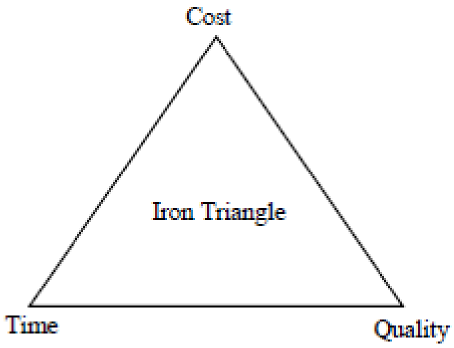


Figure 2.4: The iron triangle (Atkinson, 1999, Ebbesen & Hope, 2013)

The relevance of the iron triangle to this investigation is that labour forms part of each respective aspect of the iron triangle. The productivity of the labourers directly influences the construction period (Kriel & Wium, 2014). Also, the labourers' skills, experience and morale play a role in the quality of work they produce (Clough, Sears & Sears, 2000). These factors are all manageable in the construction environment (Tabassi & Bakar, 2009). Kriel (2013) mentioned that managing labour productivity on-site is a problem. However, it can be expected that this will be easier in a precast factory within a controlled environment. The influence of labour productivity on both construction techniques will be investigated through a risk analysis in Chapter 7.

Due to the influential role of labour in both the time and quality factors of the iron triangle, it directly influence the project cost. The "ideal project" is described by Atkinson (1999) as a high quality project which is delivered on time and within budget. Such a project is not achievable if labourers do not cooperate as expected. It is therefore important to effectively manage labourers during construction projects.

2.4.2.2 Areas of concern in construction projects

As mentioned, Kriel and Wium (2014) investigated the impact areas of concern related to the cost, time, quality and risk of a construction project. These impact areas form an important part of this study and are therefore thoroughly discussed in this section.

A survey conducted as part of a study, identified 73 areas of concern in the construction industry of Saudi Arabia (Assaf & Al-Hejji, 2006). The relevance of these areas of concern to construction projects in South Africa was determined through interviews with South African contractors. The different individuals were strategically chosen from different divisions in the civil construction industry. The interviewed individuals identified and ranked 49 relevant areas of concern considering the South African construction industry. The 9 highest ranked areas of concern were used for further evaluation considering their impact on South African construction projects. (Kriel & Wium, 2014)

(Kriel & Wium, 2014) conducted a questionnaire survey at the 2012 Construction Management Programme (CMP). The 38 delegates attending the CMP consisted of directors, managers and site agents with between 6 and 30 years' experience in the South African construction industry. The survey was conducted to determine the impact of the nine highest ranked areas of concern on project time, project cost, quality of work, and project risk. These elements all form part of the iron triangle, except for project risk.

A scale of 0-10 was used to quantify the degree of impact of the areas of concern on the identified aspects of construction projects. In this model, zero indicated no impact and ten a major impact. The averaged results of the 38 delegates were tabled according to the four identified project aspects for the various areas of concern (Table 2.1). An average of the four project aspects was determined for each area of concern and was used to rank them from high to low importance (Kriel & Wium, 2014).

The results validate the statement made in the previous section, regarding labour's importance on the iron triangle. The iron triangle represents the success factors of a construction project. Therefore, the results obtained through the survey provide a good indication of the importance of labour in the South African construction industry.

Table 2.1: A rating-sheet of areas of concern on different elements of impact on construction projects (Kriel & Wium, 2014)

Concern rank	Description of area of concern	Impact Areas				
		Time	Cost	Quality	Risk	Average
1	Low productivity level of labourers	7.69	7.72	8.19	7.92	7.88
2	Unqualified workforce	7.97	7.94	6.69	7.94	7.64
3	Inadequate experience of consultant	7.97	8.03	6.17	7.75	7.48
4	Ineffective planning and scheduling of project by contractor	7.89	7.92	6.67	6.89	7.34
5	Delay in approving major changes in the scope of work by consultant	8.50	8.31	5.11	6.94	7.22
6	Delays in sub-contractors' work	7.69	6.97	6.19	7.42	7.07
7	Late in reviewing and approving design documents by consultant	8.19	7.92	4.81	7.03	6.99
8	Equipment breakdowns	6.31	6.67	4.64	6.22	5.96
9	Accident during construction	6.39	5.86	3.89	6.75	5.72

2.4.3 Labour hour comparison between considered construction methods

As mentioned earlier, several of the reviewed investigations concluded that HCC requires less on-site labour than the in-situ concrete construction technique. A study conducted by Warszawski *et al.* (1984) compared the man-hours spent on certain activities on-site considering the use of both in-situ and hybrid concrete construction in Israel.

The project under consideration was a residential four-story building with four identical apartments on each floor. Each apartment had a gross floor area of 94 m^2. This structure is regarded as a relative small structure considering the use HCC (Warszawski *et al.*, 1984). Warszawski *et al.* (1984) divided the structure under consideration into four individual sections to simplify the comparison. These sections were: walls, columns, floor slabs, and supporting beams. The labour requirements in terms of on-site hours were derived for each of the sections per dwelling. (Table 2.2)

Table 2.2: Labour requirements on-site in different construction alternatives (Warszawski, Avraham & Carmel, 1984)

Activities group	Labour requirement, in man-hours per dwelling					
	Conventional method	Precast Floor Slabs		Non-bearing precast walls	Precast Floor Slabs and Bearing Walls	
		Span 9.60m	Span 6.60m		Span 9.60m	Span 6.60m
Walls	163.8	153.6	153.6	61.1	43.4	43.4
Columns	67.3	55.7	65.4	76.4	-	9.7
Floor slabs	173.0	75.3	50.8	173.0	75.8	51.3
Supporting beams	-	59.1	75.3	-	-	16.2
Total	**404.1**	**343.7**	**345.1**	**310.5**	**119.2**	**120.6**

Table 2.2 were setup to provide a comparison of the required labour-hours for each activity regarding the use of the conventional method (CIP), a combination of precast floor slabs and CIP, a combination of non-bearing precast walls and CIP, and a combination of precast floor slabs, bearing walls and CIP. The results shows that the combination of precast floor slabs, bearing walls and CIP construction has a 70% reduced labour-hour requirement than that of the conventional method. The other precast combinations also proved to use less on-site labour than the conventional method but not to the latter extent.

The comparison technique conducted by Warszawski *et al.* (1984) is relevant to this study as it provides a methodology to compare labour hours between in-situ and HCC. However, for this investigation further research should be done to obtain the labour-hours spent during the manufacturing of the precast elements. Although this is not relevant when conducting a cost comparison as precast elements are sold as units, it is important considering this study and to find a better understanding of the amount of labour used to construct an HCC project. Ultimately, a labour hour comparison between the two construction techniques with the consideration of labour hours spent at the precast manufacturing plant will provide relevant information regarding the technique which best suit South Africa's current socio-economic situation.

2.4.4 Considering factors for employer regarding labour force

As discussed in Section 2.4.1.2, labour is regarded as one the most important factors considering project success with regards to quality, time and cost. A study conducted on the case of human resource management in construction projects in Iran concluded that a forceful human resource management system is the most valuable asset of current century construction companies (Tabassi & Bakar, 2009). The study mentioned that Iran's labour force in the construction environment use a high fraction of unskilled labourers. This is similar to the South African construction industry in the sense that in South Africa's construction environment, skilled labour is rare but unskilled labour is abundant (Murtaza, Fisher & Skibniewski, 1993). The latter statement was supported by interviews conducted by Jurgens (2008) and by the interviews as discussed in Chapter 4

The use of inadequate labour in construction projects could result in low quality, delayed, and over budget projects. It is due to this that entities or activities such as human resource management (HRM) are implemented (Tabassi & Bakar, 2009). Previous literature concluded that a forceful HRM system is probably the most valuable asset of 21st century construction companies (Chen, Liaw & Lee, 2003). The development of people, their competencies, and the process development of the total organization are considered the main concerns of HRM (Moore, Cheng & Dainty, 2002).

According to the Project Management Body of Knowledge (PMBOK), training and motivation are considered the two main aspects of team development (Guide, 2001). Therefore, this section only focuses on the enhancement of training and motivation of labourers, so as to prevent unreliable and inadequate labour in the construction environment.

2.4.4.1 Training of labourers

Tabassi and Bakar (2009) identified two methods to simplify the training process. These are on-the-job and off-the-job training (Smith, 2002). This section is relevant to Chapter 4, which discusses the training of labourers in South Africa regarding in-situ and HCC.

On-the-job training (OJT)

The traditional technique of on-the-job training (OJT) is to promote new practices by presenting a pre-prepared course to labourers regarding a new project's procedures, regulations, and processes. This is often done at a different location than the place of work and labourers are expected to implement the knowledge gained at the course in their workplace (Tabassi & Bakar, 2009).

OJT and experience is considered the most common methods of employee development used at all levels in construction organizations. In the case where organizations require large numbers of skilled carpenters, plumbers, bricklayers, formwork workers, welders, etc. apprenticeship training is used. This training is done according to established standards (Tabassi & Bakar, 2009). The use of job rotation is also promoted by OJT. This enables labourers to gain experience and skills in various fields of expertise (Tabassi & Bakar, 2009). Angelucci (2015) mentioned that they experienced the use of job rotation as a method of skills development to be advantageous to both their precast manufacturing company and to the labourers.

Off-the-job training

Off-the-job training literally means training away from the project site. This technique consists of lectures, films, and simulation exercises. Lecturers are used to transfer specific information and to develop problem-solving and technical skills. Films provide visual aid to the lectures through explicit demonstration of the required technical skills. This technique is also helpful in cases of language difficulties. Table 2.3 shows the two proposed training techniques in comparison and shows their differences as well as their important aspects.

Table 2.3: Off-the-job training versus on-the-job training (Tabassi & Bakar, 2009:471)

	On-The-Job Training	Off-The-Job Training
Emphasis on	Getting the job done	Learning basic facts & skills
Ultimate goal	Developing "best practices"	"Knowing"
Knowledge	Dynamic, situated, practice-orientated	Static, decontextualized, general
Topics/problems	Arise from and embedded in work situation	Given by curriculum
Scope of learning	Individual, group, organisation	Primarily individual

2.4.4.2 Labour motivation

Labour motivation as discussed in Section 2.4.4.1 can be described as the willingness of an employee to attend training programs, to gain the lectured knowledge and to successfully apply the knowledge to the required project (Maurer & Tarulli, 1994; Noe & Wilk, 1993).

Even if labourers have the ability to learn the technical skill and knowledge provided through training, they are due to fail if their motivation is low (Colquitt, LePine & Noe, 2000). Labourers' motivation will not only influence their training but applies to every task they are involved in. Thus, the importance of labour motivation is ever-recurring, as the success of a construction organization fundamentally rests upon the quality and morale of its people (Clough, Sears & Sears, 2000).

According to Tabassi and Bakar (2009), to motivate employees their needs should be satisfied. Each labourer has different needs, therefore these needs are broken down into three basic categories: workers' participation, recognition and team-belonging. For workers' participation, many labourers feel motivated if they are "empowered" and feel that their participation is vital to produce a successful product. If labourers are motivated in such a way, they will not only work to meet their own needs but also the needs of the whole company. Employers should enhance labour participation through implementing a system that rewards labourers for good work (Tabassi & Bakar, 2009).

It is considered that a well-designed financial reward system can lead to higher project productivity for the employer and extra pay for the employee, resulting in a win-win situation (Olomolaiye, Jayawardane & Harris, 1998). Recognition is also regarded as a powerful technique to inspire enthusiasm among employees, especially when applied to teams. An example of this method is to give recognition through awarding a team the "team of the month" award. According to the Tabassi and Bakar (2009) various projects have reached great success by promoting motivation through recognition (Tabassi & Bakar, 2009).

Team-belonging is considered another important technique to keep labourers motivated. It is a basic need of a human being to feel part of a group or team (Jahn, 1996). It was revealed that teams are highly motivated when they are given the opportunity to "self-manage". Allowing the team to be self-manageable induces group participation, together with an increased responsibility of the group as a whole (Tabassi & Bakar, 2009).

2.4.4.3 Relevance to this investigation

Section 2.4.2 highlighted the importance of labour in the construction environment. Section 2.4.4 mentioned that a good human resource management system is important to enhance project success.

Thus, this section has identified and discussed the main aspects of team development, as this will directly influence project success. Labour force motivation forms part of the factors influencing labour productivity and the relevance of labour motivation in both the in-situ construction and precast manufacturing industries are investigated in Chapter 7.

2.4.5 Labour productivity in South Africa

Lombard (2011) revealed that the labour productivity rate in South Africa is relatively low compared to other countries implementing precast concrete construction. Labour productivity rate is defined as "the rate of output per worker per unit of time as compared with an established standard expected rate of output" (Business Dictionary, 2015). The yearly labour productivity rates of various countries are defined as the gross domestic product (GDP) per person employed. The GDP per person employed is the GDP divided by total employment in the economy. The latest data available showed that South Africa had a productivity rate of 14,569 in 2012 (The World Bank, 2015).

Countries such as the United Kingdom, Sweden, Switzerland, and the United States are all examples of developed countries. Their respective labour productivity rates are 49,428, 52,380, 41,918, and 68,374 (The World Bank, 2015). Thus, considering the labour productivity of these developed countries, it is evident that South Africa has a relatively low labour productivity.

Lombard (2011) conducted a small international survey to gain knowledge on the worldwide usage of precast elements in concrete construction. The survey questioned the extent of precast usage in the various countries' concrete construction industries and the confidence in the respective answers. Lombard (2011) plotted the various countries' survey results against their respective labour productivities. This was done in an attempt to find a relation between labour productivity rates and precast usage in different countries (Figure 2.5). The labour productivity data used to plot the graph were from 2008 and were at that time the latest figures available.

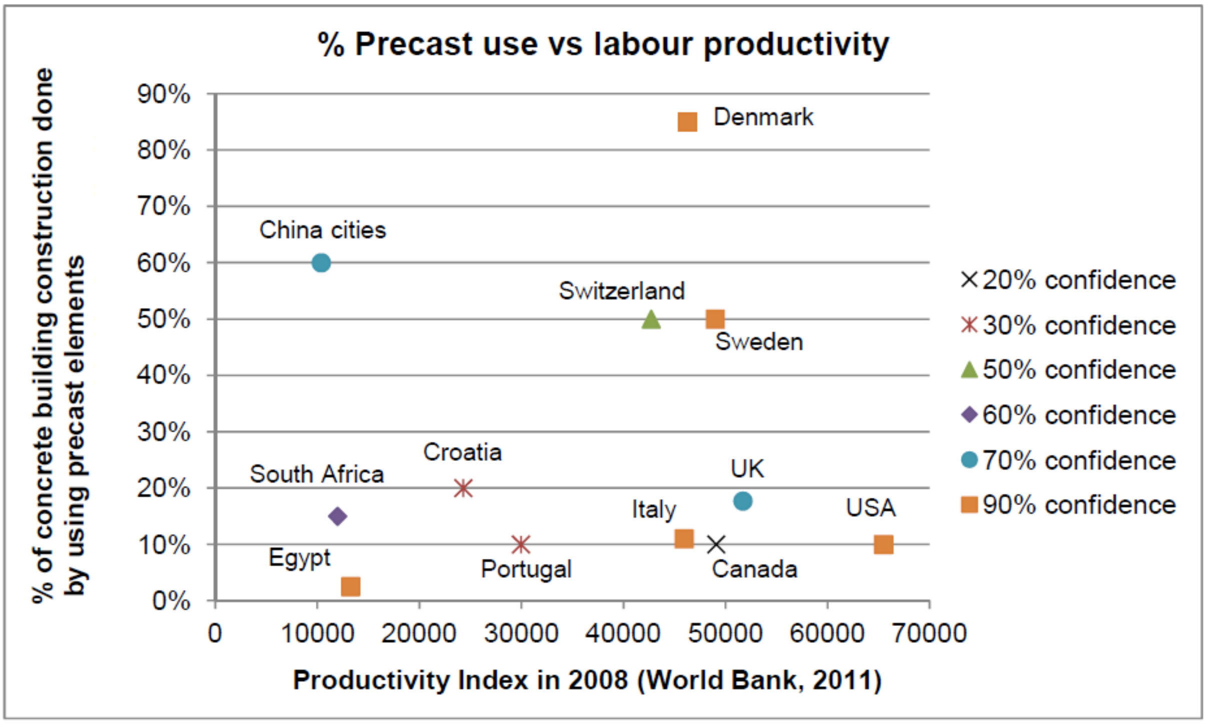


Figure 2.5: Percentage of precast use versus labour productivity indices of different countries (Lombard, 2011)

Due to this survey being based on people's opinions rather than quantitative information, conclusions drawn from Figure 2.5 cannot be expected to be accurate. It does however provide some information regarding the trends.

Apart from China, countries with high precast concrete usage have a correspondingly high productivity index. South Africa has a low precast concrete usage and according to the setup of this comparison it might be due to its low productivity index. However, Figure 2.5 shows various countries with low precast concrete usage and a correspondingly high productivity index. Thus, no reliable conclusion can be drawn regarding the reason for the low precast element usage in South Africa. Therefore, further investigation is required to provide more accurate results (Lombard, 2011).

According to statistics provided by The World Bank (2015) labour productivity in South Africa has shown a significant increase of 21.41% from 2008 up to the last data point in 2012.

2.5 Conclusion

The objective of this chapter was to provide a solid foundation which will serve as a relevant basis for the remainder of this investigation.

Relevant background information regarding each of the investigated construction techniques provided the investigation with a better understanding of what factors to consider, regarding the choice between in-situ and hybrid concrete construction methods. Previous investigations regarding HCC in the South African construction environment suggested that labour is a highly-ranked concern and can be a key driver for the decision-making between the two considered construction techniques.

Some of the investigations conducted at Stellenbosch University stated that HCC requires more high-skill labour than in-situ concrete construction, while others stated the opposite. These investigations made the assertions based on interviews conducted with people from different divisions in the South African construction industry. Therefore, there seems to be some measure of confusion regarding the required skill of labourers when implementing HCC. This motivated the researcher to identify the skills levels required for various activities during the case study conducted in Chapter 5.

Socio-economic issues were addressed which revealed that job creation appears to be a hindrance for the implementation of HCC in South Africa. The *National Development Plan* and the *Expanded Public Works Programme* are both programs established in South Africa to partially reduce the country's unemployment rate of 25.4%. The construction industry is ranked as the industry with the fifth highest employment rate in South Africa. The role of the EPWP regarding the use of HCC for construction in South Africa was investigated through interviews with suitable individuals, and the reviewing of tender documentation (Chapter 4).

The concept of the South African construction environment is that the smaller on-site labour force of HCC is experienced as a barrier for the implementation of this technique. Further investigation is thus required to find a better understanding of the combined on-site labour and labour at precast plant. HCC also contains other labour-related advantages such as better job security, skills development, and a safer environment. The extent of these advantages should also be considered when fighting poverty. Therefore, these factors will be kept in mind when conducting interviews with people from the civil construction industry (Chapter 4).

Another important factor identified in literature regarding labour was the low productivity of labourers in South Africa compared to many other countries successfully implementing HCC. Kriel and Wium (2014) concluded and verified that labour productivity was the highest ranked concern regarding construction projects in South Africa. These factors lead the investigation towards finding the most labour-effective construction technique as part of the choice between in-situ and hybrid concrete construction. This investigation should also consider the construction method best capable of managing labour productivity-related risks (Chapter 7).

CHAPTER 3

3 RESEARCH METHODOLOGY

This chapter introduces and briefly discusses the qualitative and quantitative procedures followed to develop the research. The goal of this report was to provide the civil engineering industry with relevant information to choose between in-situ and hybrid concrete construction considering the labour aspect thereof. This required labour-related fields such as of job creation, and skills development to be investigated together with the techniques which best promote high labour productivity and labour satisfaction.

Several research techniques were used to accomplish this investigation. A literature review (Chapter 2) focussed on the outcomes of previous related studies. From previous investigations the focus of the research was defined and key terms which formed the foundation of this research were identified.

After the literature study this investigation followed two distinctive paths, which both contributed to the final conclusions regarding the choice between the two considered construction techniques. These two paths are shown in Figure 3.1 and are discussed in the sections thereafter.

3.1 Justification

This investigation followed two distinctive paths for collecting data. The first used semi-structured interviews together with a case study to quantitatively support the qualitative information from the interviews. The second method of data collecting used a survey which was based on the opinions of interviewees and literature.

Previous similar (construction related) qualitative and quantitative studies by Jin and Ling (2006) and Lam, Chan and Chan (2007) made use of surveys to successfully answer research questions (Jin & Ling, 2006; Lam, Chan & Chan, 2007). Furthermore, Chan and Chan (2004) also used semi-structured interviews to assist with primary data collection (Chan & Chan, 2004). In addition, research by Ogunlana (2010) determined how various participants on large-scale construction projects perceive performance on projects, by using both semi-structured interviews (a total of 35 interviewees) and a survey questionnaire (a total of 76 respondents) (Ogunlana, 2010).

This investigation followed a similar data collection path than that of Ogunlana (2010) of interviews and a survey, but on a smaller scale. This combined method of data collection created the opportunity to ask several similar questions to various people from the civil engineering industry. Also, on-line software namely *Survey Monkey*, used to administer the survey questionnaire, made it possible to compare and filter results by either questions or respondents. The decision was made to use a survey as the primary tool for collecting research data on *labour productivity* in both the in-situ construction and precast manufacturing industries.

In the case of the data collection for the labour related *socio-economic issues* it was decided to use the semi-structured interviews as primary tool for research and to support the results with the use of a project-specific labour hour comparison between the two construction methods.

3.2 Research considerations

The interviews were considered to be advantageous in the sense that the opinions of different professionals could be compared and used as the foundation for further analysis with no real limitation to the type of questions within the field of knowledge of the individual. Thus, it was decided to first conduct interviews as a form of data gathering, as it serves a dual purpose for both the *socio-economic* and *labour productivity* aspects of the study. A possible pitfall anticipated when conducting the interviews was that the conversations could digress from the initial objective of the interviews. On the basis of this possible drawback and the success of previous investigations it was decided to compile a fixed set of questions (APPENDIX B) to guide the interviews in the direction of the objectives. Thus, semi-structured interviews were used for gathering the initial data.

Further possible drawbacks anticipated when conducting the research were that the outcome of the research would very much depend on the sample of value-chain members. It was therefore decided that survey questions should be kept simple and straight-forward with as few questions as possible, without compromising the feedback necessary to draw useful conclusions. Also, because such a variety of professions (clients, consultants, contractors and precast manufacturers) would be subject to the same set of questions, it was decided that the survey questionnaire should be tested before administering it to the various professionals, in order to flag any vague or confusing terminology, as well as to identify other problem areas up front, to keep gathered data usable as far as possible. It was realised that the survey respondents were from different backgrounds and would not respond identically to the survey. Therefore, standardised criteria were selected to mitigate this issue as best as possible. Afterwards, the data distribution (standard deviations) was analysed before comparisons were made in order to identify outliers.

3.3 Interview, survey participant and case study selection

The individuals selected for the interviews were required to have knowledge about the *socio-economic issues* related to the labourers in their respective companies and about the relevance of labour-related programmes such as the NDP and the EPWP. Some knowledge of *labour productivity* and factors affecting productivity in construction projects was also required. An email was sent to various construction firm directors which required them to identify an individual with the best knowledge in the described fields who would be able to participate in the interview. In some cases the directors themselves volunteered to be interviewed. This ensured that professionals best suited were interviewed, which contributed to more accurate data gathering.

For individuals to be considered as survey participants they had to possess knowledge in the field of construction project productivity and on factors influencing construction productivity. It is important to note that survey respondents were limited to professionals either directly or indirectly known to the researcher. This was done in order to improve the quality of the overall response as well as to improve the response rate of the survey questionnaire. Most of the respondents previously attended the annual Construction Management Programme (CMP) held at Stellenbosch University. The CMP is a 4 week long management programme aimed at middle managers in the construction industry. An email which described the field of knowledge was sent to CMP delegates of the last 7 years. They were asked whether they would be willing to participate. From these responses the survey was sent to each individual willing to participate. The interviewees were also requested to participate in the survey.

The projects selected for case study (Chapter 5) were required to make use of a large quantity of precast concrete elements. Ideally a project which uses various types of precast elements would be best. However, in this case one of the interviewed individuals was the project manager on a project which only used precast floor slabs. Also, the precast supplier of this project was interviewed in the initial stages of the investigation. It was therefore decided to use this project as the case study. Another contributing factor to the decision was the sensitivity of this information. Due to the established relationships between the researcher and the two individuals from industry, they were willing to anonymously share the required information. According to Warszawski *et al*. (1984) precast floor slabs are the most-used amongst precast elements especially considering the building industry, thus this case study was considered to be sufficient.

3.4 Procedures

In a study by Forza (2002) on surveys and the use thereof he divides survey type research into three different categories: exploratory, confirmatory and descriptive. For the purpose of this investigation, it was decided to make use of confirmatory survey research. According to Forza (2002) confirmatory research takes place when knowledge of a phenomenon has been articulated in a theoretical form using well-defined concepts, models and propositions. In the case of this investigation, data collection was carried out with a survey with the specific aim of testing the effect of the productivity-influencing factors in the in-situ construction and precast manufacturing environments. These productivity-influencing factors were identified in literature, primarily referring to the *System of productivity improvement* (Figure 6.1) as developed by Dozzi and AbouRizk (1993).

The semi-structured interviews were considered as exploratory survey research, since this methodology does not require a theoretical model and it allows the researcher to perform various trials to gather new insights from the available data and opinions (Forza, 2002). According to Forza (2002) this type of research takes place in the early stages of research into a phenomenon when the objective is still to gain preliminary insight on a topic. In the case of this research the socio-economic data sourced through the interviews was not only used as preliminary insight but also as primary data. The data gathered through the interviews served both as the basis of the case study, as well as partial guidance for the survey setup.

The procedures shown in Figure 3.1 were followed to qualitatively and quantitatively investigate labourers in an in-situ and hybrid concrete construction environment. The procedure followed two distinctive fields of investigation where different data gathering techniques were used. As shown in Figure 3.1, the one procedure is referred to as “A” and the other as “B”.

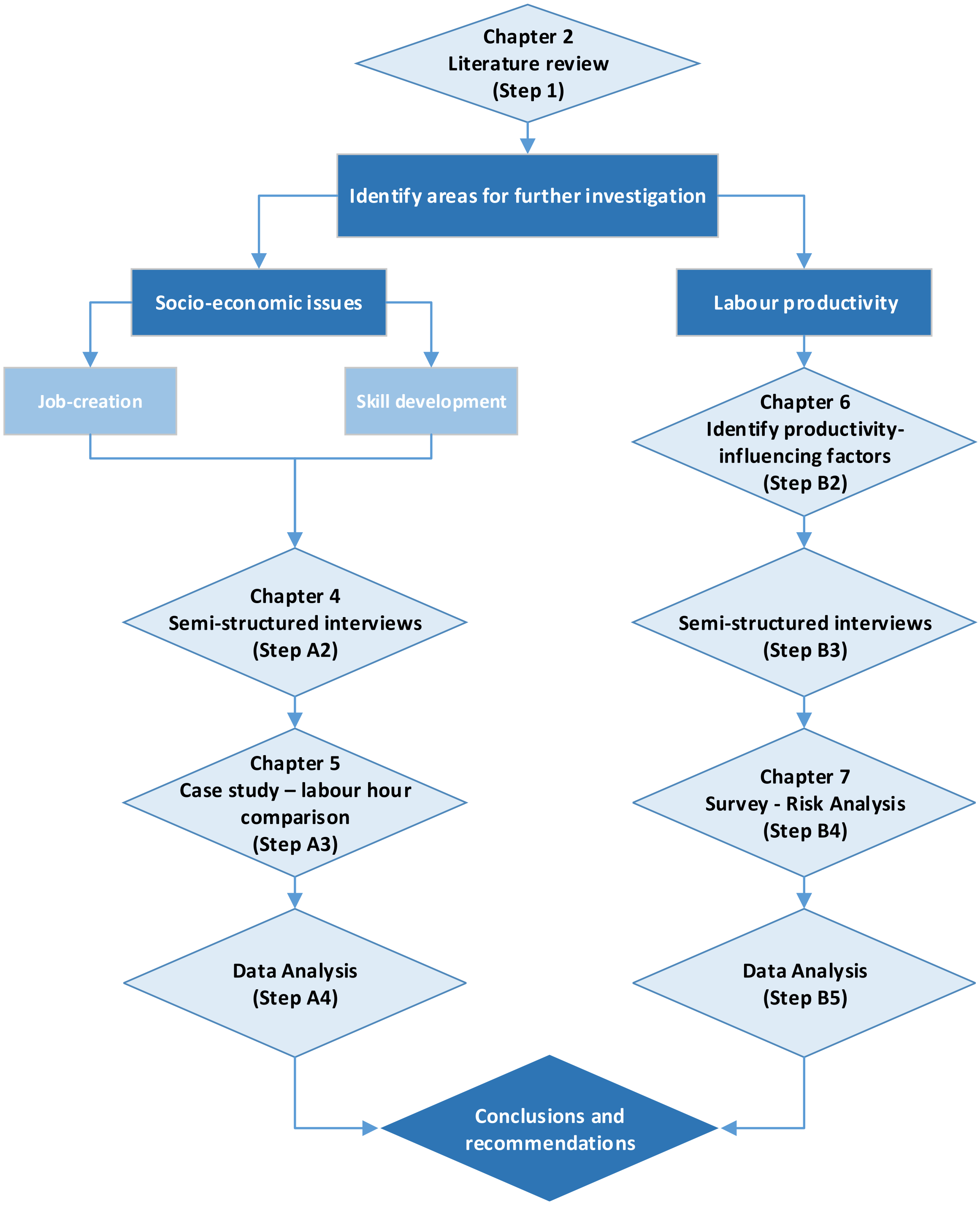


Figure 3.1: A flow diagram illustrating the breakdown of this research study

Each of these steps is discussed in more detail below:

3.4.1 Literature review (Step 1 & B2)

Step 1

Literature was investigated in the form of accredited journals, books, case studies, internet sources, publications and research reports. Research reports from previous studies at Stellenbosch University were essential to identify shortcomings and areas for further investigation in the South African construction industry. International literature provided insight on outcomes and previous results in studies relevant to this investigation. South African labour-related legislation also formed part of the literature reviewed in this study.

The literature guided this investigation into two indirectly related studies as shown in Figure 3.1. Both studies were labour-related, with procedure “A” focussing on the *socio-economic* factors related to labour and procedure “B” on *labour productivity*.

Step B2

The next step with regards to the *labour productivity* factors were to investigate literature describing labour productivity, labour productivity models, techniques to measure labour productivity and factors influencing project and labour productivity in the construction environment. The investigation of Dozzi and AbouRizk (1993) served as the foundation of this literature review whereas other sources were used to supplement and support.

3.4.2 Semi-Structured interviews (Step A2 & B3)

Ten semi-structured interviews were conducted with individuals from the civil engineering industry. These individuals were required to have knowledge on labour related *socio-economic issues* in the construction environment and to have knowledge on *labour productivity* and factors influencing labour productivity. All the interviewees resided in the Western Cape and the interviewing process was done over a period of 4 weeks. Partially different interview transcripts were followed when conducting interviews with individuals from construction, precast manufacturing plants and public clients. These transcripts served as a platform to guide the interviews and can be seen in APPENDIX B.

Step A2

The semi-structured interviews regarding the *socio-economic issues* related to labour were considered as the primary source of data collection. The type of information required from the individuals were too descriptive to use survey data collection, therefore it was decided that semi-structured interviews would be best.

Step B3

The purpose of the semi-structured interviews regarding *labour productivity* was to aid in the design of a survey and to verify the productivity-influencing factors identified in literature. Thus, in this procedure the interviews were used to assist the development of the survey, which would serve as the primary method for collecting data.

3.4.3 Survey questionnaire (Step B4)

The survey questionnaire was set up in such a way to enable a risk analysis to be performed of the various productivity-influencing factors identified through literature and through the interviews. The survey was developed in order to identify high priority risks which were labour related in both the in-situ construction and precast manufacturing environments. An investigation into research methods shows that surveys are a research methodology where the participants are sample subjects drawn from a particular population (Saunders, Saunders, Lewis & Thornhill, 2011). The population in this research was from the civil construction and precast manufacturing industries. The survey made use of matrix rating scales for the productivity-influencing factors, where multiple choice questions were used for the participants' personal information. Criteria were provided to stimulate the participants' perception of the severity of each risk and to ensure that all participants had a standardized reference point. The survey procedure was tailored according to the Forza's (2002) *survey research process*. The tailored process is shown in Figure 3.2.

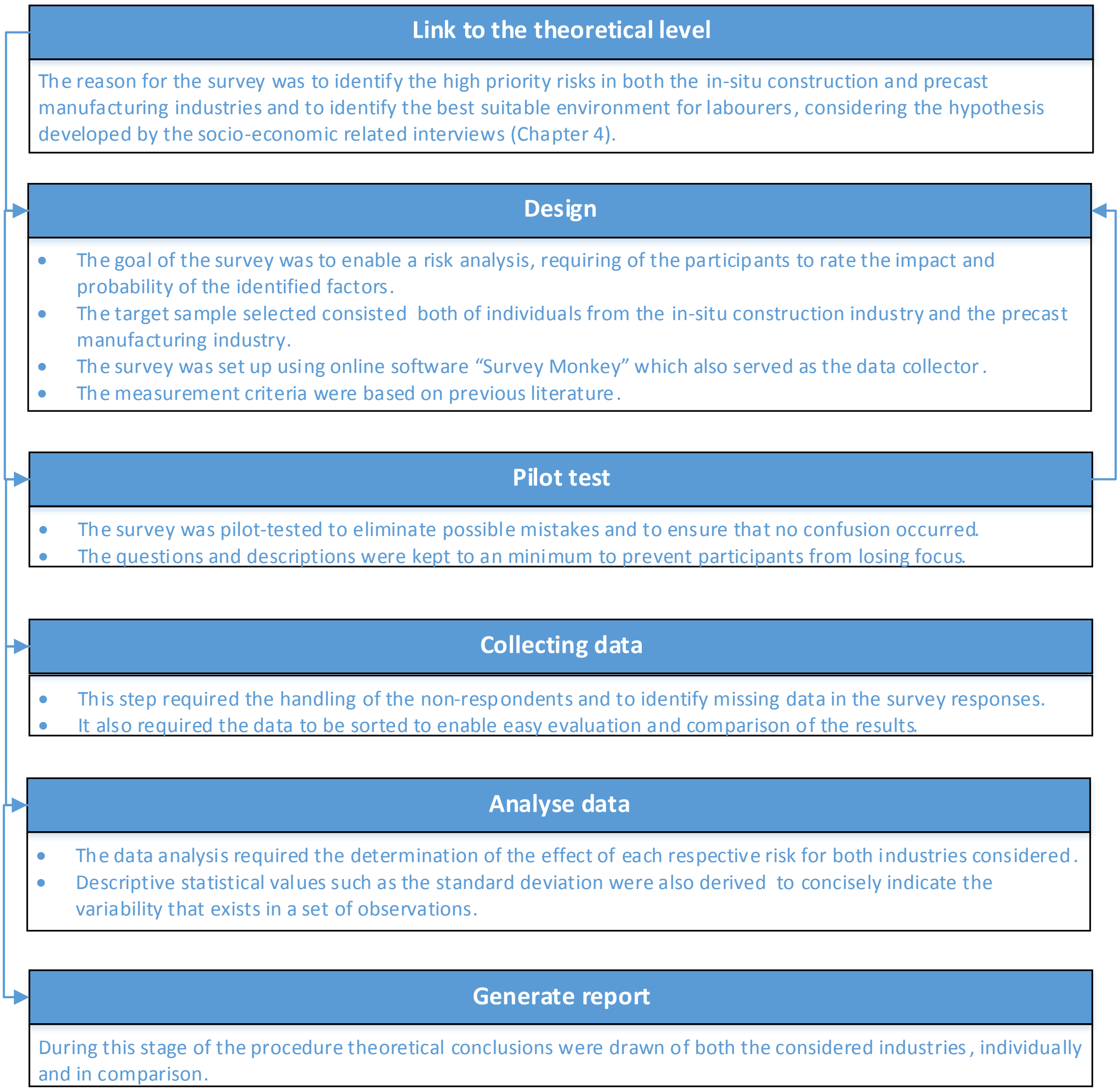


Figure 3.2: Survey research procedure as followed in this investigation

3.4.4 Case study (Step A3)

The case study was based on the study by Warszawski *et al.* (1984) as briefly discussed in Section 2.4.3. Due to the labour-related nature of this investigation, one additional factor from the case study by Warszawski *et al.* (1984) was considered in this case study. This was to include the labour hours spent during the manufacturing of the precast elements into that of the HCC process. Thus, the case study would compare the number of labour hours spent on an in-situ construction project to that of a similar HCC project while also considering the labour hours spent off-site at the manufacturing plant. This will provide quantitative information on the number of job opportunities and also on the type of job opportunities.

The factors considered when selecting the most appropriate case study were:

- The project should use sufficient precast concrete elements to enable a valid comparison.
- The type of precast elements used during the project should be widely and commonly used in the South African hybrid concrete construction industry.
- The researcher should have a trustworthy relationship with the respective companies who would share this information, as it is regarded as sensitive information, and also to ensure that trustworthy and accurate information will be provided.

3.4.5 Data Analysis

The data gathered through the interviews, survey and case study was used to relate back to the research question: Which construction technique of in-situ and hybrid concrete construction is the best for South Africa, considering the aspect of labour?

The semi-structured interviews regarding the labour related *socio-economic issues* were used to gather professional opinions on how the two construction techniques best promote job creation and skills development. The influence of the NDP and EPWP on the two methods was evaluated. The case study was done to supplement the interviewees' opinions regarding job creation in South Africa with quantitative information.

The survey was used to gather data on the effect of the various identified productivity-related risks on both the in-situ construction and precast manufacturing environments. The survey results provided quantitative information which did not only give perspective on the types of high priority risks of both industries, but it also provided relevant information regarding the best suitable environment for labourers. Thus, it contributed to the socio-economical aspect of the investigation. Effective data analyses were required to draw relevant and accurate conclusions regarding the research question.

3.5 Ethical considerations

It was required of the researcher to complete the Departmental Ethics Screening Committee Questionnaire (DESCQ). This was done to ensure that no personal boundaries were breached, since the investigation primarily relied on the personal opinion of members from the civil engineering industry. The interviewed individuals who are mentioned in Chapter 4 and in the interview transcripts (APPENDIX C) agreed to a request to use their names. The names were removed from the survey responses as it has no relevance to the study. Great care was taken not to lead the questions during the interviews or in the survey as it could possibly affect the results in favour of the expected outcomes.

3.6 Limitations to research

The research was limited by several factors which were challenging to mitigate due to the limited time available for each procedure. A considerable research limitation was that only 5 individuals participated in the survey regarding the precast manufacturing industry.

In addition, even though great care was given to the criteria supplied with the survey questionnaire, to provide an equal base for the feedback, individuals still to a certain extent responded disproportionally, as can be seen by the statistical values provided with the questionnaire survey results.

Furthermore, the conclusions drawn from the semi-structured interviews regarding the labour related *socio-economic issues* were based on only 10 participants, and thus must be seen in this light.

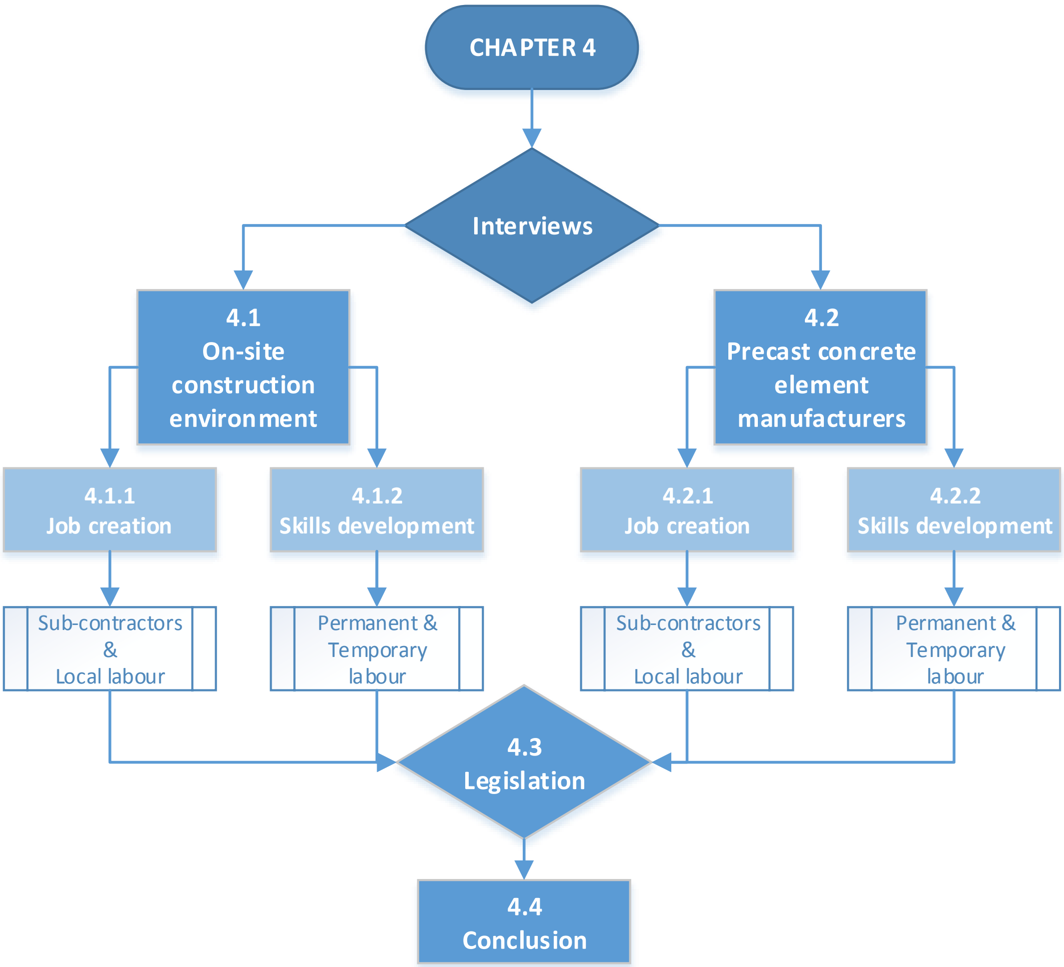
Lastly, the survey was sent to individuals from different language groups and cultures, thus terminological discrepancies may have resulted in some of the participants misinterpreting or misunderstanding certain questions.

CHAPTER 4

4 SOCIO-ECONOMIC ASPECTS OF LABOUR IN THE SOUTH AFRICAN CONSTRUCTION ENVIRONMENT

Chapter 2 provided awareness of South Africa's high poverty and unemployment rates and its influence on the construction environment. The primary objective of this chapter is to investigate the importance of these socio-economic factors in the South African construction environment and whether it has an influence on the choice between in-situ and hybrid concrete construction.

This chapter also serves as motivation for further quantitative research regarding the construction technique which best promotes job creation in a choice between in-situ and HCC. The quantitative comparison is done by means of a labour hour comparison (Chapter 5). This chapter followed the methodology explained in the flow diagram below.



The objectives of this chapter were investigated by conducting personal interviews with the following individuals:

Table 4.1: Interviewed individuals

CONTRACTORS			
Name	**Company**	**Profile**	**Experience (Years)**
Morkel Stofberg	Power Construction Group	Human Resource Manager	20-25
Craig Hoskins	NMC	Project Manager	30
Johan Bezuidenhout	NMC	Project Manager	10-15
Tony Byleveldt	ASLA Construction	Divisional Director	30+
Kylan Stone	Stefanutti Stocks Marine	Senior Quantity Surveyor	5-10
Grant Bergh	Group 5 Construction	Engineer	5-10
PRECAST MANUFACTURERS			
Nico Heyns	Portland Hollowcore	Director	15-20
Attilio Angelucci	Cobute	Director	30+
Anonymous	Anonymous	Manager	30+
PUBLIC CLIENT			
Jan Van Rensburg	Department of Public Works – Western Cape	Capital Works Program Manager	30+

The objectives of the interviews were to:

- Identify how the NDP and EPWP are understood by contractors and to what degree these programmes are implemented in South African construction projects.
- Investigate the influence of these programmes on the decision to use less labour-intensive construction techniques such as HCC.
- Examine the permanent and temporary workforce of both the on-site construction industry in general and the precast concrete manufacturing industry.
- Use knowledge gained to further investigate appropriate legislation.

The conclusions drawn from the interviews are summarised in this chapter. APPENDIX C provides the detailed report of the individuals' comments during the interviews.

4.1 Socio-economic factors in the South African on-site construction environment in general

All of the interviewed contractors were well aware of South Africa's high unemployment rate and understood that the construction industry has a partial responsibility towards job creation and skills development in South Africa. Both the NDP and EPWP strive to create temporary and permanent job opportunities to unemployed individuals and also attempt to provide these individuals with some level of training. Although these programmes are primarily enforced in governmental projects, it is considered to be an important factor for contractors to consider as the South African government is one of the biggest clients in the civil construction industry, as shown in Table 4.2 (Marx, 2014).

The results shown in Table 4.2 were obtained through a contractor survey conducted by the CIDB in 2014. A total number of 3475 projects were completed by contractors in 2013. A survey was emailed to each contractor involved and 1519 (44%) responded. Only the information regarding the civil construction industry is shown in Table 4.2 since only this is relevant to this investigation.

Table 4.2: Contractor survey response distribution per project type and employer category (Marx, 2014)

Project Type	Total No. of Projects	Number of projects							
Employer Category		Private Sector	Public Corporation e.g. ESKOM, ACSA	National Department	Provincial Department	Metropolitan Council	Regional / District Council	Public Private Partnership	Not Specified
Residential Buildings	120	59	9	7	33	8	1	3	-
Non-residential Buildings	347	132	68	25	91	17	8	6	-
Civil Works	405	132	34	20	83	86	46	3	1

4.1.1 Job creation in the South African on-site construction environment

An overview of the labour force used in projects by the various construction companies interviewed is given in Table 4.3. These values should not be considered as fixed but rather as a guideline since it is based on the interviewee's personal experience and opinions and can differ from project to project and also in different stages of the project.

Table 4.3: Labour force breakdown of interviewed construction companies

Company	Permanent Labour	Temporary Labour	
		Sub-contractor	Local labour
Power Construction	20%	40%	40%
ASLA	30%	25%	45%
NMC	30%	40%	30%
Stefanutti Stocks Marine	10%	75%	15%
Group 5	10%	70%	20%

As shown in Table 4.3, only a small percentage of the total labour force consists of permanent employees. These permanent employees are in most cases machine operators, skilled labourers and supervisory workers (Stofberg, 2015). The sub-contractors also employ a high percentage of their labour force from local communities, as most of the smaller sub-contractors used by the main contractor are locally based (Byleveldt, 2015; Hoskins, 2015; Stofberg, 2015). These observations are based on governmental projects. The labour force breakdown of Group 5 is based on a project done for a private client. For this project no legislative requirements were specified by the client regarding the use of local labour and job creation. Although they sub-contracted a large portion of their work, these sub-contractors were proposed by the client and were not from the local community.

Job creation in the South African construction environment is done by employing local labourers and low graded sub-contractors from the local communities. These two methods of job creation are subject to different procedures and regulations and are therefore discussed individually.

Local labour

Job creation in the South African construction environment is primarily achieved through the temporary employment of labourers from the surrounding area of a construction project. Initially this type of job creation was governed by legislation which forced contractors to allocate a certain percentage of the labour to local labourers. These local labourers are usually unskilled, therefore if not managed correctly they can become a major concern for the cost, quality and duration of a project.

In more recent contracts this legislation has been changed or rephrased to force contractors to employ local labour as far as possible rather than to provide them with a required number of local labourers for each project. The new legislation provides contractors with better control over their employed workforce, as they have the power to employ the required labourers rather than the prescribed labourers. The following example of how contractors are required to employ local labour was extracted from a construction tender document compiled by the Department of Public Works:

> '*It is the intension that this contract should make maximum use of the local labour that is presently unemployed.*
>
> *To this end the Contractor is expected to limit non-local employees to key personnel only and to employ and train local labour on this Contract.*
>
> *The Contractor shall fill in a form: Key personnel, and state how many non-local key personnel he intends to employ in the various categories.*
>
> *The numbers stated on the above-mentioned form will be strictly controlled during the Contract period and any increase in numbers is subject to the approval of the employer.*
>
> *The contract will also appoint a community liaison officer (CLO) who will be from the community. 3 names will be presented to the contractor to interview and appoint his preferred CLO.*'

The use of a CLO to employ local labour ensures that the correct number of labourers are employed from the various local communities and that the communities are aware that local labour is used. Although contractors are only required to employ local labour where possible i.e. activities with low skills requirements, they do prefer to use more local labour than permanent employees, since it can be more cost-effective if managed correctly (Byleveldt, 2015). Various reasons why local labour is preferred above permanent employees were identified in the interviews and are shown in Table 4.4.

Table 4.4: Benefits using temporary local labour

Benefit	Description
Cost	No extra expenses such as living allowances or transport costs.
Safety	Lower risk of site being sabotaged by local community.
Delays	Less stoppage time due to strikes by the local communities.
Client satisfaction	Higher client satisfaction regarding the NDP and EPWP.
Cost	Local labour is considered as low-cost labour compared to permanent labour.
Less responsibility	In between projects the contractor has no responsibility towards temporary labourers.

Although local labour appears to be advantageous in various aspects, it is still a threat to construction projects due to the local labourers' low skill levels. This risk is minimised by assigning simple site activities to these labourers. The specialised activities such as formwork erection, scaffolding, steel fixing, concrete placement, concrete element placement (HCC), machine operation etc. are carried out by skilled and semi-skilled labourers where in many cases local labourers are only used as support labourers. These skilled and semi-skilled labourers are usually permanent labourers or from sub-contractors hired by the main contractor (Bergh, 2015; Bezuidenhout, 2015). A thorough labour breakdown structure for each respective site activity for a specific project is shown and discussed in Chapter 5.

All of the interviewed contractors stated that temporary local labourers do have the opportunity to become permanent employees if they prove to have adequate skills and motivation to become part of the company. However, in most cases local labourers fail to meet the required expectations and are only used for the duration of the project. Another reason is that construction companies can only accommodate a certain number of permanent employees, as they are dependent on new projects to create more job opportunities. Therefore, the majority of temporary local labourers are in effect employed only for the duration of the project. The contractor does provide the temporary labourers with some skills but due to the low skills activities they conduct, they are not recognised as semi-skilled or skilled labourers after a project. Thus, concluding from the interviews, local employees have a very low level of job security.

According to Bezuidenhout (2015), in-situ construction methods accommodate more unskilled labour on-site than HCC. Therefore, when using in-situ construction, contractors are expected to employ higher numbers of local labour than when implementing HCC. This is enforced by legislation and if not implemented, local communities can become a risk to the project through riots and site sabotaging. Bezuidenhout (2015) mentioned that although HCC makes use of less local labour the community understands that the work is specialised and that their skills are inadequate to perform the tasks at hand. The use of less on-site labour may seem to reduce job creation in South Africa but to justify this impression the off-site labour that goes with HCC needs to be considered to make accurate statements.

Implementing HCC requires up to 50-80% less on-site labour than the conventional method, depending on the extent of precast usage (Bergh, 2015; Irish Concrete Federation, 2014). This is due to a large portion of the work being done off-site at the precast plant. A labour-hour comparison is done in Chapter 5, considering both in-situ and hybrid concrete construction techniques for the same project type. The HCC technique’s labour hours will include the amount of labour hours spent at the precast manufacturing plant. This ensures that all labour is considered when comparing the two techniques. The results obtained from this comparison will provide a better understanding of the amount of job creation provided by the two construction techniques. This comparison will also consider the type of labourers used in both techniques and the extent of job security experienced by these labourers.

Sub-contractors

Sub-contracting is another form of job creation implemented by the government. In some public tenders, contractors are required to sub-contract a certain percentage of their work to low grade CIDB sub-contractors from the local area (Byleveldt, 2015; Hoskins, 2015; Van Rensburg, 2015). These sub-contractors also provide permanent and temporary job opportunities to individuals from the local communities. However, local labourers experience better job security if employed by a sub-contractor rather than the main contractor (Stofberg, 2015).

In public projects where sub-contracting is used, the government client provides the employed contractor with a list of proposed sub-contractors established in the surrounding area of the construction project. This is done to ensure that sub-contractors have sustainable job opportunities. The government also prefer that these sub-contractors should be employed by larger contractors, as it serves as a form of training for both the managers and labourers of the sub-contractor.

According to research done by the CIDB, 70% of building and 30% of civil construction projects are sub-contracted. The most prevalent types of sub-contracting are labour-only, trade-contracting in the building sector and specialist sub-contracting in the building and civil sectors. The typical work duration for sub-contractors in the building industry is between 3 and 6 months, while in the civil industry it extends to an average of 12 months. Two of the key factors influencing the main contractor’s choice of sub-contractor are the sub-contractor’s compliance with legislative requirements and its BEE status. These factors are key in public projects as they are imposed to promote job creation in previously disadvantaged communities. (Construction Industry Development Board, 2013)

The programme manager of the capital works programme at the Western Cape Department of Public Works mentioned that the employed contractors are keen to employ sub-contractors from the list of local sub-contractors provided with the tender (Van Rensburg, 2015). The interviewed contractors also mentioned that they have previously employed sub-contractors proposed by tenders to great effect. The advantage of employing sub-contractors is that they provide the contractor with labourers possessing the required skills to perform assigned activities. In the case where they lack skills, the sub-contractor is required to substitute these labourers with suitable labourers (Byleveldt, 2015; Stofberg, 2015).

The contractors created a general impression that they prefer to employ local labour through sub-contractors or community liaison officers, rather than to directly employ them. This is beneficial for the contractor as he is not required to deal directly with temporary labourers’ issues, since it is the responsibility of the sub-contractor. In previous projects contractors have experienced that the risk of an unhappy labour force is reduced when they are employed by a local sub-contractor rather than the main contractor (Byleveldt, 2015). This is primarily due to labourers having higher wage expectations when employed by a large recognized company rather than by a small local sub-contractor.

4.1.2 Labour skills development in the on-site construction environment

Both the NDP and EPWP strive to promote the level of education amongst poor communities as discussed in Section 2.3.2. In the on-site construction environment labourers receive training as a form of education. This training is done on and off-site, depending on the construction company and the required skills level. On and off-site training were discussed in Section 2.4.4.1 and will thus not be covered in this section.

The interviewed construction companies provide their permanent labourers with high skill-level training by sending them on occasional short courses. Some construction companies offer these short courses in-house, while others make use of courses provided by private entities. According to the interviewees, temporary labourers rarely receive this type of high-skill training and in most cases only receive on-site training by supervisory labourers. Therefore, even though the temporary labourers receive some form of training, they are rarely recognised as skilled labourers after a project (Byleveldt, 2015; Hoskins, 2015; Stofberg, 2015). They do however have some construction experience after a project and if they promote themselves in the construction industry they are likely to be employed by local sub-contractors (Stofberg, 2015).

Certain public construction projects are part of the EPWP's *National Youth Service* (NYS) which aims to train young people and provide them with practical work experience. This is similar to the in-house training of local labour, except that when a contractor is subjected to the NYS the contractor is obliged to train these labourers according to NYS legislation provided in the tender documents. The contractor is obliged to train the youth labourers to be able to execute quality work. This ensures that these labourers have adequate skills to be recognized in a certain trade.

Labourers employed by sub-contractors usually have adequate skills to perform tasks in the required trades. These labourers acquire their skills through repetitive construction work on different projects and also receive in-house training from supervisory labourers from the main contractors (Bergh, 2015; Byleveldt, 2015). The reason why their skills not do deteriorate like those of temporary local labour is due to the higher level of job security experienced by these labourers.

According to the programme manager of the capital-works programme at the Western Cape Department of Public Works, contractors with a CIDB level of 3-5 receive free managerial skills development as submitted by the EPWP (Section 2.3.2.2). Names of these contractors are also proposed to large contractors appointed by the Department of Public Works.

Adequate Documentation

The *National Youth Service Brochure* is a programme implemented by the Department of Public Works which forms part of the EPWP. The objectives of this service are to: (Department of Public Works, 2013d)

- Create work and training opportunities for the unemployed youth and at the same time address the shortage of artisan skills in the building industry.

- Ensure participation of the youth in community service delivery and thereby instilling the spirit of patriotism in young South Africans.
- Ensure that youth develop skills, understanding and aspirations for working within the building industry.

The training is divided into two components, which consist of 6 months theoretical training and 6 months on-site training where beneficiaries are placed with the contractor for gaining practical training experience in their respective trades. The technical-training is funded by the Department of Higher Education & Training. The technical training trades selected must meet the needs of the project within the building industry and construction. (Department of Public Works, 2013d)

After the beneficiaries had undergone this year-programme they can follow either of the following pathways: (Department of Public Works, 2013d)

- Further learning and training through institutions of higher learning
- Employment by the Department, contractor or private company
- Small micro medium enterprise development

All exited learners are kept on the Departmental database for future opportunities and are proposed to contractors conducting projects in the surrounding areas of the exited learners.

4.2 Socio-economic factors related to precast concrete element manufacturers

Section 2.3 discussed the *socio-economic factors* influencing the South African construction industry. This section focus on the *socio-economic aspects* of the precast concrete element manufacturing plants of the South African industry.

To enable the *socio-economic factors* related to the precast manufacturing industry to be comparable to that of the in-situ construction industry, the interviews focussed on job creation and skills development of labourers in this industry.

4.2.1 Job creation in the precast manufacturing environment

A labour force breakdown for the interviewed companies was done to allow a comparison between the interviewed construction companies. Table 4.5 shows the labour force breakdowns of the three interviewed precast concrete element manufacturers. When reviewing these values it should be considered that these figures are directly related to the respective companies' labour force at the time of the interviews and can differ, depending on the type of projects conducted.

Table 4.5: Labour force breakdown of interviewed concrete precast manufacturers

Company	Permanent Labour	Temporary Labour	
		Sub-contractor	Local labour
Anonymous Company	40%	30%	30%
Cobute	100%	0%	0%
Portland Hollowcore	100%	0%	0%

According to the labour force breakdown given in Table 4.5 it is evident that the anonymous precast element manufacturer does not solely make use of permanent labourers as the other two interviewed manufacturers. The reason for this is that at the time of the interview the anonymous company was busy with a big contract where they manufactured large specialised, project-specific elements. Due to the nature and size of the project, the anonymous precast manufacturer was required to employ extra temporary labourers. These labourers were required to be from the surrounding area of the construction site according to requirements from the client. Thus, depending on the client and project size, precast concrete element manufacturers may also be subject to the employment of local labour where required. However, this is also subject to the type of manufacturing technique used by the precast manufacturer, i.e. some precast manufacturers produce their precast concrete elements with the use of equipment. Therefore, the use of extra labour will not be able to enhance the production rate, since it is subject to the production speed of the equipment (Heyns, 2015). In a case where the manufacturing is done in a labour-intensive manner, the production speed can be enhanced through the employment of temporary labour.

In the case where this anonymous manufacturer operates normally, its workforce will also consist of 100% permanent labourers, like the other interviewed manufacturers. Precast concrete element manufacturers operate as a factory. They have certain products which they manufacture and with a permanent workforce the manufacturing process becomes routine. This enables labourers and the process as a whole to manufacture elements more time-efficient and cost-efficient than when done on site in unpredictable and less controllable circumstances (Heyns, 2015).

Job creation in this industry, considering employment of local labour, is rarely implemented because the manufacturing plants are considered similar to a supplier of material in the in-situ construction environment. Where the precast manufacturers are employed as the main contractor as in the instance of the anonymous manufacturer in Table 4.5, the manufacturer is obliged to comply with the requirements provided by the client, regarding job creation. This will occur when a precast concrete element manufacturer is employed as a sub-contractor, rather than as the precast concrete element supplier. Therefore, there are some cases where job creation amongst the local communities is promoted in the precast manufacturing industry. However, it should be taken into account that even if the precast manufacturer does not employ local labour when providing a contractor with precast concrete elements, the contractor will still be obliged to promote job creation if it is required in the tender. Thus, implementing HCC does not necessarily mean that the project will not contribute to job creation in South Africa, but the use of local labour will probably be less than when implementing in-situ concrete construction (Bezuidenhout, 2015).

Precast plants do however hold other advantages regarding labour and reducing poverty in South Africa. According to the interviewed precast concrete element manufacturers, labourers in the precast industry experience high job security which ultimately contributes to a better life expectancy. The director of Cobute stated that when they experience economical tough times, they try to maintain all their employees. If, in extreme cases, the company needs to let some of the employees go, Cobute strives to re-employ the released labourers when possible. The anonymous manufacturer mentioned that the temporary labourers who performed well during the project will be contacted if new employment opportunities arose at the company and some of the temporary labourers will be permanently employed after the project has been completed. This shows that there is opportunity for job creation in the precast manufacturing environment although it is less than in the on-site construction environment.

These opinions did not provide real comparable values when considering job creation in both in-situ and hybrid concrete construction. Therefore, it served as motivation to conduct the labour-hour comparison.

4.2.2 Labour skills development in the precast manufacturing environment

The type of skills required for manufacturing precast concrete elements depends on the manufacturing technique of the respective manufacturers. All the interviewed precast concrete element manufacturers trained their labourers in-house. At Cobute labourers are taught all the different trades which they conduct in their company. This is to ensure that all the labourers are able to perform any activity without delaying the process, if it is required of them. Portland Hollowcore use machinery to manufacture their precast concrete elements, therefore except for the machine operators, fewer skilled labourers are required in the process. At the anonymous precast manufacturing firm the labourers are more specialised in their respective trades. According to the project manager, this ensures more efficient manufacturing due to labourers being specialists in their respective trades.

Thus, concluding from the interviews with the precast manufacturers, the skills of the labourers are dependent on the type of manufacturing process used. In the case where manual labour is used labourers do acquire various skills which can be helpful if they are in positions where they need to apply for other jobs. Labourers working at precast plants which make use of machinery to conduct the skilled activities acquire lower skills, since they are mostly performing basic activities. These labourers are considered as performing the same type of activities as general labourers in the in-situ construction environment. However, in the precast manufacturing environment these labourers still experience better job security than in the in-situ construction environment.

4.3 Influence of the NDP and EPWP on the decision to implement HCC

The primary goal of the NDP and EPWP is to reduce poverty in South Africa. The *Grant Manual* of the EPWP mentions that one of the key characteristics of the EPWP is to employ large numbers of local, low-skilled, unemployed individuals who are willing to work (Department of Public Works, 2013b).

Government entities implement job creation schemes in the projects' tender documentation. The extent of job creation in these contracts is dependent on the type of project and activities conducted (Stofberg, 2015; Van Rensburg, 2015). Projects subjected to the EPWP legislation are penalised if the number of projected labour hours is not reached or, in the case of the NYS, if the required number of labourers are not employed (Hoskins, 2015; Stofberg, 2015). However, the influence of the EPWP with regards to the choice between the construction methods considered in this investigation is limited, since only certain construction activities are subjected to the EPWP (Department of Public Works, 2013a).

According to the product ranges of many of the South African structural precast concrete suppliers, elements such as slabs, beams, columns and stairs are used in South Africa. Specialized elements can also be manufactured at a number of these organizations but are not common and therefore not considered in this comparison. Some of these South African pre-fabricated concrete manufacturers are listed in APPENDIX A

The activities required to manufacture precast concrete elements are not considered to be subjective to the EPWP's proposed labour intensive activities. According to the document *EPWP Large Projects Guidelines* (Section 2.3.2.2) only the following activities are relevant when considering the use of HCC in structural building type of projects: (Department of Public Works, 2012)

- Excavation of trenches by hand
- Excavation of sewer manholes
- Manufacture of masonry elements on site
- Site clearance

Both considered construction techniques require the above mentioned activities to be conducted on-site. Therefore, the type of construction technique is irrelevant considering the EPWP. Although HCC makes use of less on-site labour due to the transference of some activities to a manufacturing plant, the project can still be done under the EPWP.

Most of the on-site activities replaced by the use of precast concrete elements are skilled activities such as formwork erection, fixing of reinforcement steel, placing of concrete, finishing of concrete and the removal of shuttering. None of these activities are described by the EPWP legislation as activities where labour-intensive methods are required on site. Therefore, transferring these activities to a manufacturing plant off-site does not interfere with the EPWP legislation.

Contributing to the conclusion that the EPWP does not limit the use of HCC in Public projects is the fact that the EPWP also strives to promote the construction of cost-effective and quality assets as mentioned in Section 2.3.2.2. The programme manager of the capital works programme at the Western Cape Department of Public Works mentioned that despite the fact that the government strives to create as many job opportunities as possible, they have a responsibility towards the country to execute projects in the most cost-effective manner (Van Rensburg, 2015).

4.4 Conclusions

Job creation as described by the EPWP is executed through implementing labour-intensive construction techniques in certain activities of a project. It was found that these activities are rarely related to projects where HCC is implemented. Van Rensburg (2015) justifies this finding by mentioning that specialised work such as formwork erection, steel fixing, placement of concrete etc. cannot be governed by job creation programmes. These are the on-site activities which are considered to be replaced when using HCC, therefore programmes such as the EPWP has no legal authority to prevent the use of HCC in the structural building environment. This is due to the specialised nature of precast element manufacturing. Thus, no low-skilled activities are replaced when using precast elements.

However, job creation through the employment of local labour and low-graded local sub-contractors is implemented in most public projects regardless of the construction technique. Therefore, the EPWP legislation has little influence on the type of construction technique used when considering in-situ and HCC.

It is expected that HCC will create less job opportunities. However, according to three interviewed individuals from the South African civil engineering environment labour skills are deteriorating, especially amongst temporary labour (Jurgens, 2008). The use of precast in this situation offers the ideal solution, as skilled work is done off-site by an experienced manufacturing team and assembled on site by the same manufacturing company. The off-site concrete element manufacturing mostly substitutes the skilled activities and unskilled labour can still be used on-site. This allows more efficient use of skilled labour and reduces quality-related and performance-related risks due to less unskilled labour assisting with technical activities on-site.

Both construction techniques have their respective advantages and disadvantages, as discussed in Section 2.1. From the interviews it seems that in-situ concrete construction does create more job opportunities than HCC. The validity of this will be established through the labour-hour comparison done in Chapter 5.

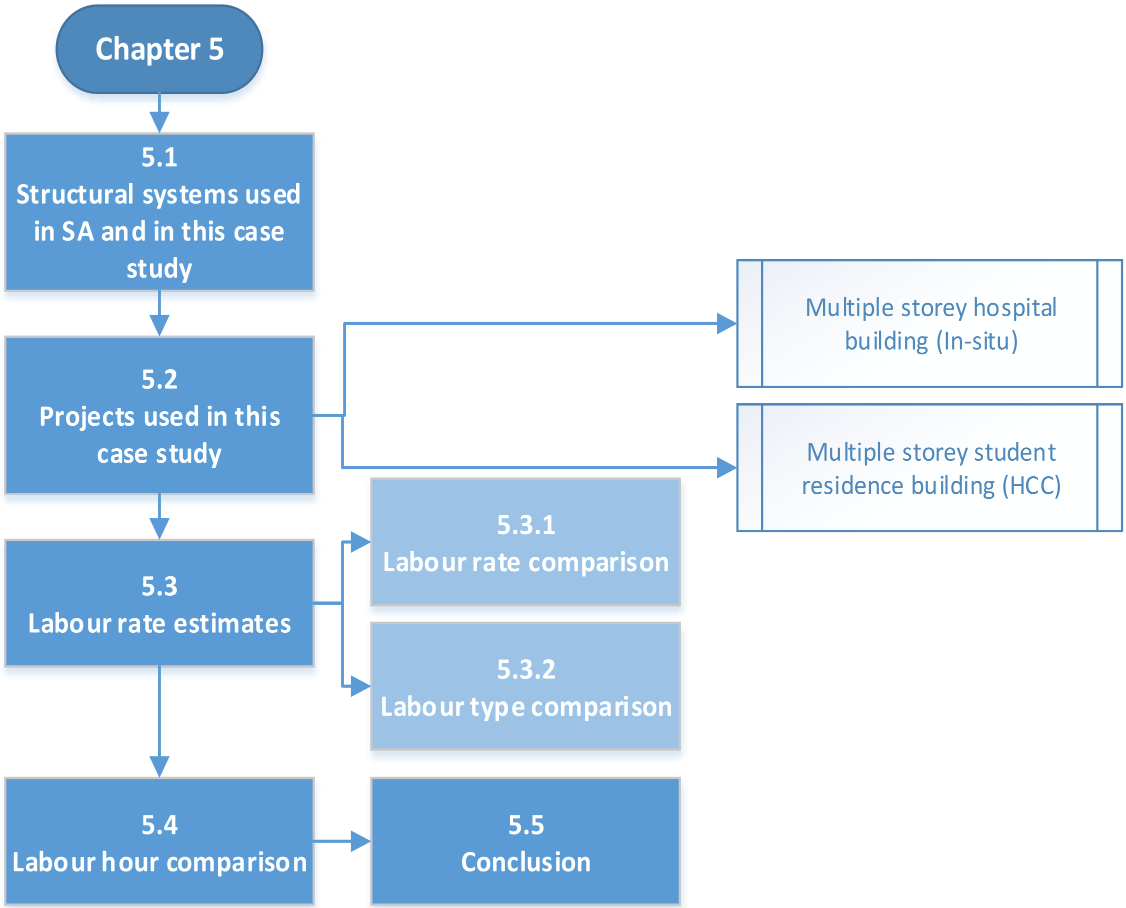
Another aspect that needs to be considered is that labourers working at a precast manufacturing plant experience high levels of job security. According to some of the interviewees, better job security promote better living circumstances, since many temporary labourers live well for the duration of a project but after the project they are likely to be unemployed and fall back below the poverty level, as explained in Section 2.3.1.1. This is therefore only a temporary solution to the problem. However, if these labourers are able to gain adequate experience in a specific trade they are likely to be employed by local sub-contractors who specialise in that trade.

Permanent labourers are likely to experience little adversity when reapplying for new job opportunities, since they have adequate skill in a certain trade. It is therefore important to focus on skills development when employing temporary labourers. This is one of the EPWP's goals and is implemented through the NYC (Section 4.1.2). However, most of the interviewees only made use of informal in-house training. This can be sufficient if labourers are subjected to adequate supervisory personnel. The NYC can be used to great effect and are compatible with both in-situ and HCC.

CHAPTER 5

5 LABOUR HOUR COMPARISON – A CASE STUDY BETWEEN IN-SITU AND HYBRID CONCRETE CONSTRUCTION

Chapter 4 provided qualitative information on *socio-economic issues* such as job creation, job security and skills development. The next step was to compare those observations with a quantitative labour hour comparison between an in-situ project and a hybrid concrete construction project. The hours of the HCC project would include labour hours spent at the precast manufacturing plant. The relevance of this case study is supported by the investigation of Lombard (2011), where a labour hour comparison was identified as an adequate technique to quantitatively compare job creation between in-situ and hybrid concrete construction.



5.1 Structural systems used in South Africa and in this case study

The South African construction industry makes use of a number of structural systems in the structural building industry. Figure 5.1 and Figure 5.2 show the in-situ and HCC structural systems most often used in the structural building industry.

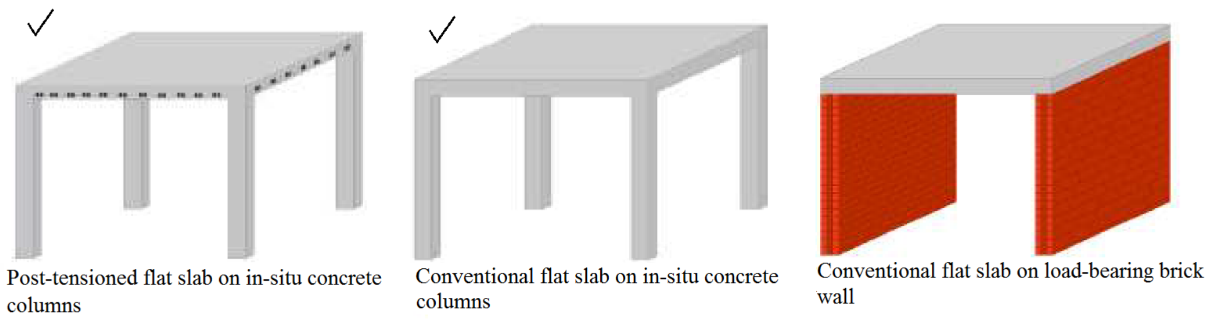


Figure 5.1: In-situ structural systems used in South Africa (Lombard, 2011)

Figure 5.2: HCC structural systems used in South Africa (Lombard, 2011)

Project-specific labour hours of activities for post-tensioned flat slabs and conventional flat slabs on in-situ concrete columns as shown in Figure 5.1 were obtained through site visits and through meetings with the project manager and quantity surveyor of an example project.

Information regarding the labour hours of a hybrid concrete construction project was also gathered through meetings with the on-site project manager and quantity surveyor and through a meeting with the director of an anonymous precast manufacturer in South Africa. The HCC structural system used at the project considered for this case study was a hollowcore floor system on loadbearing brick walls as identified by the check mark in Figure 5.2.

The structural systems used in the case study were a function of the availability of data from the individuals interviewed for this case study. The construction company which provided the researcher with the labour hour rates of execution predominantly used hollowcore floor slabs on loadbearing brick walls in their HCC projects. In their in-situ projects they used all three techniques shown in Figure 5.1. However, data was only available for the first two in-situ structural techniques shown in Figure 5.1 for the project considered as the in-situ example project.

Lombard (2011) conducted a survey on the use of different structural systems in the South African construction industry. The survey obtained the opinion of nine contractors and consultants who rated the use of the different structural systems in South Africa. The results of the survey suggested that all three systems shown in Figure 5.1 are often used in the South African construction industry. When using hollowcore precast floor elements, loadbearing masonry walls were considered to be the most commonly used structural support system. Thus, the structural systems considered in this case study (check-marked systems in Figure 5.1 and Figure 5.2) are not only most often used by the construction company providing the rates, but also in general in the construction industry in South Africa.

5.2 Projects used in this case study

In order to enable a labour hour comparison between the two construction methods, similar in-situ and HCC projects had to be compared. Information for a HCC project was available, but an in-situ replica of the HCC project was not. Therefore improvisation was required. This was done using the available in-situ construction rates from the construction of a multi-storey hospital building. The project manager of the in-situ project was able to provide the construction rates of execution for the two structural systems identified by the check marks in Figure 5.1. A part of the hospital floor plan is shown in Figure 5.3. It was decided to use these rates as basis for the in-situ project and to apply them to an in-situ concept of the HCC example project.

The same construction company who provided the rates of the in-situ hospital building was able to provide the rates of an HCC four storey student residence building. The building was constructed using loadbearing masonry walls with hollowcore floor slabs, as shown by the check-marked concept in Figure 5.2. The floor plan of the student residence building is shown in Figure 5.4. By conceptually placing columns in the residence building as shown in Figure 5.5, a floor span configuration reasonably similar to that of the hospital building could be obtained. Also, the floor loadings of imposed load and masonry walls would be reasonably similar. By applying the in-situ execution rates (from the hospital building) to the configured residence building (Figure 5.5) provided an in-situ alternative for comparison with the HCC example building.

Due to the symmetrical design of the residence building, Figure 5.5 only shows one half of the in-situ structural concept of the residence building. It is important to note that the masonry walls for the in-situ design of the residence building is non-loadbearing and all the inner walls are single-layered, which is similar to the hospital concept from where the in-situ execution rates were obtained. On the other hand, the outer brick walls of the HCC design are loadbearing together with the thicker inner walls which are also double-layered loadbearing walls.

Both projects were constructed by the same construction company in the same year. This ensured minimal labour execution rate fluctuations between the two considered projects. The precast floor slabs used in the HCC project were manufactured using the extrusion process which is a highly mechanized manufacturing process. The precast manufacturer who provided the precast element manufacturing rates is a well-recognised hollowcore floor slab manufacturer in South Africa, which contributes to the reliability of the rates.

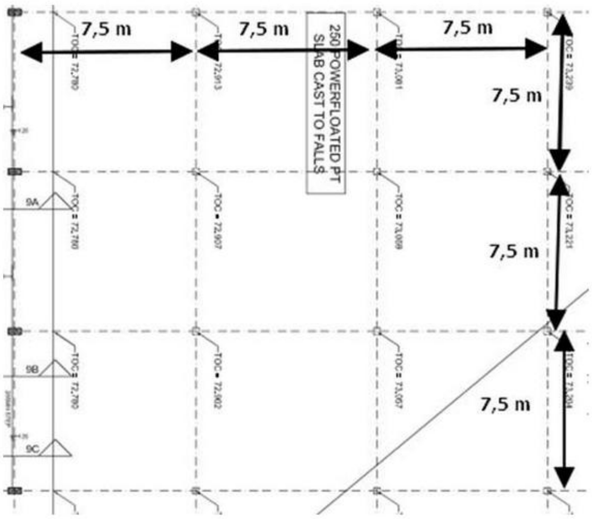


Figure 5.3: Part of the floor plan of the hospital building

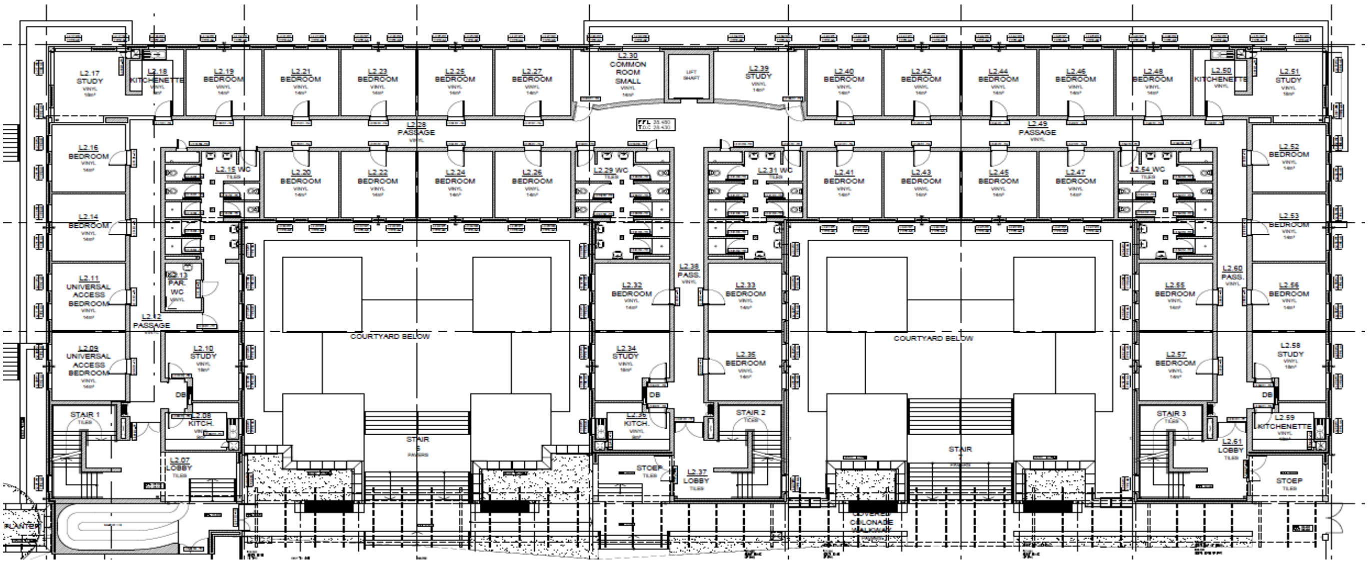


Figure 5.4: Original floor plan of the student residence building

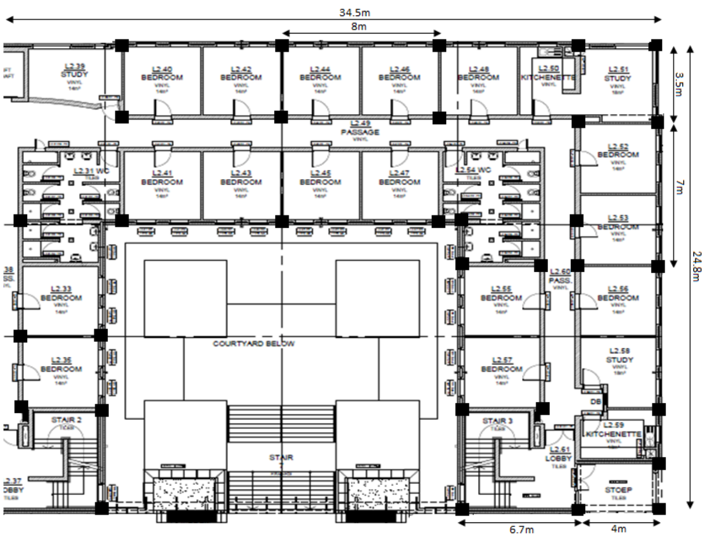


Figure 5.5: In-situ structural concept of student residence building

5.3 Labour rate estimates

The labour rates of execution as received from the project managers of both projects were a function of the labour teams used. These execution rates were simplified to units per hour for a corresponding labour team, where the unit is a function of the type of activity. The in-situ construction unit rates from the hospital project, with the corresponding labour teams as obtained from the project managers, are shown in Table 5.1.

Table 5.1: In-situ construction labour rates with corresponding labour teams (Hospital building project)

Unit rates for each activity				Related labour teams				
	Activity	**Rate of execution**	**Production Unit**	**Supervisor**	**Operator**	**Skilled**	**Semi-skilled**	**General labour**
Columns	Erect formwork	24.19	m^2/h	1	-	-	2	4
	Re-bar	1.57	m^3/h**	1	-	-	3	-
	Cast concrete	4.18	m^3/h	1	-	-	1	2
	Dismantle formwork	30.24	m^2/h	1	-	-	-	4
Deck (Flat slab-250mm)	Erect formwork	15.63	m^2/h	1	-	-	5	8
	Stop-ends	50.00	m^2/h	-	-	-	2	-
	Re-bar	20.83	m^2/h	1	-	-	10	-
	*Install post-tensioned cables	2.63	cables/h	1	-	-	6	-
	Concrete placement	25.00	m^3/h	1	-	-	2	6
	Powerfloating (concrete)	83.33	m^2/h	-	-	3	-	-
	Curing compound (concrete)	166.67	m^2/h	-	-	-	-	2
	Remove stop-ends	62.50	m^2/h	-	-	-	-	4
	*Stressing of post-tensioned cables	4.20	cables/h	1	-	-	3	-
	Strip formwork	20.83	m^2/h	1	-	-	-	6
Masonry Walls	Single layer	14.42	m^2/h	1	-	-	10	6
	Double layer	7.21	m^2/h	1	-	-	10	6

Note: For the deck, the rates for the stop-ends and the re-bar are given as per the area of the floor
* Activities only related to the post-tensioned (PT) flat slab alternative
** The rebar for the column is given as the volume of concrete reinforced per hour

The execution rates provided in Table 5.1 are project-specific to the hospital building. The project manager mentioned that the rates used for the in-situ hospital building project are relatively the same for other similar projects constructed by their company.

Table 5.2 shows the HCC rates of the student residence building with the corresponding labour teams. The rates from this project are also expected to be relatively constant for the construction of other similar buildings using HCC.

Table 5.2: HCC on-site labour rates with corresponding labour teams (Student residence project)

Unit rates for each activity				Related labour teams				
	Activity	**Rate of execution**	**Production Unit**	**Supervisor**	**Operator**	**Skilled**	**Semi-skilled**	**General labour**
Deck (Structural topping -60mm)	Precast element placement	31.25	m^2/h	1	1	-	-	4
	Formwork to edges	50.00	m^2/h	1	-	-	2	4
	Props	62.50	m^2/h	-	-	-	2	2
	Mesh installment	20.58	m^2/h	-	-	-	-	4
	Concrete placement	12.43	m^3/h	1	-	-	2	6
	Powerfloating (concrete)	83.33	m^2/h	-	-	3	-	-
	Curing compound (concrete)	166.67	m^2/h	-	-	-	-	2
	Strip formwork	2.25	m^2/h	1	-	-	-	4
	Strip props	62.50	m^2/h	-	-	-	-	4
Masonry Walls	Single layer	14.42	m^2/h	1	-	-	10	6
	Double layer	7.21	m^2/h	1	-	-	10	6

Note: The rates for the formwork to the edges and for the props are given as per the area of the floor

The execution rates of the precast manufacturing plant and related labour teams are shown in Table 5.3. This information was obtained from an interview with the director of a precast manufacturing plant. The precast plant has the capacity to manufacture 650m^2 concrete floor slabs per day, but the director mentioned that an average of 500m^2 is manufactured. The average production rate was used in the calculations shown in Table 5.3. The hollowcore elements manufactured at the precast plant have a width of 1200mm, thickness of 160mm, with a maximum span of 6.5m. The cross-section of the elements is shown in Figure 5.6.

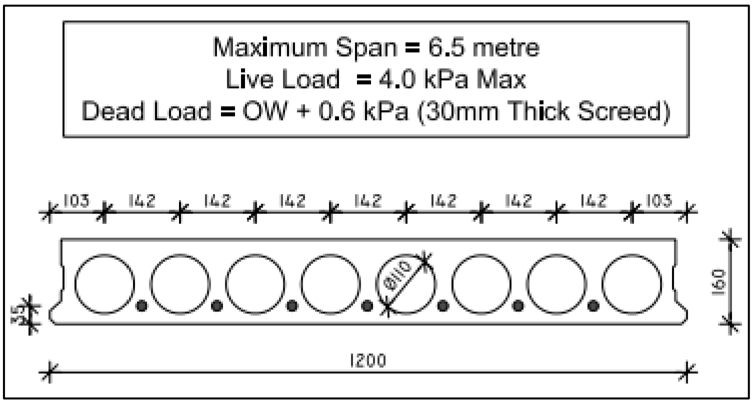


Figure 5.6: Cross-section of hollowcore precast slab

Table 5.3: Labour manufacturing rates at precast plant

Unit rates for each activity				Labour teams			
	Activity	**Rate of execution**	**Production Unit**	**Supervisor**	**Operator**	**Semi-skilled**	**General labour**
Production	Cable placement & stressing	86.67	m^2/h	-	1	2	-
	Casting	130.00	m^2/h	1	4	-	4
Stripping	Measure & cutting	130.00	m^2/h	1	2	4	-
	Removal from cast bed	65.00	m^2/h	-	1	-	4
	Move from stockyard onto truck	65.00	m^2/h	-	1	-	4
Note: All the rates in this table are given as the per area of the floor							

The preceding tables provide information on the execution rates for construction activities with their corresponding labour teams. The comparison of the labour execution rates, amounts of labour, and the types of labour used in the in-situ and HCC environments would provide a better understanding of the effectiveness of labour application, and the type of labour in both environments. These comparisons will be done in sections 5.3.1 and 5.3.2.

5.3.1 Labour rate comparison

The rate at which concrete is placed in the in-situ method is given as $25m^3/h$ (Table 5.1) for a flat deck with a thickness of 250mm and average spans of 7.5m. The labour team used to obtain this execution rate consisted of nine members. This rate is equivalent to $100m^2/h$ ($11.11\ m^2/h$/labourer), while in the precast manufacturing industry concrete casting is done at a rate of $130m^2/h$ with a labour team of 9 individuals ($14.44\ m^2/h$/labourer). However, it should be considered that the hollowcore elements have a cross-sectional area of $1160\ cm^2$ (per 1.2m width) due to the hollow cores as shown in Figure 5.6.

Considering these rates, Table 5.4 provides the reader with a comparison of the execution rate per labourer. Table 5.4 shows that the execution rate per labourer for concrete casting in the precast manufacturing plant is higher than in the in-situ method, but only by a small margin. However, the considerable difference between the two methods occurs for formwork erection and for the fixing of steel reinforcement of the floor slabs.

The conventional flat slab considered in this comparison used reinforcing steel while the precast hollowcore slabs used pre-tensioned cables as reinforcement. A steel fixing team of 11 individuals is able to produce an execution rate of $8.93m^2/h$ ($0.81m^2/h$/labourer), while three individuals are able to reinforce $86.67m^2/h$ ($28.89m^2/h$/labourer) in the precast manufacturing industry. The equivalent execution rates per labourer are shown in Table 5.4. The execution rate per labourer is considerably lower in the in-situ environment than in the precast manufacturing environment. This considerable difference is due to the design of the precast hollowcore slab and the mechanized advantage it has over the labour-intensive reinforcement process of the in-situ environment. Nevertheless, these activities are not really comparable, but it provides relevant information regarding the productiveness of the considered construction methods. This is done further on for various activities (Tables 5.4 and 5.5).

As mentioned, formwork erection also plays a considerable role in the execution rate comparison between the two construction techniques. Formwork erection for an in-situ conventional flat slab is done at a rate of 15.63m^2/h with a labour team of 14 individuals (1.12 m^2/h/labourer). Thus, formwork erection is considered as a time-consuming and labour-intensive activity in the in-situ environment. However, in the precast industry, formwork erection barely consumes any time, as permanent formwork is used repetitively and only requires cleaning after the concrete elements have been removed. Another contributing factor is that all the precast elements are manufactured at ground level, reducing the use of temporary formwork and scaffolding, which also contributes to the quality and safety of the process as previously discussed in Section 2.1.2.1.

Table 5.4: Labour execution rates comparison of deck construction (In-situ vs. precast plant)

Activity	**Execution rate (m^2/h/labourer)**	
	In-situ (conventional flat slab)	Precast plant (hollowcore pre-stressed slabs)
Concrete placement	11.11	14.44
Steel fixing (in-situ) / Cable stressing (precast)	0.81	28.89
Formwork erection (in-situ)	1.12	-

From the comparisons shown in Table 5.4, the manufacturing process of the floor slabs in the precast environment seems to be much more effective with regards to the manufacturing execution rates shown in Table 5.4. However, it should be considered that in some cases precast floors require an in-situ structural topping, as in the case of the student residence building considered in this comparison. Thus, the steel reinforcement and formwork for the structural topping should be included in a comparison. The surfaces of the structural in-situ topping of both the HCC project and the in-situ conventional slab were finished using power floaters.

The structural topping only requires formwork to the sides of the floor, since the precast slabs serve as permanent formwork, thus a smaller amount of formwork is required than the equivalent in-situ flat slab. The steel mesh reinforcement is pre-manufactured which is placed on top of the precast floor elements, thus the reinforcement process is less labour-intensive than the conventional in-situ process. The execution rates of these two activities are 50m^2/h (formwork) and 20.58m^2/h (steel reinforcement) with their corresponding labour teams which consist of seven and five labourers respectively. The rate at which concrete is placed for the 60mm in-situ structural topping of the student residence HCC project is given as 12.23m^3/h (Table 5.2). The labour team used to obtain this execution rate consist of nine members. This rate is equivalent to 207.16m^2/h (23.02 m^2/h/labourer).

Table 5.5: Labour execution rates comparison of in-situ conventional deck and in-situ structural topping of HCC floor

Activity	**Execution rate (m^2/h/labourer)**	
	In-situ (conventional flat slab)	In-situ (structural topping to hollowcore slab)
Concrete placement	11.11	23.02
Steel fixing (in-situ) / Placement of sheet (precast)	0.81	4.12
Formwork erection (in-situ)	1.12	7.14

From the comparison of different construction activities shown in Table 5.5 it is clear that the in-situ activities of the HCC project have a higher execution rate than the corresponding activities of the in-situ conventional flat slab. From both Table 5.4 and Table 5.5 it can be concluded that the in-situ process has relatively low manufacturing execution rates compared to the HCC process. Also, it seems that HCC uses its labour force more effectively, as the execution rate per labourer is higher. The extent of the influence of these rate variations will be shown in the labour hour comparison (Section 5.4) where the execution rates are applied to the quantities of both project concepts.

5.3.2 Labour type comparison

In Chapters 2 and 4 it was concluded that labour skills in the South African construction industry are low. In Chapter 4 a suggestion was made that the use of precast concrete elements in the construction industry may serve as a solution to this problem, since most of the skilled work is done off-site at the precast manufacturing plant. Thus, it still requires the temporary lower-skilled labour on-site, without negatively affecting the productivity and quality. This theory is qualitatively tested in Sections 5.3.2.1 and 5.3.2.2.

5.3.2.1 Labour skills breakdown by means of numbers

The comparison of the types of on-site labour used in the in-situ and hybrid concrete construction projects, as provided by the project managers, will address the validity of the HCC technique to serve as solution for the current low skills of South African labourers. It should be taken into consideration that this is done using only one example project of each construction technique. However, according to the project managers of both projects, these labour teams and rates remain relatively constant for similar projects. Table 5.6 shows the on-site labour skills breakdown of the construction of the floor system shown in Figure 5.4 for both considered construction types (In-situ and HCC). These values were obtained from Tables 5.1, 5.2 and 5.3. The labour information of the in-situ conventional floor system (Figure 5.1) were used for the in-situ construction type shown in Table 5.6, as this technique is more commonly used in South Africa than the post-tensioned (PT) flat slab system (Lombard, 2011).

Note that supervision was not considered in this comparison as they are not considered as part of the workforce. Also, the number of supervisors used in the considered techniques was relatively similar.

Table 5.6: On-site labour skills breakdown for the construction of the floor slab

Construction type	Labour skills						
	General		Semi-skilled		Skilled		Total
	Number	% of total	Number	% of total	Number	% of total	
In-situ	26	45.6	28	49.1	3	5.3	57
HCC	30*	75.0	6**	15.0	4	10.0	40

*Example - General labour (Table 5.2) 4+4+2+4+6+2+4+4 = 30
**Example – Semi-skilled (Table 5.2) 2+2+2 = 6
Note: Machine operators are considered as skilled

From Table 5.6 it is evident that the conventional in-situ floor slab construction requires more labourers than the on-site construction of the hollowcore precast elements with an in-situ structural topping. However, this does not show the labour hours required for each alternative. This will be discussed in the following section.

The in-situ labour breakdown shown in Table 5.6 consists of 45.6% *general* and 49.1% *semi-skilled labourers*. Whilst for the HCC alternative, 75% of the labour consists of *general labourers*. Thus, the majority of HCC's labour force is low-skilled labour, which suggests that HCC could serve as the ideal construction technique to the current labour scenario of South Africa, as skilled labourers are scarce but low-skilled labourers are in abundance. It is important to note that this comparison is only valid for the use of precast floor systems in the structural building industry, and should serve only as an indication for other precast usages.

Also, from Table 5.6, it is evident that HCC requires less overall labourers on-site. This indirectly serves as a risk reduction technique to the contractor as he deals with less labour related risks. The extent of this advantage is investigated in Chapter 7 by means of a risk analysis.

5.3.2.2 Labour skills breakdown by means of hours

It was decided to conduct a similar comparison as shown in Table 5.6 but by considering the amount of hours worked by each type of worker. Note that for this comparison, as with the comparison shown in Table 5.6, only the floor segment was considered.

Table 5.7: On-site labour hours per type of worker

Construction type	Labour skills						
	General		Semi-skilled		Skilled		Total
	Hours	% of total	Hours	% of total	Hours	% of total	
In-situ	1004.5	36.2	1728.0	62.3	41.5	1.5	2774.0
HCC	713.5	80.5	94.1	10.6	78.3	8.8	885.9

Note: Supervisors were not considered in this comparison, therefore the total hours is less than that of Table 5.9

Table 5.7 shows that *general labour* conduct 80.5% of the work in the HCC alternative, whilst in the in-situ alternative, *general labour* only conduct 36.2% of the work. Also, important to note is that *semi-skilled labour* conduct 62.3% of the work in the in-situ alternative. Thus, the HCC alternative requires little skilled and semi-skilled work on-site. Thus, HCC serves as the ideal solution to the current low skills of labour in South Africa, as it largely rely on *general labour* to conduct the majority of the work.

Table 5.7 also serves as verification of the conclusions drawn from Table 5.6.

5.4 Labour hour comparison

The labour hour comparison is based on the labour execution rates (Tables 5.1, 5.2 and 5.3) applied to the quantities used (Table 5.8). It is important to note that the in-situ rates shown in Table 5.1 were obtained from the hospital building project (Figure 5.4) and applied to the in-situ concept of the student building, as shown in Figure 5.5. The quantities of both the in-situ and HCC concepts as used in the labour hour comparison are shown in Table 5.8. Note that the quantities are provided in the same units as the execution rates in Section 5.3.1. These units were received from project managers and quantity surveyors and are not necessarily expressed in the expected units for the specific materials.

Table 5.8: Quantities of material used in both construction techniques as provided by project managers

Structural section	Material	Production Unit		In-situ (Conventional slab)	In-situ (Post-tensioned slab)	HCC (on-site)	HCC (plant)
Support structure	Concrete	m^3	*	12.54	12.54	-	-
	Steel	m^3	*	12.54	12.54	-	-
	Formwork	m^2	***	120.96	120.96	-	-
	Single walls	m^2	***	740.18	740.18	316.88	-
	Double walls	m^2	***	435.20	435.20	858.50	-
Floor slab	Concrete	m^3	***	288.00	288.00	69.12	111.33
	Steel	m^2	**	1152.00	1152.00	1152.00	-
	Formwork	m^2	**	1152.00	1152.00	1152.00	-
	Stop-ends	m^2	**	1152.00	1152.00	-	-
	Post-tensioned cables	No	***		138.00	-	-
	Pre-tensioned cables	m^2	**	-	-	-	1152.00

* These quantities are given as the volume of concrete in columns
** These quantities are given as the floor area
*** These quantities are given as the unit of their respective materials itself

The labour hours of the three construction alternatives are shown in Table 5.9. The labour hours spent at the precast plant are also included in the labour hour comparison.

Table 5.9: Labour requirements in different construction alternatives

Labour requirements, in man hours per floor level (Figure 5.4)			
Activities group	**In-situ concrete construction**		**Hybrid concrete construction**
	Post-tensioned floor slab	Conventional floor slab	Precast floor slabs and bearing walls
Walls	1898.3	1898.3	2397.3
Columns	377.4	377.4	-
Floor slabs (on-site)	2805.7	3117.3	1030.3
Floor slabs (plant)	-	-	355.3
Total	**5081.5**	**5393.1**	**3782.9**

The on-site labour requirements of the floor slabs are validated by the labour hour comparison conducted by Warszawski *et al.* (1984), shown in Section 2.4.3, Table 2.2. In the study of Warszawski *et al.* (1984), the HCC alternative required 36.7% (the average of 75.8 and 51.3 divided by 173, Table 2.2) of the on-site labour hours used in the conventional method to construct the floor slab. In the case study of this investigation, as shown in Table 5.9, HCC required 33.1% (100 x 1030.3/3117.3) of the on-site labour used in the conventional method to construct the floor slab. This comparison proves that the execution rates provided by the project managers are similar to those used by Warszawski *et al.* (1984). Also, this corresponds to the proposed labour reduction of 50% to 80% as stated by the *Irish Concrete Federation* (Section 2.1.2.1). Note, for the latter comparison the HCC alternative refers to the amount of on-site labour used to construct the HCC floor slab, seeing that Warszawski *et al.* (1984) did not include the factory hours in his comparison.

The floor slab is the only structural element constructed using precast elements in the HCC alternative. Therefore, this activity will be compared in isolation. The labour requirements for the HCC alternative are 1385.6 hours (1030.3 + 355.3), while the conventional method requires 3117.3 hours. This indicates a 55.6% reduction in labour for the construction of the floor slab when using HCC. However, in the structural building industry, all the components are rarely constructed using only precast elements, therefore considering the construction of all the components will provide a better indication of the labour requirements for both techniques.

Considering the total labour requirements as shown in Table 5.9, it is evident that HCC only requires between 70.1% and 74.4% of the labour force used in the two in-situ alternatives. This comparison includes the floor system, floor supports and supporting walls. Thus, considering the labour requirement reduction of the HCC alternative, it follows that this alternative is more labour effective since it uses less labour to construct the same building. However, referring to these values, the use of HCC directly implies job loss which verifies the argument mentioned in Section 2.3.1.2. The latter statements are verified by the required man hours to construct a square meter of one level of the student residence (including all activities to construct the walls, columns and floor slabs) as shown in Table 5.10.

Table 5.10: Man hours required per square meter

Floor slab	**Rate (Man hours/m^{2}storey)**
In-situ (conventional)	4.68
HCC	3.28

5.5 Conclusion

This chapter compared items of the two considered construction techniques. These were:

- Labour execution rates
- Labour teams used
- Labour hours required

Considering these comparisons from a client's point of view, the use of HCC seems advantageous when implemented at projects such as those considered in this case study. Not only does the use of HCC produce a higher production rate than the conventional method, but it requires 17 less labourers on-site (74 in-situ vs. 57 HCC) which directly reduces labour-related risks for the client and the contractor. Chapter 6 identifies all the labour-related risks in the construction environment and in Chapter 7 the effect of these risks in both the on-site construction and precast manufacturing environments are investigated.

Another HCC-related advantage to consider is the reduced amount of higher skilled labour used during the HCC alternative. The labour force of an HCC activity comprises 75% (from a total of 40) *general labour*, which is a high percentage when compared to the conventional method's 45.6% (from a total of 57). These *general labourers* are responsible for 80.5% and 36.2% of the work of the HCC and in-situ alternatives respectively. Where, *semi-skilled* and *skilled labourers* are responsible for 19.4% and 63.8% of the work of the HCC and in-situ alternatives respectively. With the current shortage of *semi-skilled* and *skilled labour* in South Africa, HCC serves as the ideal solution, as only a small percentage of the work require these types of labourers.

Considering the comparisons conducted throughout this chapter, from the implementation of the NDP's point of view, it seems to be discouraging, since overall 29.5% (Table 5.9) less labour is used in the HCC alternative than in the conventional construction technique. However, considering the job creation schemes of the NDP and EPWP in the construction industry, these programmes promote job creation by employing temporary local labour and local sub-contractors as mentioned in Section 4.1.1. Thus, using HCC does provide a better environment to accommodate less-skilled labourers, as a large portion of the skilled work is done by the permanent labourers in the precast manufacturing plant.

The overall number of labourers involved in the construction of the in-situ concept of the resident building was 74 (57(floor slab) + 17(brick walls)). The HCC concept of the same building involved 86 labourers (40(on-site for floor slab) + 17(brick walls) + 29(precast plant)). Thus, although the HCC method used 29.5% less labour hours, it provided 12 more job opportunities, although for a shorter period. The reason for the significantly reduced labour hours, even though more labourers are involved is due to the effectiveness of the precast manufacturing process, utilizing labour to greater effect than in the in-situ process. Stofberg (2015) mentioned that tender documents describe job creation as the number of job opportunities created by means of labour hours. Thus, in this case, HCC required less labour than the corresponding in-situ method. However, utilizing HCC exposed more individuals to the construction environment than the in-situ method.

Therefore, it is concluded that HCC utilizes less labour than in-situ concrete construction, making the latter technique the best, for job creation. Skills development is also an important *socio-economic issue* addressed in this investigation and HCC seems to introduce more labourers to the construction environment, making the latter technique the favourite to promote skills development. HCC also seems to be the more economical technique as it utilizes less labour than the in-situ method for an equivalent structure.

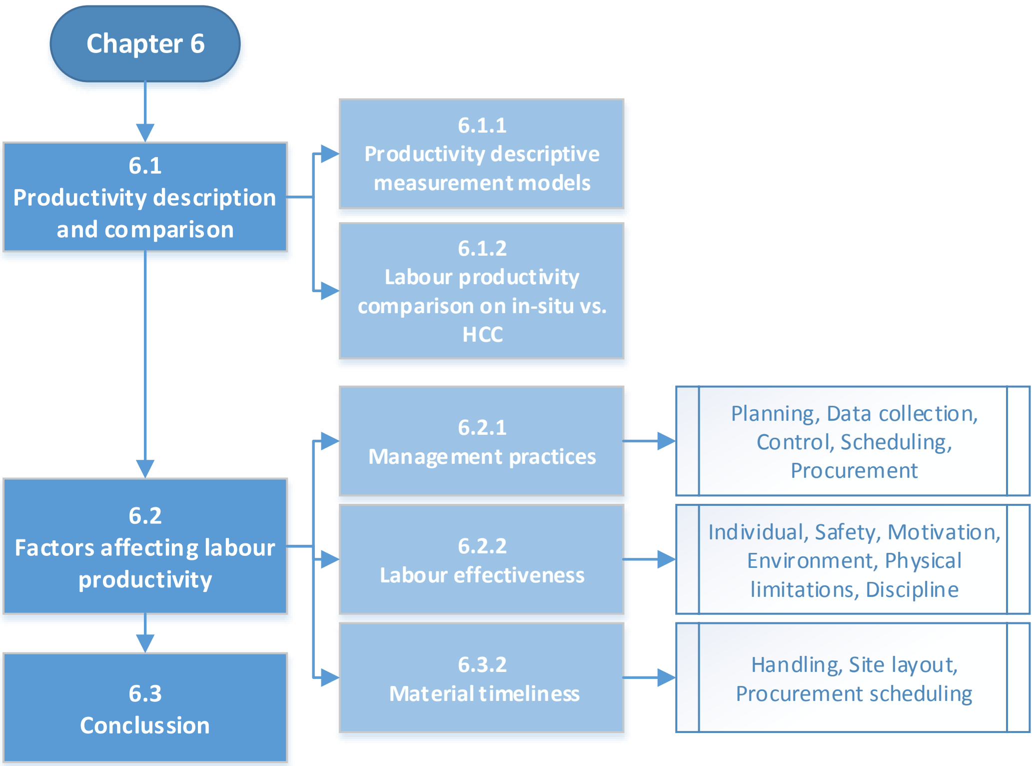
Note that the on-site labour hour requirements of the conventional in-situ floor slab and the HCC hollowcore floor were validated by means of a comparison with a previous, similar labour hour case study conducted by Warszawski *et al.* (1984). In the case study of Warszawski *et al.* (1984), the on-site activities of the HCC alternative required 36.7% of the labour force of the in-situ alternative, where in this case study, HCC required 33.1% of the in-situ alternative's labour force. This shows a 90% similarity, which validates the results of this case study.

CHAPTER 6

6 LABOUR PRODUCTIVITY IN CONSTRUCTION

Chapter 2 discussed the key areas of concern in the South African construction industry. These areas of concern were ranked by 38 delegates attending the CMP course in 2012, as previously discussed. Labour productivity was ranked as the most influential area of concern in the construction industry as shown in Table 2.1.

This chapter will further investigate labour productivity in construction so that the sources of the concern can be better understood and to identify the factors influencing labour productivity. The relevance of the influential factors with regards to the South African on-site construction industry as well as the precast manufacturing industry of South Africa will be determined through a risk analysis survey conducted in the next chapter.



6.1 Productivity description and comparison

In general, productivity can be described as the ratio to measure how well an organization (or individual, industry, country) converts input resources (labour, materials, machines etc.) into goods or services. Productivity is usually expressed as ratios of inputs and outputs i.e. cost (input) per good / service (output). (Kathuria, Raj & Sen, 2012; Thomas & Yiakoumis, 1987)

According to Dozzi and AbouRizk (1993) productivity is described through an expression of inputs versus outputs. The relationships and units of the inputs and outputs can vary, depending on the purpose of the calculation. In the construction industry contractors price an activity according to the estimated cumulative productivity based on the conditions under which the project work will be conducted. If the contractor is awarded the contract, they need to ensure that they achieve the same or better productivity than that of their tender. In this case, contractors are usually interested primarily in the cumulative average productivity value. (Thomas, Maloney, Horner, Smith, Handa & Sanders, 1990)

Input and output unit rates can differ depending on how productivity is measured. Thomas *et al*. (1990) identified three different models by which productivity can be measured. These models will only be discussed briefly to give a better understanding of what productivity means and how it can be expressed in different situations. The three models that define productivity as described by Thomas *et al*. (1990) are the *Economic model*, *Project-Specific model* and *Activity-Orientated model*.

6.1.1 Productivity descriptive measurement models

Economic model

The *Economic model* measures productivity in a fraction called the total factor productivity (TFP) with the inputs and outputs expressed in a specific currency such as rand, since it is the only measure common to both inputs and outputs. The model is mostly used by the Department of Commerce, Congress, and other governmental agencies in the forms shown in Equations 6.1 and 6.2. Equation 6.2 is a simplified example of Equation 6.1. (Thomas *et al*., 1990)

$$TFP = \frac{Total\ output}{Labour+Materials+Equipment+Energy+Capital} \qquad 6.1$$

$$TFP = \frac{Rand\ value\ of\ output}{Rand\ value\ of\ input} \qquad 6.2$$

Thomas *et al.* (1990) explained that these equations are useful in policy-making and to evaluate the state of the economy, but are not that useful for contractors. Applying the *Economic model* to a specific construction project or site is possible, but it can be inaccurate due to the difficulty in predicting the various inputs (Thomas *et al*., 1990).

Project-Specific model

This model is more accurate for specific programme planning or for specific individual projects. Productivity regarding the *Project-Specific model* is measured in terms of money value per unit of measure. Equation 6.3 shows a typical example of square meters per cost of a project, whereas Equation 6.4 represents a simplification of Equation 6.3. (Thomas *et al*., 1990)

$$Productivity = \frac{Output}{Labour+Equipment+Materials} \qquad 6.3$$

$$Productivity = \frac{Square\ meters}{Total\ rands\ spent} \qquad 6.4$$

Activity-Orientated model

This model was developed to be used by contractors where the units of output are specific for generic activities. The output units used are usually cubic meters, tons, and square meters. The model can be applied to various activities which include activities such as formwork erection, steel reinforcement, and concrete placement. The *Activity-Orientated model* expresses productivity as the units of output per rand or per work-hour. In the case where contractors are interested in the labour productivity this model can be modified to provide the productivity in terms of labour productivity. Equation 6.5 shows how labour productivity can be calculated. (Thomas *et al*., 1990)

$$Labour\ productivity = \frac{Volume\ produced\ (cubes, squares, tons)}{Labour\ cost\ or\ total\ work\ hours} \quad 6.5$$

When contractors tender for a project they are required to provide the client with an estimated project cost which is also known as the estimated unit rates. A performance factor can provide valuable information to the contractor to improve his productivity rates for certain activities in the future. This performance factor is the ratio between the estimated unit rates of labour productivity and the actual labour productivity rates, as shown in Equation 6.6. (Thomas *et al*., 1990)

$$Performance\ factor = \frac{Estimated\ unit\ rate}{Actual\ unit\ rate} \quad 6.6$$

The models discussed explain how and why productivity is measured for different purposes, depending on the reason for measurement.

6.1.2 Labour productivity comparison on in-situ versus HCC

The case study conducted in Chapter 5 performed a thorough labour hour comparison between the two considered construction techniques for a specific project. This information gathered for the case study also enabled a labour productivity comparison, using the method described by Equation 6.5.

It was decided to compare only the conventional floor system with the HCC floor system as described in Section 0. The values required for the productivity comparison were obtained from the labour hour comparison shown in Table 6.1.

Table 6.1: Man hours required for constructed volume

Construction method	Volume produced (m^2)	Total man hours required
In-situ construction	1152	5393.1
HCC	1152	3782.9

The values shown in Table 6.1 were used as input values for Equation 6.5. The labour productivity rates for both construction techniques as described by the *activity-orientated model* were 0.214 m^2/h and 0.305 m^2/h for in-situ and HCC respectively.

From these calculations it is evident that the HCC method produces a higher labour productivity rate than the in-situ method, considering the use of precast hollowcore floor slabs. Thus, concluding from this comparison, labourers are more productive in the HCC environment than in the in-situ environment.

6.2 Factors affecting labour productivity

In Section 6.1, productivity in general and labour productivity were discussed using different models to define productivity. The labour productivity of the two considered construction methods were also compared, using information from the case study of Chapter 5.

This section primarily focuses on the identification and discussion of the key factors influencing productivity in the construction industry. Secondly it is considered as a foundation for the risk analysis conducted in Chapter 7.

Dozzi and AbouRizk (1993) suggested that to better understand productivity and the improvement thereof, a construction project should be seen as a complete system. As shown in Figure 6.1, the system comprises of different inputs such as materials, personnel, management, and equipment. These inputs all consist of different measurement inputs and are used in different quantities. The construction project as a system consumes the inputs to produce outputs. These outputs are called production units and, concerning a construction project, it can be a road, building, bridge or any other end product of a construction project. The production unit is a function of the system used. In the case where the system is defined by an activity, the production unit can be a laid brick, a standing wall or a complete building. The production unit is therefore dependant on the level of detail in which the productivity measurement is calculated.

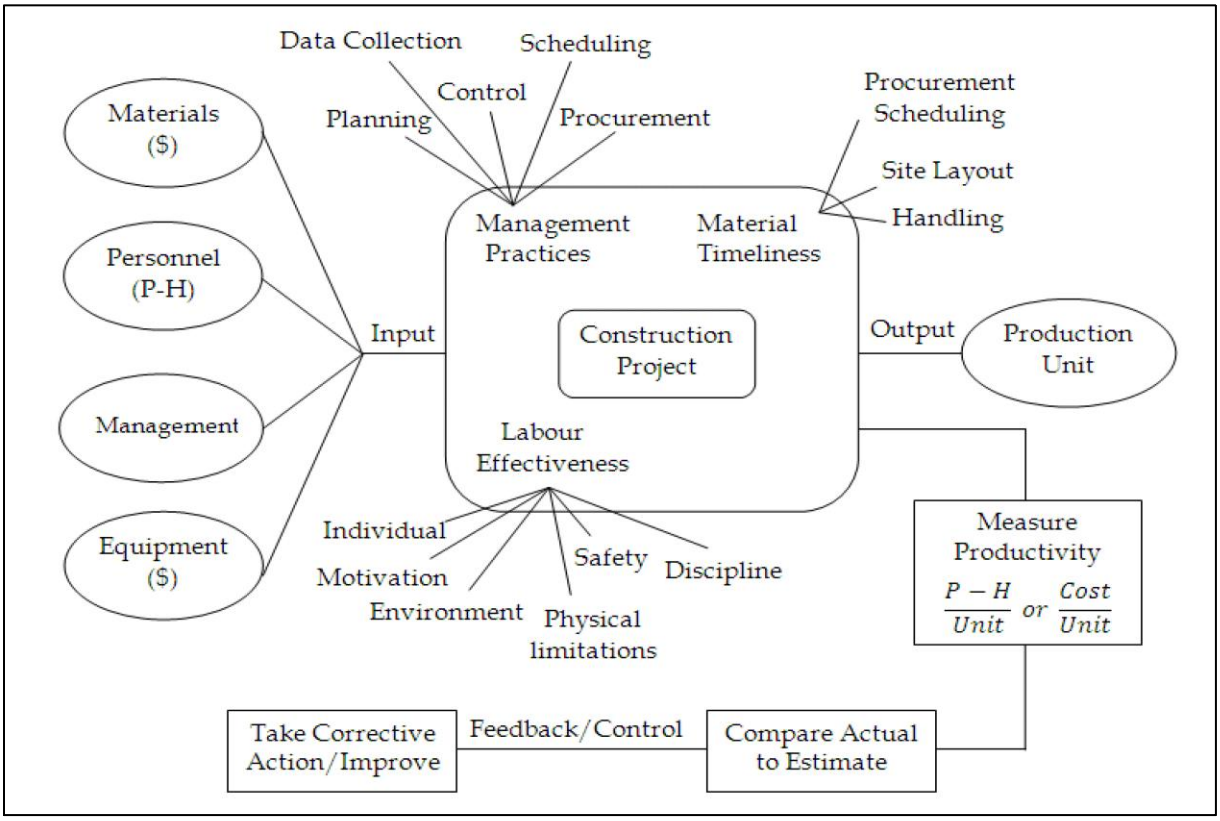


Figure 6.1: System for productivity improvement (Dozzi & AbouRizk, 1993)

Dozzi and AbouRizk (1993) explained that there are different factors within the system influencing the productivity. Figure 6.1 shows that the influential factors are divided into three main categories, namely: Management practices, Material timeliness and Labour effectiveness.

As this investigation as a whole focuses on labour-related aspects of a construction project it might seem sufficient to only investigate factors related to *labour effectiveness* in isolation. However, because a construction project is considered as a complete system and the factors categorised under *management practices* and *material timeliness* might also influence the effectiveness of the labourers, it was decided to investigate all three categories. Hendrickson & Au (1989) supported this statement, as they stated that it is not only the labour capacities that influence the productivity of labour on a construction site.

Hendrickson & Au (1989) defined labour productivity as a measurement of the effective utilization of labour, equipment and capital, and not only the measure of the labour capacities alone. Their investigation revealed that all these elements work together to generate a labour-based output. This statement motivated the investigation of all three influence categories rather than only labour effectiveness.

Therefore, the following sections will identify and discuss the different influential factors of all three categories identified by Dozzi and AbouRizk (1993) and shown in Figure 6.1. The categories discussed in the following sections are management practices, labour effectiveness and material timeliness. All the factors influencing productivity will be printed in *italics* to simplify the identification process to the reader.

6.2.1 Management practices

In this section the five management practice factors shown in Figure 6.1 are discussed. This comprises the factors of planning, data collection, control, scheduling and procurement.

6.2.1.1 Planning

Effective work distribution and planning of the overall project can play an important role in the success and productivity of site operations. Sufficient planning and design prior to the start of the project is important to ensure minimal *rework* and *design changes*. Adequate planning is also required to ensure that a trade should only be called to site once preceding trades have made sufficient progress to prevent *stacking of trades*. This is important as *stacking of trades* can negatively influence labour and ultimately, project productivity. (Dozzi & AbouRizk, 1993)

Overall good planning also serves as a motivator to the workforce since it prevents unnecessary interruptions. *Change orders* are an effect of poor planning and can require the contractor to make use of a different construction method because of the quantity of work changes. Additional work or *change orders* also influence productivity due to the fact that the momentum of workers is interrupted and that a stop-go phenomenon will exist (Dozzi & AbouRizk, 1993). A *change order* has major influences on labour productivity and should be carefully monitored by the contractor.

6.2.1.2 Data collection

Accurate and timely data collection plays an important part in taking corrective actions to assist in delivering projects within budget and on time. There are three main reasons why data collection is important. These are to: (Allen & Alexander, 2013)

- Monitor the progress of the project
- Satisfy all of the contract requirements
- Track the productivity for project management and profitability purpose

6.2.1.3 Control

Security is used as a control mechanism on construction sites in order to manage and prevent illegal weapons, workers, drugs or tools to enter or leave the site (Keyte, 2013). When considering large construction sites, security can affect labour productivity. Security checks consume valuable time and reduce labourers' focus on their work (Intergraph Corporation, 2012). Thus increased control is not always regarded as a productivity enhancer but can also cause a reduction in labour productivity.

Rework as mentioned in Section 6.2.1.1 is an influential factor that needs to be controlled if possible. Rework occurs when the initial product or work has not been manufactured or done according to the required specifications, and needs to be redone. Projects rarely make provision for rework and resources and time spent on this type of work. This directly reduces expected profits, therefore it is an important factor to consider. Rework is caused by various sources which include poor instructions to labourers, poor supervision, inadequate training of workers, incorrect tools and inadequate materials, etc. (Dozzi & AbouRizk, 1993).

Rework management is considered a form of control during a construction project, since it equips project managers with adequate resources to implement mitigating actions and to obtain direction when dealing with tough rework issues (Kriel, 2013). An effective rework management system will help to restrict rework operations to a minimum and in turn help to reduce the company's vulnerability to adverse effects on productivity.

The *transition* from one activity to another during a day's work is a normal occurrence in construction projects (Adrian, 2013). This transition has been observed to regularly occur in an ineffective way, which results in delays to start the new task. The motivation and productivity of labourers are low during this transition phases of a project. Adrian (2013) suggested that this concern can be addressed by management through improved and more efficient control. A reward system for the successful completion of tasks has also proven to be effective. (Adrian, 2013)

Another influential factor which should be controlled by management is the labour-supervisor ratio. This ratio is the relationship of the number of supervisors required for a given number of labourers. The amount of labour is usually regulated by policies or legislation, whereas the extent of supervision is regulated by the contractor (Adrian, 2013). Too little supervision could have a negative impact on productivity and effectiveness of work, whereas too much supervision could be uneconomical (Adrian, 2013). Great care should also be given to management of project *logistics*, as it is important to manage labourers in such a way as to prevent labour teams from working in many different places at the same time. Dispersing the tasks geographically can result in possible time loss due to extensive transport of labourers, material and equipment and also due to *dilution of supervision (Intergraph Corporation, 2012).*

From the discussion above it is evident that control on a construction site can prove to be both beneficial and detrimental, depending on how control is exercised.

6.2.1.4 Scheduling

Scheduling can be divided into a number of areas that have an influence on productivity. Although these areas of scheduling are discussed separately, they can occur simultaneously and have a combined effect on productivity. These areas are *stop and go*, *ripple effect*, *shift management*, *concurrent operations* and *overtime*.

Stop and go can be the result of bad scheduling and occurs when a crew or a part thereof is forced to stop their current activity and return to it at a later stage or move to another activity. This area of influence is usually a result of poor instructions or a lack thereof, insufficient resources or a poor schedule. Approval of workmanship is a regular occurrence in construction which also causes *stop and go* operations and plays an important role in maintaining steady productivity (Kriel, 2013). Adrian (2013) mentioned that the waiting period for instructions after the completion of an activity before the end of a day results in 10% of time to be non-productive. Therefore it is recommended that management and supervision should always have a secondary task assigned to labourers so that they can continue with this task once the primary task has been completed and no new tasks have been assigned to them. *Holidays* and public *holidays* also contribute to the stop and go effect, since activities can possibly be placed on hold for the holiday, which will ultimately affect productivity, since it will take some time for labourers to regain their momentum after returning from holiday (Intergraph Corporation, 2012). Management should prevent major activities from running over holiday periods and should try to finalise such activities before scheduled breaks (Intergraph Corporation, 2012).

Ripple effect is another area that is considered within the schedule of a construction project and is defined as the unforeseen effects of a change that occurred (Intergraph Corporation, 2012). The effect of this area is often only seen after the final loss and profit statements are drawn up (Kriel, 2013). The ripple effect is therefore regarded as a management-related factor, but can be very hard to eliminate, except if minimal changes occur regarding the schedule of the project (Intergraph Corporation, 2012).

Shift management within the schedule is considered to be an influential factor regarding labour productivity, as it changes the daily pattern of labourers. Multiple shifts can often be the cause of lower labour productivity (Intergraph Corporation, 2012). This is due to different groups of labourers working on the same activity at different working hours. Thus, labourers are not always familiar with their working conditions, as they do not continue from where they previously ended. Simple trades with small learning curves have proved to use multiple shifts to great success considering labour productivity. However, this is contradictory to precision and technical trades, because these areas experienced decreased productivity levels. Not only does shift work affect the labour productivity in this manner, but it also influences the labourers' sleeping and eating routine. Research has proven that the human body adapts to these types of changes within 30 days (Kriel, 2013). In the construction industry shifts are often rotated every 30 days for fairness, but this essentially leads to lower labour productivity due to the continuous adaption the labourers experience each month (Kriel, 2013).

Concurrent operations tend to negatively influence management's scheduling and results in lower productivity (Intergraph Corporation, 2012). *Concurrent operations* occur when small tasks are added in between or after other finalised tasks. These tasks happen without any compensation in the schedule therefore tend to create higher workloads in the same planned schedule (Intergraph Corporation, 2012). This lack of definite goals and milestones negatively influences labourers' motivation which also results in further productivity loss.

Adrian (2013) mentioned that it is rarely possible for management to drive labourers to perform in every activity. However, a solution for this situation is to identify activities on the critical path and to motivate labourers to work on these activities with a sense of urgency.

Sometimes a sense of urgency might still be insufficient to catch up on the time lost on the critical path. An obvious and widely used solution is *overtime*. Overtime is defined as the time worked in excess of the normal 40 hours a week. According to Dozzi & AbouRizk (1993) a 40 hour work week is recognized as the optimal working hours to achieve the best progress, and working an excess of 40 hours a week will decrease labour effectiveness and output rate. An investigation revealed that after 9 consecutive 50 hour work weeks, the 50 hour work week had a lower output rate than a standard 40 hour work week (Dozzi & AbouRizk, 1993). Table 6.2 shows the relationship between the number of hours worked per week and the corresponding inefficiency factor. The corresponding inefficiency factor is shown for short and long term effects and for weeks with different numbers of work days.

Table 6.2: Relationship of overtime and the inefficiency factor (Dozzi & AbouRizk, 1993)

Days per week	Daily hours	Weekly hours	Inefficiency factor			
			7 Days	14 Days	21 Days	28 Days
5	9	45	1.03	1.05	1.07	1.1
5	10	50	1.06	1.08	1.12	1.14
5	11	55	1.1	1.14	1.16	1.2
6	9	54	1.05	1.07	1.1	1.12
6	10	60	1.08	1.12	1.16	1.21
6	12	72	1.13	1.2	1.26	1.32
7	8	56	1.1	1.15	1.2	1.25
7	9	63	1.12	1.19	1.24	1.31
7	10	70	1.15	1.23	1.3	1.38
7	12	84	1.21	1.32	1.42	1.53

Table 6.2 shows that by working less continuous *overtime*, work will be done more effectively. Considering this together with the other discussed influential areas, scheduling can be seen as a major factor that influences productivity on a construction site. Another managerial factor mutual to scheduling is the procurement of labour, which is discussed in the following section.

6.2.1.5 Procurement of labour

Procurement of labour can be divided into different areas which all influence productivity. These areas are *stacking of trades*, *crowding*, *late crew build-up* and *overstaffing*.

Stacking of trades occurs when two or more trades are forced to operate within the same physical space at the same time (Intergraph Corporation, 2012). This creates congestion and the work area becomes a space where unsafe practices are exercised. Also, productivity is lost due to the inability to locate or use tools conveniently, an increase in visitors to the congested area, additional safety hazards, difficulty of movement and transport of materials and the prevention of crew size optimum (Intergraph Corporation, 2012). According to Kriel (2013), the perception of working in a smaller area also contributes to productivity losses.

Crowding is similar to *stacking of trades* in the sense that it creates congestion. However, *crowding* is a result of accelerated work due to schedule pressure, where *stacking of trades* is the result of bad scheduling (Dozzi & AbouRizk, 1993). *Crowding* can be measured by using standards which specify the accepted area required to perform tasks in. In the case where an area can house 12 labourers and is occupied by 15 labourers, the crowing is calculated as 3/12 = 25%. Figure 6.2 shows that 25% crowding results in an 11% loss of efficiency. This is equivalent to an 11% increase in the normal time it would take to finish a task.

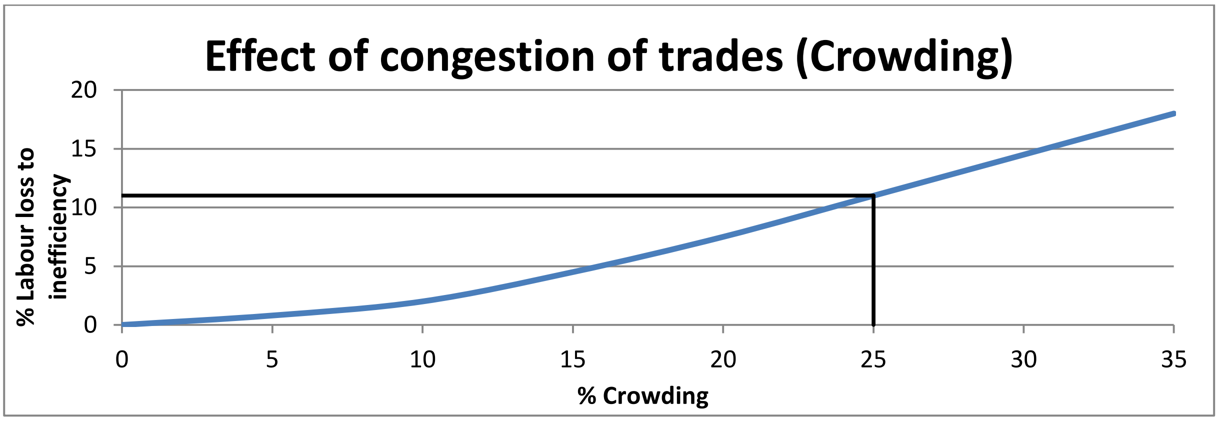


Figure 6.2: Effect of congestion of trades (Dozzi & AbouRizk, 1993)

Late crew build-up occurs when planned project labour teams are altered due to required labourers not being available (Intergraph Corporation, 2012). This causes a slower build-up of manpower due to competition for resources. Manpower loading is when workers are assigned to specific tasks or operations in the project schedule (Business Dictionary, 2012). Late crew build-up also results in a lack of team cohesion, which has been found to negatively influence the productivity of labourers (Intergraph Corporation, 2012).

Crew build-up should happen as quickly as possible to prevent the use of inadequate labour, and managers in charge should be aware of the crew sizes. Managers should not have a perception that a bigger labour crew is always better, and should consider optimal crew size as discussed below.

Dozzi and AbouRizk (1993) describes *overstaffing* as the occurrence where more labourers are assigned to a task than required to do the work the most productively. *Overstaffing* results in the loss of productivity due to the imbalance between the acceptable rate of progress and the highest level of productivity.

The optimum crew size is considered to be the minimum number of crew members that can economically complete tasks within the scheduled time. Figure 6.3 shows how the efficiency of the total crew is influenced with the increase of members above the optimum number.

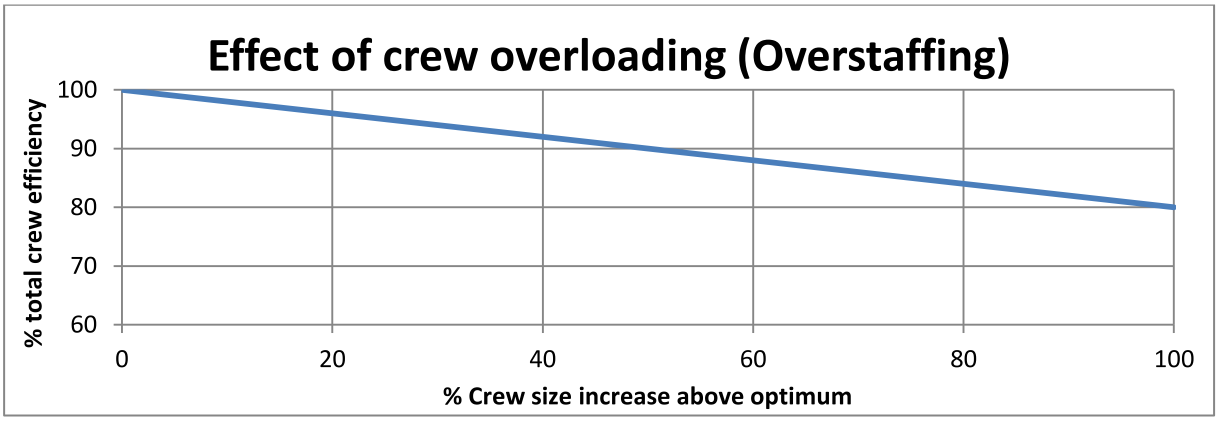


Figure 6.3: Effect of crew overloading (Dozzi & AbouRizk, 1993)

6.2.1.6 Summary of management practices

Throughout this section it was clear that management-related factors play an important role in the productivity of a construction project. The importance of these factors in the two considered construction techniques will to some extent indicate which technique is best manageable. These factors are considered to be of high importance in both the in-situ construction and the precast manufacturing environment. However, one might argue that due to the systematic nature of the precast environment factors such as effective planning, data collection, accurate and timely data, and effective scheduling are more important than in the in-situ construction environment.

The latter argument is only opinion-based and the validity thereof will be tested by the risk analysis conducted in the following chapter. The risk analysis will rank the identified productivity-influencing factors for both the in-situ construction and the precast manufacturing industries in South Africa.

6.2.2 Labour effectiveness

This section investigates another category within the *productivity improvement system,* which has an influence on productivity of a construction project. The investigation of labour effectiveness focuses more on the labourer as an individual and how certain changes in the work environment affect the productivity of the labourer. This category comprises of six sub-categories, namely qualities of the individual, safety, motivation, environment, physical limitations and discipline.

6.2.2.1 Qualities of the individual

In many work places, the *attitude and personality of an individual* to a certain extent determine their productivity. This can also play an important role in the productivity of other crew members. According to Dozzi and AbouRizk (1993), labourers with an optimistic and positive attitude are more likely to suggest innovative and imaginative solutions in the workplace. Labourers with a sense of humour can also enhance other labourers' productivity rates, as some humour can lift peoples' spirits and can relieve stress (Dozzi & AbouRizk, 1993).

The *health and safety* of labourers can also play a role in a project's productivity. A healthy and safe individual is not as likely to be injured or to be in an accident, thus less downtime is experienced during the project. *Creativity* of labourers is also an aspect which can enhance an individual's as well as the whole teams' productivity through the substitution of complex manners with more practical solutions. (Dozzi & AbouRizk, 1993)

When an individual is unfamiliar with a certain activity he or she is deemed to take longer than one who has the required experience. This phenomenon is known as the *learning curve* and is explained in Figure 6.4, which shows the decrease of time required to perform a task as the cumulative units increase. The cumulative units refer to the number of times the respective individual has performed a certain task. The reduction of time occurs due to the fact that the individual learns how to optimise the task at hand if he has gained previous experience on that specific task. (Dozzi & AbouRizk, 1993)

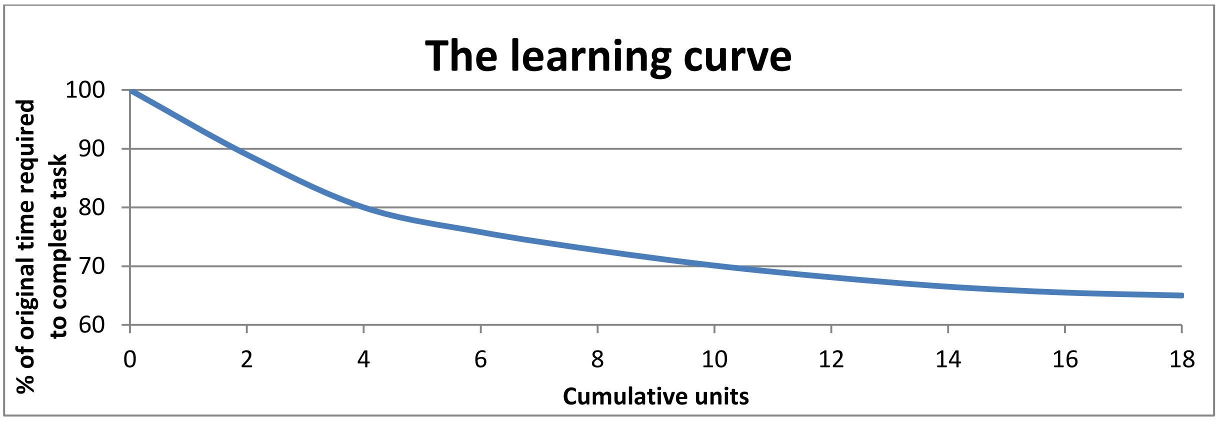


Figure 6.4: The learning curve showing reduction in time due to the increase of tasks completed (Dozzi & AbouRizk, 1993)

During interruptions between repetition cycles of completing tasks an individual is likely to "unlearn" how to perform tasks optimally. This "unlearning" effect also happens to individuals who are constantly shifted between areas of work and constantly have to learn to perform new tasks. Therefore, shifting workers between work areas has a negative effect on the productivity of the individual. (Dozzi & AbouRizk, 1993)

Figure 6.5 shows the learning curve of an individual where an interruption occurred after he or she had completed 4 similar tasks. At that stage the time required to complete the tasks has dropped to 85% of the initial required time. After the interruption the required time to complete the task has risen to 93% of the initial time. This shows that after an interruption an individual has "unlearned" how to optimize the time needed to complete the task. Therefore, it is important to minimise interruptions and stoppages.

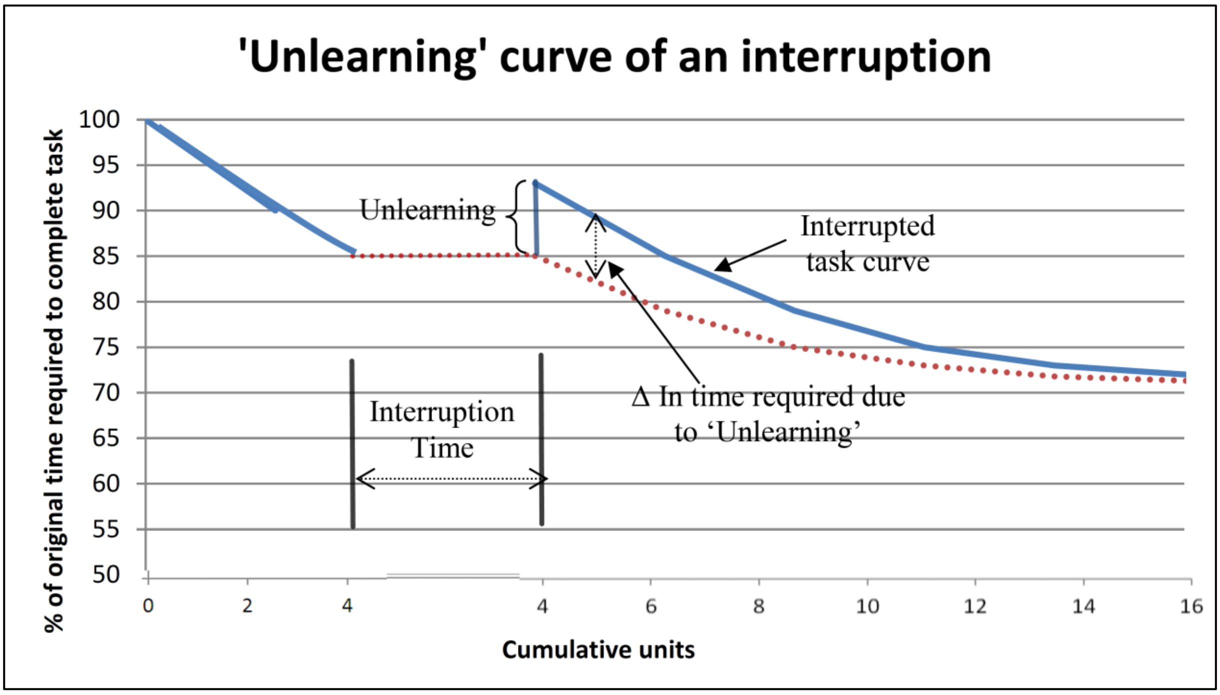


Figure 6.5: The "unlearning" effect when an interruption occurs (Dozzi & AbouRizk, 1993)

6.2.2.2 Safety

Safety on a construction site is not only a moral responsibility of management but has also proven that it can have an important economic impact on construction projects. Even though safety is a considerable expense to construction companies, these companies do benefit from a safer site. The main advantages of a safe site are less accidents and higher labour motivation (Dozzi & AbouRizk, 1993). Workers have shown to perform better when they are aware that care is given to their wellbeing. The benefit of fewer accidents on site has a financial advantage due to the reduced injury compensation, liability claims and loss of property (Dozzi & AbouRizk, 1993).

Usually once the project crew members experience pressure they tend to neglect safety. However, this statement does not imply that neglecting safety will increase productivity; on the contrary, a safe site can improve productivity due to the motivation and high awareness of labourers (Dozzi & AbouRizk, 1993). Dozzi and AbouRizk (1993) stated that on-site safety is an inevitable responsibility which can ultimately increase productivity, save project time and reduce accident costs.

6.2.2.3 Motivation

The effort an individual is willing to put into his daily work activities is largely determined by his level of motivation. It is estimated that the difference in productivity levels between a motivated and an unmotivated individual can be as much as 60% (Productivity SA, 2015). There are various factors that influence the motivation of an individual and many of them are identified throughout Section 6.2. Table 6.3 describes Frederick Herzberg's seven principles for enhancing motivation amongst labourers.

Table 6.3: Frederick Herzberg's seven principles for the enhancement of motivation (Dozzi & AbouRizk, 1993)

Principle Number	Description
1	Remove some measures of control, but keep measures of accountability.
2	Accountability of individuals should be increased for work done by them.
3	Assign a complete natural unit of work to a worker.
4	Additional authority should be given to an individual whilst he or she is managing his or her own work.
5	Periodic reports should be made available to the individuals performing the work.
6	New and more difficult tasks should be introduced to the team or individual.
7	Specific and specialized tasks should be assigned to individuals so that expertise is achieved within these tasks.

Like there are motivators shown in Table 6.3, there are also de-motivators which are factors that negatively influence the motivation of individuals and consequently reduce their productivity. Some de-motivators mentioned in Section 6.2 include *overstaffing*, *overtime*, *stop-go operations*, *crowding*, *multiple shifts* and the *stacking of trades*. Ng, Skitmore, Lam and Poon (2004) believe that just removing de-motivating factors rather than implementing motivators can still have a positive influence on the productivity of a project. Some of the de-motivators identified through a survey conducted by Ng *et al.* (2004) are shown in Table 6.4.

Table 6.4: Predominant de-motivators of civil engineering (Ng, Skitmore, Lam & Poon, 2004)

De-motivators	No. of affirmative responses				% of affirmative responses				Rank
	Plant Operator	Carpenter	Steel fixer	Total	Plant Operator	Carpenter	Steel fixer	Total	
Rework	24	22	11	57	55	58	48	54	1
Overcrowded work areas	26	19	9	54	59	50	39	51	2
Crew interfacing	18	19	7	44	41	50	30	42	3
Tool availability	12	18	12	42	27	47	52	40	4
Inspection delays	12	17	13	42	27	45	57	40	4
Material availability	10	19	9	38	23	50	39	36	6
Foreman incompetence	16	12	9	37	36	32	39	35	7

Table 6.4 shows that having to do rework is a major de-motivator which influences labourers' morale to a great extent. Many of these identified de-motivators such as *overcrowded work areas*, *crew interfacing*, *inspection delay*, and *tools and material availability* have been addressed in preceding sections. Therefore, Table 6.4 shows resemblance to the factors identified by other references in the preceding sections.

6.2.2.4 Environment

Dozzi & AbouRizk (1993) mentioned that labour effectiveness on a construction site is also influenced by the work environment. The enhancement of labour productivity by creating a better *work environment* can be done by providing labourers with the basic needs to make them feel valued. These needs include sanitary facilities, protective gear, drinking water, site access, protective gear and parking. Also, it is important to provide labourers with a safe, healthy and organised workspace.

Keeping the workspace organised and clean has proven to be worthwhile due to efficiency gains and prevention of unnecessary time loss. (Dozzi & AbouRizk, 1993)

It is not only the internal work environment that plays a role in labourers' performance but also the external environment. Dozzi & AbouRizk (1993) proposed the optimum productivity regions to be within temperatures of 4-21 ˚C and a relative humidity varying from 20 to 60%. This is represented by the green section in Table 6.5. The information provided by Table 6.5 shows that climate and weather change can influence labour productivity, thus it can be expected that labour productivity can vary depending on the time and season of the year. Shorter daylight hours can also influence the productivity of the labourers and are also dependant on the time of the year (Intergraph Corporation, 2012). This is an important factor to consider when measuring labour productivity on a construction project.

Table 6.5: Productivity percentage given relative humidity and temperature (Dozzi & AbouRizk, 1993)

	Temperature °C												
Relative Humidity %	**-23**	**-18**	**-12**	**-7**	**-1**	**4**	**10**	**16**	**21**	**27**	**32**	**38**	**43**
90	56	71	82	89	93	94	98	98	96	93	84	57	0
80	57	73	84	91	95	98	100	100	98	95	87	68	15
70	59	75	86	93	97	99	100	100	99	97	90	76	50
60	60	76	87	94	98	100	100	100	100	98	93	80	57
50	61	77	88	94	98	100	100	100	100	99	94	82	60
40	62	78	88	94	98	100	100	100	100	99	94	84	63
30	62	78	88	94	98	100	100	100	100	99	83	83	62
20	62	78	88	94	98	100	100	100	100	99	82	82	61

6.2.2.5 Physical limitations

The *physical limitations* of a human being are the reason for resting periods such as tea and lunch breaks during a work day. Construction work is almost entirely comprised of physical activities, therefore these breaks become even more important and the absence thereof can result in low labour productivity. According to an investigation to improve construction productivity it was estimated that a young male can produce 21kJ/min of power (Oglesby, Parker & Howell, 1989). An average of 4.18kJ/min is required to live and to keep the metabolism active (Oglesby, Parker & Howell, 1989). The human body only has a certain instant accessible storage capacity which according to Oglesby *et al.* (1989) is 10.5kJ. It is estimated that an average construction task consumes 17.24kJ/min, therefore 0.42kJ/min more than a young male can produce (21kJ/min-(17.24+4.18) kJ/min). This requires of the worker to consume of his stored energy, which will only last 25 minutes at a rate of 21.42kJ/min. If, however, the task only requires 16.82kJ/min (21kJ/min – 4.18kJ/min) the worker could maintain the work as it is equal to his capacity production rate (Oglesby, Parker & Howell, 1989). These values assume a young male as the worker.

The nutrition a worker consumes during and after working hours directly influences his or her strength and ability to function on site (Oglesby, Parker & Howell, 1989). In sub-Saharan Africa labourers consuming insufficient nutrition have proven to work ineffectively (Svedberg, 1990). Dozzi and AbouRizk (1993) identified breaks to be a major product inhibitor and although they are important to maintain good productivity they should be carefully monitored. According to Adrian (2013) these breaks added to unnecessary additional late starts and early finishes. Adrian (2013) mentioned that a 10 minute late start and early finish can consume up to 10% (40 minutes) of a total working day. Thus, this contributes to Dozzi and AbouRizk's (1993) statement that breaks should be carefully monitored.

6.2.2.6 Discipline

Absenteeism is one of the major concerns considering the discipline of labourers, as it affects labourers' productivity due to the waiting period for replacements and the time it takes for the team to become effective again. Dozzi and AbouRizk (1993) identified the six top reasons for absenteeism in the construction environment as shown in Table 6.6.

Table 6.6: Top six reasons for absenteeism (Dozzi & AbouRizk, 1993)

Order of importance	Reason for absenteeism
1	Personal or family illness
2	Overall management is poor
3	Supervision on poor standard
4	Travel distance from house is long
5	High rework amount
6	Working conditions are unsafe

Concluding from Table 6.6, five of the six main reasons for absenteeism are partially controllable issues. Therefore, it is important for management to identify and manage these factors to maintain high labour effectiveness.

Turnover of workers on-site is another factor that influences labour productivity in a negative way and the cost is estimated at 24 person-hours for each resignation (Intergraph Corporation, 2012). Table 6.7 shows the reasons for *turnover* according to the study by Dozzi and AbouRizk (1993).

Table 6.7: Reasons for turnover (Dozzi & AbouRizk, 1993)

Order of importance	Reason for turnover
1	Tools and equipment are inadequate
2	Surveys of on-site work by owner are excessive
3	Planning is poor
4	Overall management is poor
5	Supervision not up to standard
6	Another job offers overtime
7	Relationship with boss is unsatisfactory

6.2.2.7 Summary of labour effectiveness

This section has covered factors influencing labour productivity on a construction project, categorised under labour effectiveness. As mentioned, labour effectiveness related factors focus on the labourer as an individual and how certain changes in the work environment affect the productivity of the labourer.

The precast manufacturing environment is considered as a controlled environment, as discussed in Section 2.1.2.1. Therefore, productivity-influencing factors such as the *learning curve* or *"unlearning" curve* are not considered to be such high risks as in the in-situ construction environment due to the repetitive or systematic nature of the precast industry and the fact that labourers in the in-situ construction environment are being more exposed to unfamiliar circumstance. Also, the de-motivating factors shown in Table 6.4 should receive high priority in the in-situ construction environment due to the latter supposition. According to PMBOK, as discussed in Section 2.4.4, labour motivation is an important factor in the construction industry, thus mitigating de-motivating factors are important to consider in the in-situ construction environment (Guide, 2001).

The work environment is another productivity-influential factor addressed in this section. Considering the description of this factor in Section 6.2.2.4, it is expected that it will have a higher influence in the in-situ construction environment. This is partly due to the weather not playing a considerable role in the precast environment, as the manufacturing is generally done in an enclosed environment.

Physical limitations such as *fatigue* of labourers are considered important in both industries. However, the nature of in-situ construction requires more physical labour, as the precast manufacturing industry is more mechanised. The precast manufacturing industry is also considered to present a safer working environment than in-situ construction, since all the work is done on ground level. This also proved to be a considerable factor affecting labour effectiveness. The influence of these factors on both environments, as experienced by individuals from the South African industry, is discussed in the following chapter.

6.2.3 Material timeliness

Hendrickson and Au (2008) stated that effective handling of material can reduce project costs. This section will however focus on how material and the availability thereof influence productivity. Project productivity does influence project cost and thus these are considered to go hand in hand. The areas that will be discussed in this category include handling, site layout and procurement scheduling.

6.2.3.1 Handling

Tool shortage is one of the identified factors which can influence productivity in a construction project. This occurs when the tools needed are unavailable or inadequate to conduct the required tasks (Hendrickson & Au, 1989). Inadequate tool usage has been identified as the main reason for absenteeism (Table 6.6). However, it also plays an important role in the timeliness at which tasks are performed. Materials and equipment which are not placed in suitable positions also result in lost time, due to its negative effect on productivity. This factor should be dealt with by management, as it is an unnecessary occurrence which can be mitigated through providing labourers with adequate information as how to use and where to place material and equipment after it is used.

According to studies conducted in the Japanese construction industry, two-way communications proved to improve productivity in the industry. Therefore a conclusion can be drawn that timely and open communication amongst labourers and between labourers and supervisors will result in better material handling.

6.2.3.2 Site layout

An effective *site layout* can increase productivity on-site by increasing efficient timing and the convenience of site access. Effective site layout is achieved through efficient planning at an early stage of the project's lifecycle, which ensures that all factors are taken into account. Environmental issues, site access points, and the different trades present should receive special attention and should be synchronized with the schedule to ensure that the site operates effectively. Site offices, sanitary facilities and lunch and tea rooms should be placed strategically to ensure that no extra time is lost while traveling between these areas and the work place and to minimise safety issues such as theft and 'brassing' (Intergraph Corporation, 2012).

6.2.3.3 Procurement scheduling

Procurement should be done in a strategic sequence to ensure that risks regarding materials on-site are minimised and that the procurement is done at the best possible time (Sun, Liu & Lan, 2010). Material Procurement Planning (MPP) is described by Sun *et al*. (2010) as a material-specific method of procurement scheduling which is useful in lowering material costs, as the material prices tend to fluctuate over time. MPP can also be used to minimise work flow disruptions or waiting-time due to unavailability of materials (Sun, Liu & Lan, 2010).

6.2.3.4 Summary of material timeliness

In the category of material timeliness three main factors were identified which have an influence on construction productivity. These factors are also considered to be the responsibility of management as in Section 6.2.1.

Tool shortage was one of the identified factors and the main reason for absenteeism in the construction industry. It is considered relevant in both the in-situ construction and precast manufacturing industries but is expected to have a greater consequence in the precast manufacturing industry since this industry operates as a factory and tool and material shortage will bring the procedures to a halt.

A practical and effective *site layout* also proved to be an important factor to optimize productivity but it should not be done in such a manner that it negatively affects the project cost. In the case of the precast manufacturing plant, this factor has inevitable importance due to the nature of this industry i.e. if time is lost due to the site layout the time will be lost repetitively.

Well-implemented procurement plans can enable resources to be managed effectively, which will have a positive influence on productivity and result in reduced project time and risks. This factor is considered of high importance in both industries. Altogether, material timeliness seems to be of more importance to the precast manufacturing industry. The importance of material timeliness in the in-situ construction industry greatly depends on the stage of the project.

6.3 Conclusion

This chapter has defined general productivity and labour productivity through a brief overview of various explanatory productivity models. A labour productivity comparison based on the *activity-orientated model* concluded that in-situ and HCC have labour productivity rates of 0.217 m^2/h and 0.303 m^2/h respectively. Thus, considering the activity compared (floor systems), HCC has a higher labour productivity rate than in-situ, concluding that HCC utilizes the labour in a more effective manner than in-situ.

The second objective of this chapter was to identify the factors influencing labour productivity in a construction project. However, Dozzi and AbouRizk (1993) mentioned that to better understand productivity in the construction environment, the whole system needs to be considered, since factors which are not directly related to labour can influence the productivity of labourers.

Various influential factors have been identified and discussed throughout this chapter. These factors and their relevance and importance in the South African construction and precast industry will be investigated through a thorough risks analysis in the following chapter. The risk analysis will address the importance of all the identified productivity influencing factors in both the on-site and precast manufacturing construction industries.

CHAPTER 7

7 RISK ANALYSIS-FACTORS INFLUENCING LABOUR PRODUCTIVITY

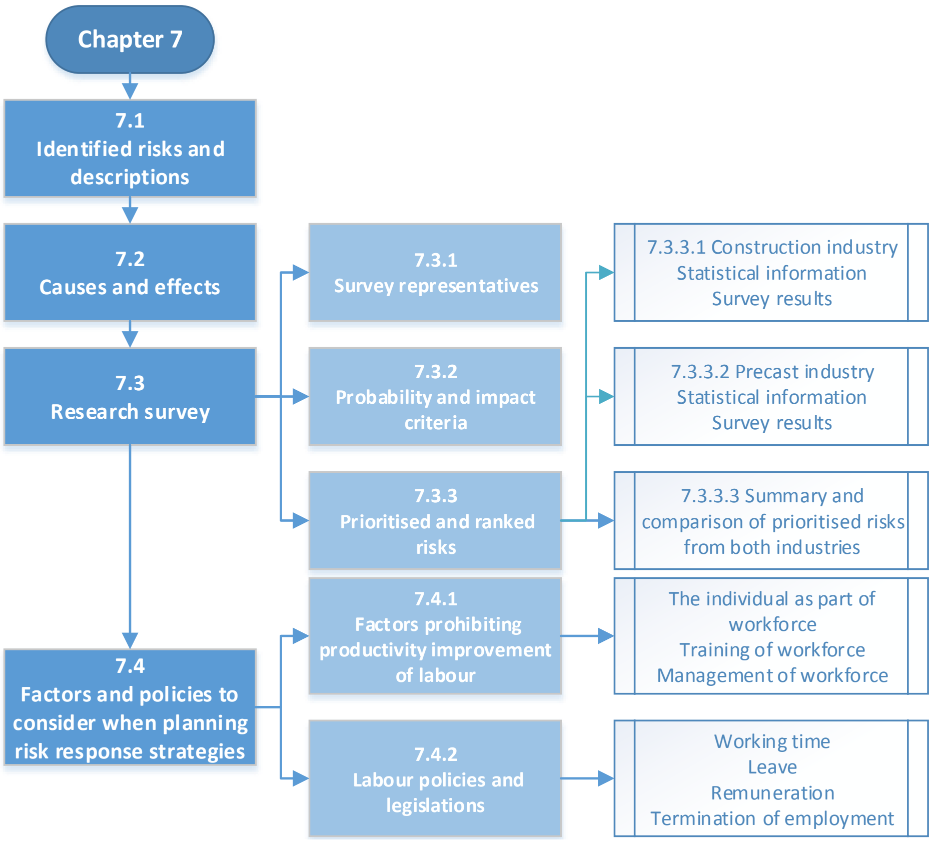
In the previous chapter an investigation was carried out to investigate factors influencing productivity in the construction environment. It was decided that a thorough risk analysis should be conducted on these influencing factors to provide a better understanding of the possible impact these factors have on the on-site activities of construction projects in South Africa. Also, the impact of these factors in the South African precast manufacturing environment will be investigated through a similar risk analysis.

Note: The in-situ construction environment refers to all activities conducted on-site.

The factors identified in the previous chapter were considered as possible labour risks influencing the in-situ construction environment and the precast manufacturing environment. These factors were incorporated into a survey which was sent to clients, consultants, contractors and precast manufacturers from the South African construction industry. This survey will not only rank the identified risks but will provide information regarding importance of labour in both environments.

The objectives of this risk analysis were to:

- Identify the importance of the respective factors in terms of cost, time and quality on the in-situ construction environment and on the precast manufacturing environment.
- Compare the results of both environments.
- Identify factors to consider when preparing risk response strategies.



The global construction environment involves a variety of possible risks, some complex and others simple. Project managers are liable for the identification and mitigation of the risks involved in a project. This can be done by the use of a risk register. A risk register includes the identification of the risks, a risk breakdown structure, prioritisation of risks, and the possible response strategies and mitigating actions. This chapter investigates the risk of the productivity-influencing factors identified in Chapter 6 on both the in-situ construction environment and the precast manufacturing environment. These factors all have a direct influence on productivity, which ultimately affects projects in terms of cost, time and quality. Therefore, it was decided that a thorough risk analysis will give perspective on the influence of these factors on the productivity of both considered environments. The ranking of these risks in both environments will also bring perspective on the importance of labour-related risks in both environments.

7.1 Identified of risks and descriptions

The productivity-influencing factors identified in the previous chapter are considered as risks in the construction environment. These factors were identified through investigating various literature sources of which the investigation of Dozzi and AbouRizk (1993) formed the foundation. Some of these factors were also verified during the interviews conducted. Although these interviews were mostly focussed on the *socio-economic aspect* of labour, certain conversations covered some of the *productivity issues*.

Table 7.1 shows all these risks (R_i) in their respective categories as explained in Chapter 6. A description of each risk is given to provide a better understanding of each risk and its possible effect on labour productivity and the productivity of the project.

Table 7.1: Identified risks and their descriptions

Category	(i)	Risk (R_i)	Description
Management Practices	1	**Overtime**	Working extended work hours and days.
	2	**Crew size inefficiency**	Altering optimal crew size by adding or removing crew members.
	3	**Over-manning**	Too many labourers are assigned to one task.
	4	**Late crew build-up**	Planned project labour teams are altered due to required labourers not being available.
	5	**Start/stop**	Stops in the project such as public holidays, pauses between activities etc.
	6	**Errors and omissions / Rework**	Errors and mistakes made during construction which require rework.
	7	**Stacking of trades**	Operations take place within physically limited space with other contractors, resulting in congestion of personnel.
	8	**Concurrent operations**	This is the effect of adding operations to any sequence of operations that has already been planned, without a gradual and controlled implementation of additional operations.
	9	**Logistics**	Inefficient planning can cause material delivery problems. This can disrupt the flow of workers due to forced stoppages. Labourers struggle to find rhythm again.
	10	**Security check**	Security checks need to be conducted to control labourers and to protect tools and materials.

	11	**Ripple effect**	Unforeseeable effects of a change that occurred during construction.
	12	**Dilution of supervision**	This occurs when the supervision is required to manage unforeseen events and is distracted from productive, planned, and scheduled work.
	13	**Holidays**	Labourers working during the holidays.
	14	**Shift work**	This is when work is performed at any time other than the first shift or the morning shift of a work day.
Labour Effectiveness	**15**	**Fatigue**	Labourers do not have the required energy to perform tasks.
	16	**Morale and attitude**	Spirit and motivation of workers can affect how they work.
	17	**Learning curve**	This refers to the period of orientation when new labourers are employed or when unskilled labour is used.
	18	**Reassignment of manpower**	When workers are reassigned to another activity or project.
	19	**Hazardous working area / Safety**	This occurs where labourers work in a hazardous area that requires special safety equipment and clothing. Restrictions can limit workers and the setup of special safety requirements can consume valuable time.
	20	**Absenteeism and turnover**	Absenteeism during project requires new labourers to be employed or reassigned from other crafts.
	21	**Weather and seasonal changes**	Performing work in a change of season, temperature zone, or climate change resulting in work performed in either very hot or very cold weather.
Material Timeliness	**22**	**Tool and equipment shortage**	This is caused when there is insufficient quantity or quality of tools and equipment to meet the needs of the amount of labourers on a project.
	23	**Site access / Site layout**	This is a result of interferences to the convenient or planned access to work areas. This can be due to blocked stairways, roads, walkways, insufficient man-lifts, or congested work sites.

7.2 Causes and effects of identified risks

The labour-influencing factors identified in the previous chapter all pose a threat to construction projects, as it has a negative influence on the productivity as well as on the labourers. Therefore, these factors are considered as risks in this chapter. The causes and effects of these risks (R_i) are described in Table 7.2

Table 7.2: Causes and effects of the identified risks (Dozzi & AbouRizk, 1993; Intergraph Corporation, 2012; Lim & Alum, 1995; Sun, Liu & Lan, 2010)

Risk		Cause	Effect
1	Overtime	Work is behind schedule, labourers are required to work in excess of normal 40 hours per week.	Decrease labour effectiveness and output rate.
2	Crew size inefficiency	Workers are added or removed from original crew size.	Breaks up original team efforts and rhythm.
3	Over-manning	More labourers are assigned to tasks than required.	Loss of productivity due to an imbalance between acceptable and highest productivity level.
4	Late crew build-up	Crew members are altered from what was planned initially.	Slower build-up of manpower thus lowers labour productivity.

5	Start/stop	Suspension of work due to breaks, public holidays, pauses between activities etc.	Workers struggle to get back into routine; therefore a drop in productivity occurs.
6	Errors and omissions / Rework	Due to dilution of supervision or the use of inadequate labour.	Lower morale of labourers, which leads to an unproductive team.
7	Stacking of trades	More than one trade in the same physical space due to bad scheduling.	Creates congestion and workspace becomes unsafe and unproductive.
8	Concurrent operations	Unscheduled tasks occur which require immediate attention.	Higher workload in the same planned schedule lowers workers' motivation, affecting their productivity.
9	Logistics	Insufficient planning.	Can prevent, delay or disrupt normal material workflow to a work area, warehouse or laydown yard, therefore resulting in delays.
10	Security check	Workers entering or leaving the area, workers "brassing" in and out, toolbox checks, checks for drugs and weapons.	Productivity is negatively influenced by security measures and this results in time loss.
11	Ripple effect	Unforeseen change occurs.	Influences productivity of project.
12	Dilution of supervision	Increase in manpower, work areas, or project size without an increase in supervision.	This negatively influences labour productivity as well as project productivity.
13	Holidays	Project is behind schedule and needs to regain some time to prevent penalties.	Labourers' morale is affected due to being away from families or working instead of enjoying a well-earned holiday. Ultimately affecting their productivity.
14	Shift work	The last shift is shorter than the morning shift.	Workers struggle to pick up where they left off, which results in lowered productivity.
15	Fatigue	Prolonged or unusual physical exertion. Also due to inadequate supplementation.	Labourers are tired which results in them being unproductive.
16	Morale and attitude	There are various factors which influence labourers morale and attitude (Table 6.4)	Labourers with low morale levels tend to work less productive.
17	Learning curve	Contractors are required to use local labour during public projects. These local labourers are usually unskilled.	Unskilled labour requires time to gain adequate experience to work more effectively, in the meanwhile the learning process results in time loss.
18	Reassign-ment of manpower	After or during projects labourers are reassigned to other projects where they are required.	Labourers experience unexpected or excessive changes, losses caused by move-on or move-off reorientation, which all result in productivity loss.
19	Hazardous working area / Safety	Some construction projects tend to have hazardous areas such as excessive heights or rough oceans etc.	Special safety equipment and restriction slow down labourers, which result in productivity loss.
20	Absentee-ism and turnover	Labourers are ill, family loss, poor management and supervision, long travel distance etc. (Table 6.6)	Lower productivity due to crew members waiting for replacements.
21	Weather and season changes	Excessive heat or cold, high humidity, snow, rain etc.	When labourers perform work outside the optimal weather conditions their productivity level lowers.
22	Tool and equipment shortage	Theft or poor management and supervision.	Low productivity due to work being performed by inadequate equipment. Also, waiting for adequate tools consumes time.
23	Site access / Site layout	Insufficient planning or poor execution of plans due to poor supervision and management.	Delayed material drop-off, low manoeuvrability on site. These result in time loss and low productivity.

These risks were ranked using a survey which was sent to practitioners from industry. The next section will discuss the survey and how the respondents prioritised the risks for both the in-situ construction and precast manufacturing environments.

7.3 Research survey

The prioritisation of risks is an important step in a risk analysis. This feature enables the identification of the top-ranked risks which should receive high priority when managing a project. The information regarding the impact and probability of the respective risks were obtained through a research survey. This survey is discussed in this section.

7.3.1 Survey representatives

The need to manage risks is relevant to all professionals and groups (clients, consultants, contractors, precast manufacturers, etc.) in the construction industry, as they are all concerned with cost, time and quality (Akintoye & MacLeod, 1997). In this study the need to manage labour productivity related risks are considered as top priority. The importance of labour-related risks was highlighted by Kriel (2013) who conducted a survey which identified labour productivity as the key area of concern in the South African construction environment.

The survey in this study concentrated on two categories of respondents: in-situ construction industry (client, consultant and contractors) and the precast manufacturing industry, as it compares labour in the two environments.

The sample survey included a total of 53 individuals from well-recognized firms in South Africa comprising 46 from the in-situ construction environment and eight from the precast manufacturing environment. 85% of individuals from the in-situ construction environment were selected from a list of delegates from the Construction Management Programme held annually at Stellenbosch University as discussed in Section 3.3. The other 15% of the individuals were randomly selected. The eight individuals from the precast industry comprised four individuals which were interviewed in Chapter 4, whereas the other four individuals were randomly selected from relevant precast manufacturers in South Africa.

The overall response to the survey was comprised of 38 individuals from the in-situ construction environment and 5 from the precast manufacturing environment, which represents a total response rate of 80%. The proses consisted of an email informing individuals about the survey, the actual survey, and a reminder 1 week later to those individuals that had not responded to the survey request. The response rate is considered high for a construction industry questionnaire survey and cannot be regarded as biased. Moser and Kalton's (1971) asserted that the results of a postal survey are considered biased and of little value if the response rate was between or lower than 30-40%, depending on the sample size.

The survey was mainly completed by individuals in management positions in their respective firms. The experience of the respondents from both the in-situ construction and precast manufacturing environments is shown in Figure 7.2 and Figure 7.3 in Sections 7.3.3.1 and 7.3.3.2 respectively. The average experience of the individuals from both industries is 17.5 years and 27.5 years respectively.

On the basis of position, work experience, and educational and professional background, it can be concluded that the respondents have adequate knowledge of the subject of productivity influencing factors on the considered environments.

Individuals from various occupations participated in the survey. Figure 7.1 shows the breakdown of the total 43 individuals whom participated in the survey. As shown, the majority of respondents were contractors. This ensures higher survey accuracy as contractors have first-hand experience with these types of productivity factors. Although, it was considered that the opinion of individuals from a client's and a consultant's perspective could contribute to the value of the survey.

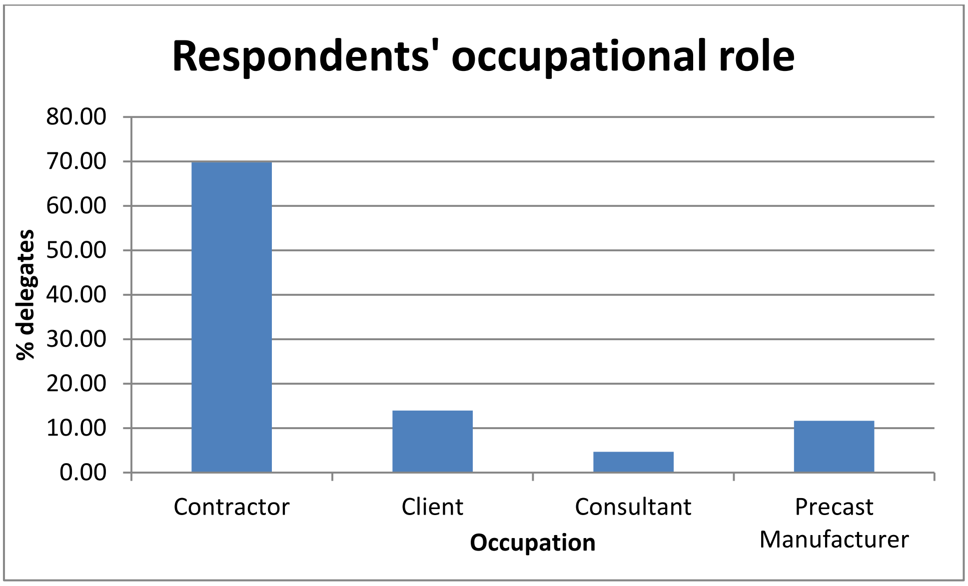


Figure 7.1: Respondents' occupational role

7.3.2 Probability and impact criteria

The questionnaire survey presented to respondents (Appendix D) required of each individual to rate each of the risks identified in Section 7.1 in terms of its cost (C_d), time (T_d) and quality (Q_d) impact on a construction project as well as the probability (P_d) of the risk occurring during the project. This enabled the investigation to identify the impact area with the highest level of concern. The rating was done according to the criteria provided in Tables 7.3 and 7.4.

It was realised that the survey respondents were from different backgrounds and could possibly place a different value on the importance of impact areas and probabilities of various risks, due to different size projects conducted by the various respondents. Therefore, it was decided to use criteria which ranked the impacts according to a percentage of the project of reference of each participant (Tables 7.3 and 7.4). Thus it partially mitigated the inconsistency of the different backgrounds amongst respondents.

Table 7.3: Risk assessment table explaining the impact of risk on cost, time and quality of a project (Guide, 2001)

Impact (I_G)	**Very low/0.05 (1)**	**Low/0.10 (2)**	**Moderate/0.20 (3)**	**High/0.40 (4)**	**Very high/0.80 (5)**
Cost (I_C)	Insignificant cost increase	<10% cost increase	10-20% cost increase	20-40% cost increase	>40% cost increase
Time (I_T)	Insignificant time increase	<5% time increase	5-10% time increase`	10-20% time increase	>20% time increase
Quality (I_Q)	Quality barely affected	-	Quality reduction requires client's approval	-	-

Table 7.4: Risk assessment table explaining the probability of risk occurring (Guide, 2001)

	Very low/0.10 (1)	**Low/0.30 (2)**	**Moderate/0.50 (3)**	**High/0.70 (4)**	**Very high/0.90 (5)**
Probability (P)	Occurs rarely	Improbable	Medium	Real Chance	Almost Certain

Table 7.5 shows the probability-impact matrix which is used as the criterion to rank the respective risks according to their effect. The effect (E) of a specific risk (R_i) is determined as shown in Equation 7.1.

$$E(R_i) = P_A(R_i) \times I_{MAX}(R_i) \quad (7.1)$$

Where:

E = Effect as function of R_i

P_A = Average probability of a risk occurring during project (Equation 7.2)

I_{MAX} = Maximum of the average impact of a risk on project (Equation 7.6)

In this risk analysis the respondents (n) rated 23 risks (R_i). The average probability of a risk (R_i) is represented by P_A, where the average cost, time and quality impacts of a risk are represented by I_C, T_C, and Q_C respectively. The number of respondents was 38 for the in-situ construction industry and five for the precast manufacturing industry. In the following equations 38 will be used as the number of respondents; however, it should be noted that only four respondents were used when determining the values for the precast construction industry, since one response was ignored. The average of the respective impact areas and probability of each risk (R_i) were determined as shown by Equations 7.2 to 7.5.

$$P_A(R_i) = \sum_{d=1}^{38} P_d(R_i)/38 \quad (7.2)$$

$$I_C(R_i) = \sum_{d=1}^{38} C_d(R_i)/38 \quad (7.3)$$

$$I_T(R_i) = \sum_{d=1}^{38} T_d(R_i)/38 \quad (7.4)$$

$$I_Q(R_i) = \sum_{d=1}^{38} Q_d(R_i)/38 \quad (7.5)$$

Equation 7.6 below was used to determine the maximum impact of I_C, I_T, and I_Q which is used to predict the effect (E) on each respective risk as shown in Equation 7.1.

$$I_{MAX}(R_i) = Maximum\left(I_C(R_i), I_T(R_i), I_Q(R_i)\right) \tag{7.6}$$

The effects of the respective risks ($E(R_i)$) as determined by Equation 7.1 are tabled in descending order. The risk priority is determined from Table 7.5 and the risk response strategy is described by Table 7.6 in the following section.

Table 7.5: Probability and impact matrix (Guide, 2001)

Probability (P)	**Impacts (I)**				
	0.05	**0.10**	**0.20**	**0.40**	**0.80**
0.90	0.05	0.09	0.18	0.36	0.72
0.70	0.04	0.07	0.14	0.28	0.56
0.50	0.03	0.05	0.10	0.20	0.40
0.30	0.02	0.03	0.06	0.12	0.24
0.10	0.01	0.01	0.02	0.04	0.08

7.3.3 Prioritised and ranked risks

The ranked risks according to the survey are shown in Table 7.7 and Table 7.8 for the in-situ construction and precast manufacturing industries respectively. Each of the risks' probabilities, impacts and overall effect is shown in the tables. The highest-ranked impact for each respective risk is shaded in light red. This impact (I) and the corresponding probability (P) of each risk are used to calculate the effect (E) according to Equation 7.1. This effect (E) is used to rank the risks according to their importance and also to represents the risk response as explained in Table 7.6.

Table 7.6: Risk response criteria (Guide, 2001)

Trigger	**Effect**
Action	>= 0.18
Monitor	>=0.06 & < 0.18
Accept	< 0.06

A response strategy should be implemented for the risks, requiring an action according to Table 7.6. The response strategy can be done either by transferring the risks to another party, by accepting the risk and its possible consequences, or by mitigating the risk (Guide, 2001). Various risks have different owners, where in most cases these owners are in management positions. It is the responsibility of the owner to choose an adequate response strategy for the respective risks. These identified and ranked risks can serve as a guideline for project managers from both the in-situ construction and precast manufacturing industries. However, it should be considered that these risks are not project specific but rather from a general point of view and therefore should serve only as a guideline.

7.3.3.1 In-situ construction environment

The 38 respondents from the in-situ construction industry had an average of 17.5 years of experience in the civil engineering industry. The experience breakdown in number of years of the in-situ construction industry survey is shown in Figure 7.2.

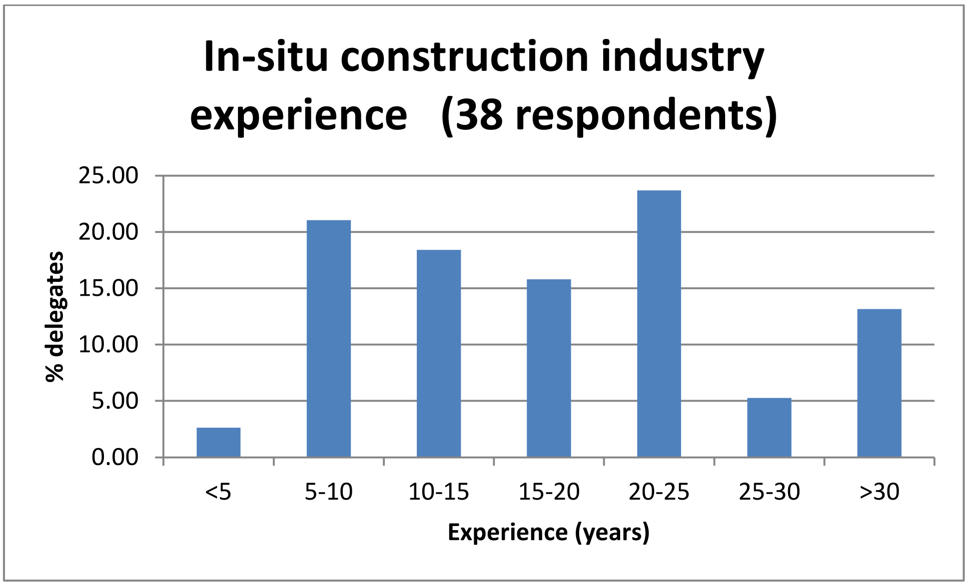


Figure 7.2: Construction industry experience breakdown

As mentioned earlier, the respondents were required to rank the impacts and probability of each risk on a scale from 1-5 as shown in the criteria (Table 7.3 and Table 7.4). The averaged prioritised risks as ranked by the 38 respondents of the in-situ construction environment are shown in Table 7.7. The standard deviation of the probability and impacts of the respective risks are also shown in Table 7.7 and are also compared to one another by data bars. The data bars are shaded green in the probability cells and light blue in the impacts cells (Table 7.7 and Table 7.8). The maximum of the data bars are 0.9 and 0.8 for the probability and impacts respectively, as these are the upper limits of the standard deviations.

These standard deviations give an indication of the distribution of the responses for the various impacts and probabilities of the respective risks. Thus, a small standard deviation represents a narrow distribution, which indicates that the responses were coherent. In the case where responses are coherent, the results are expected to have higher accuracy.

The standard deviation of the probability and impacts shown in Table 7.7 is relatively constant. The probabilities' highest standard deviation is 0.25 which is considered to be relatively high but, considering the type of survey, this is assumed to be acceptable since the respondents are from different types of construction industries and are subject to different work environments. The standard deviation of the impacts was also relatively constant throughout the survey with a maximum of 0.3.

Table 7.7: Prioritised and ranked risks in the in-situ construction industry

Rank	Risk	Probability		Cost		Time		Quality		Effect
		(P_d)	Std. dev (σ)	C_d	Std. dev (σ)	T_d	Std. dev (σ)	Q_d	Std. dev (σ)	
1	Errors and omissions / Rework	0.64	0.19	0.54	0.25	0.49	0.26	0.50	0.27	**0.34**
2	Fatigue	0.56	0.23	0.31	0.29	0.29	0.21	0.49	0.24	**0.27**
3	Overtime	0.66	0.21	0.41	0.18	0.25	0.22	0.22	0.19	**0.27**
4	Learning curve	0.67	0.21	0.33	0.22	0.35	0.20	0.39	0.27	**0.26**
5	Hazardous working area / Safety	0.56	0.24	0.41	0.29	0.40	0.24	0.26	0.22	**0.23**
6	Absenteeism and turnover	0.58	0.23	0.37	0.30	0.40	0.27	0.39	0.29	**0.23**
7	Morale and attitude	0.60	0.21	0.31	0.23	0.31	0.23	0.39	0.25	**0.23**
8	Over-manning	0.53	0.21	0.42	0.25	0.22	0.16	0.21	0.21	**0.22**
9	Holidays	0.51	0.23	0.44	0.27	0.25	0.20	0.21	0.20	**0.22**
10	Logistics	0.53	0.21	0.41	0.27	0.42	0.26	0.20	0.16	**0.22**
11	Late crew build-up	0.55	0.19	0.36	0.27	0.38	0.25	0.31	0.21	**0.21**
12	Tool and equipment shortage	0.52	0.25	0.40	0.26	0.40	0.24	0.40	0.28	**0.21**
13	Stacking of trades	0.54	0.20	0.38	0.28	0.35	0.23	0.34	0.25	**0.21**
14	Dilution of supervision	0.51	0.23	0.29	0.17	0.30	0.22	0.40	0.29	**0.20**
15	Start/stop	0.55	0.22	0.28	0.24	0.31	0.23	0.20	0.20	**0.17**
16	Crew size inefficiency	0.55	0.20	0.30	0.20	0.26	0.15	0.22	0.19	**0.16**
17	Site access / Site layout	0.46	0.20	0.31	0.24	0.35	0.25	0.16	0.14	**0.16**
18	Concurrent operations	0.53	0.18	0.26	0.17	0.30	0.20	0.23	0.24	**0.16**
19	Ripple effect	0.47	0.19	0.28	0.23	0.30	0.21	0.19	0.20	**0.14**
20	Reassignment of manpower	0.53	0.19	0.23	0.23	0.26	0.22	0.23	0.18	**0.14**
21	Weather and season changes	0.50	0.22	0.20	0.16	0.22	0.19	0.20	0.20	**0.11**
22	Shift work	0.44	0.19	0.21	0.13	0.22	0.19	0.19	0.18	**0.10**
23	Security check	0.39	0.24	0.18	0.17	0.21	0.20	0.09	0.06	**0.08**

Table 7.7 shows the ranked risks as rated by the 38 respondents from the in-situ construction industry. According to this survey, 14 of the 23 identified labour productivity influencing factors are considered as high priority construction risks. This supports the high importance of labour productivity in a construction project. The subsequent 8 risks were considered as medium priority and according to the response criterion these risks should be monitored during construction projects. None of the risks were considered as "acceptable", according to the respondents. The high priority risks as identified by the respondents were *rework, fatigue, overtime, learning curve, hazardous working area and safety, absenteeism and turnover, morale and attitude, over-manning, holidays, logistics, late crew build-up, equipment shortage, stacking of trades, and the dilution of supervision*. The highest ranked risks are discussed below.

Table 7.2 shows that the cause of *rework* is due to dilution of supervision or the use of inadequate labour. Dozzi and AbouRizk (1993) mentioned that *rework* can also be caused by poor instructions to labourers and *incorrect tools* and *inadequate materials. Rework* is expected to negatively influence project costs, as the time and resources spent on this work directly reduces the contractor's expected profits. This is supported by the survey as the cost impact is ranked highest amongst the risk's impacts. *Rework* according to Table 6.4 in the previous chapter is considered to be a major de-motivator for labourers in the civil engineering industry and the morale of labourers is ranked seventh in Table 7.7. Thus, by mitigating this risk, the morale of labourers will also improve. According to Dozzi and AbouRizk (1993) *rework* is the responsibility of management, and through sufficient planning, adequate designs and construction drawings, and training to both labourers and supervisory individuals *rework* can be minimised. *Rework* should also be controlled during the construction phase (Dozzi & AbouRizk, 1993).

Fatigue was the second highest ranked risk in the in-situ construction environment. It can have extensive quality impacts on a construction project as shown by its high impact rating in Table 7.7. *Fatigue* is mainly caused by prolonged or unusual physical exertion and possibly inadequate supplementation. Labourers should receive adequate resting periods to maintain productivity (Oglesby, Parker & Howell, 1989). Also in cases where labourers do not receive adequate supplementation, the contractor can provide them with some nutrition as possible mitigation to prevent labourers from being fatigued. This risk received a high probability rating, meaning that *fatigue* amongst labourers is a usual occurrence in the construction industry. This risk has a direct influence on the standard of living and the alleviation thereof should be considered as a priority by project managers. Hanekom (2011) mentioned that in-situ construction is physically exhausting on labourers compared to HCC, therefore *fatigue* is expected to be a lower priority risk in the precast environment and will be verified in Section 7.3.3.2.

Overtime was ranked third by the 38 respondents and is the result of projects running behind schedule, ultimately requiring of labourers to work more than the normal 40 hours per week. *Overtime* is another factor that de-motivates labourers and also contributes to *fatigue*; therefore through proper management both these risks can be reduced, which will also contribute to the motivation of labourers. To best mitigate this risk, management should focus on setting up realistic project schedules and assign suitable supervisors to manage these schedules (Dozzi & AbouRizk, 1993).

During public projects contractors are required to employ local labour as far possible. Local labourers in South Africa are often unskilled and require training and guidance to perform certain tasks, since they have no or little experience (Chapter 4). This phenomenon is known as the *learning curve*, as discussed in Section 6.2.2.1, Figure 6.4. The highest impact area of this risk is quality, which can be expected with the use of unskilled labour. This is also supported by a survey conducted by Kriel and Wium (2014) where the use of unqualified workforce was ranked as the second highest area of concern in the construction industry. These unskilled labourers should be managed in such a manner that they do not have such a significant effect on project productivity. Byleveldt (2015) mentioned that their company developed a construction technique which enables them to use unskilled labour with similar productivity as when using more skilled labour with the conventional construction method.

Chapter 5 also concluded that the use of HCC enabled low skilled labourers to perform similar tasks to semi-skilled labourers in the conventional construction method. The latter argument only applies to on-site activities.

Morale and attitude of labourers are also considered a high priority risk according to Table 7.7. Except for *rework* and *learning curve*, the *stacking of trades, over-manning* and *tool availability* are all high priority risks which according to Table 6.4 in the previous chapter are considered as de-motivators of labourers. Ng *et al*., (2004) mentioned that by removing de-motivators, labourers will be motivated. Therefore, it is important to consider the mitigation of these risks, not only because of their individual importance but also due to their effect on the morale of labourers.

Not all high priority risks have been discussed in this section, but a brief summary of all the identified risks were given in Chapter 6.

7.3.3.2 Precast manufacturing industry

The survey of the precast manufacturing industry consisted of 5 respondents with an average experience of 27.5 years in the precast manufacturing industry. This is considered to be a high experience figure and thus, although the number of respondents is low, their opinion is of highly valued. After the data analysis it was noticed that one of the respondent's rankings significantly increased the standard deviations of the impacts. The higher standard deviation implies that there are less coherent responses amongst respondents. Due to the small sample size, this individual's rating significantly influenced the number of high priority risks in the precast manufacturing industry. It was therefore decided to investigate the extent of the influence of this participant's opinion to determine whether or not the opinion should be used to determine the survey results.

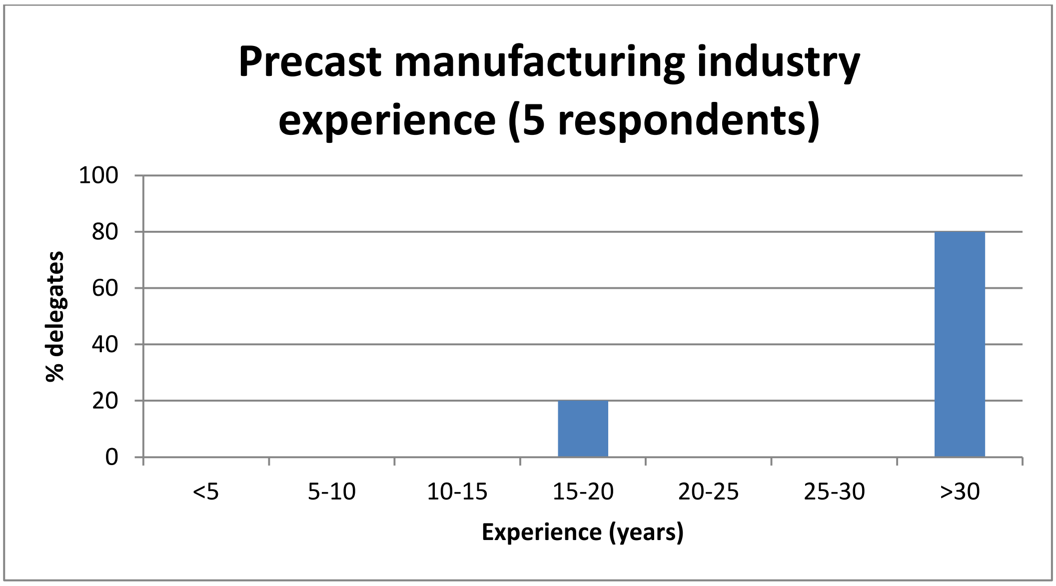


Figure 7.3: Precast manufacturing industry experience breakdown

The investigation revealed that, when including the individual, no significant difference occurred in the probability ratings. However, the impact ratings were significantly influenced, where 83% of the cost, 65% of the time and 57% of the quality impacts were ranked higher by this individual than the average of the other 4 respondents. The standard deviations of the respective impacts when considering the opinion of the individual were increased by an average of 39%, 25% and 23%. The individual ranked all the risks as high priority, except for *shift work*. It is quite improbable that all the identified risks can have such an extensive effect on the precast manufacturing industry.

This individual has been subject to different manufacturing conditions for the last year and a half, which required the firm to manufacture unfamiliar elements under new legislative requirements. It could be due to these unfamiliar conditions that the individual considered the impacts of the various risks to be more severe. The ranking order of the risks had an insignificant change when considering the individual's opinion; however, the effect of the risks were greatly influenced (by including the individual's opinion resulted in the 15th ranked risk to have an effect of 0.18). Therefore, it was decided to ignore the individual's opinion. The survey result of this individual is provided in APPENDIX F for any further evaluation.

Table 7.8: Prioritised and ranked risks in the precast industry

Rank	Risk	Probability		Cost		Time		Quality		Effect
		(P_d)	Std. dev (σ)	C_d	Std. dev (σ)	T_d	Std. dev (σ)	Q_d	Std. dev (σ)	
1	Tool and equipment shortage	0.65	0.38	0.45	0.25	0.55	0.30	0.23	0.20	**0.36**
2	Holidays	0.65	0.38	0.35	0.30	0.48	0.38	0.14	0.18	**0.31**
3	Stacking of trades	0.55	0.25	0.38	0.31	0.53	0.34	0.16	0.16	**0.29**
4	Site access / Site layout	0.60	0.38	0.45	0.40	0.45	0.25	0.19	0.15	**0.27**
5	Over-manning	0.60	0.38	0.45	0.25	0.18	0.17	0.15	0.17	**0.27**
6	Learning curve	0.55	0.34	0.38	0.31	0.45	0.25	0.44	0.42	**0.25**
7	Late crew build-up	0.50	0.28	0.28	0.15	0.38	0.31	0.35	0.33	**0.19**
8	Logistics	0.45	0.34	0.35	0.10	0.40	0.28	0.09	0.08	**0.18**
9	Errors and omissions / Rework	0.55	0.25	0.31	0.18	0.26	0.17	0.23	0.20	**0.17**
10	Overtime	0.65	0.38	0.15	0.06	0.26	0.36	0.09	0.08	**0.17**
11	Morale and attitude	0.75	0.19	0.23	0.13	0.21	0.14	0.19	0.15	**0.17**
12	Absenteeism and turnover	0.45	0.34	0.18	0.15	0.30	0.34	0.36	0.33	**0.16**
13	Dilution of supervision	0.50	0.33	0.10	0.00	0.28	0.15	0.19	0.15	**0.14**
14	Hazardous working area / Safety	0.75	0.19	0.15	0.06	0.09	0.08	0.09	0.17	**0.11**
15	Concurrent operations	0.40	0.12	0.18	0.15	0.28	0.15	0.25	0.37	**0.11**
16	Start/stop	0.60	0.35	0.16	0.08	0.13	0.09	0.13	0.08	**0.10**
17	Crew size inefficiency	0.50	0.28	0.15	0.06	0.11	0.06	0.09	0.08	**0.08**
18	Fatigue	0.45	0.25	0.15	0.17	0.08	0.03	0.13	0.09	**0.07**
19	Reassignment of manpower	0.40	0.35	0.15	0.06	0.13	0.05	0.10	0.07	**0.06**
20	Security check	0.40	0.38	0.10	0.00	0.14	0.08	0.05	0.00	**0.06**
21	Shift work	0.35	0.38	0.15	0.17	0.15	0.17	0.06	0.03	**0.05**
22	Weather and season changes	0.50	0.37	0.06	0.03	0.10	0.07	0.08	0.03	**0.05**
23	Ripple effect	0.30	0.40	0.15	0.06	0.15	0.06	0.06	0.03	**0.05**

The standard deviation of the probabilities in Table 7.8 was relatively high, which implies that there was some disagreement between the respondents on the probability rating of the risks. The top 8 risks had relatively high impact standard deviations whilst the impacts of the remaining risks had low standard deviations. This implies that there were disagreement between the respondents regarding the impact rating of the high priority risks, but they were in agreement on the impact ratings for the medium and low priority risks, as the standard deviation shows coherent responses. The small standard deviation regarding the low and medium ranked risks implies that these rankings could be considered as accurate.

Table 7.8 shows the precast-manufacturing risks as ranked by the four respondents. Although the survey sample is small, they have an average experience of 27 years (ignoring one respondent) and according to the standard deviations of the lower-ranked risks these rankings can be assumed correct. Eight of the risks were ranked as high priority and should be addressed in the precast manufacturing industry. These eight risks were *tool and equipment shortage, holidays, stacking of trades, site access, over-manning, learning curve, late crew build-up,* and *logistics.*

The precast manufacturing industry operates similar to a factory, where uniform concrete elements are manufactured in a closed and controlled environment according to fixed procedures. Thus, *tool and equipment shortage* will directly result in loss of time on the critical path of the process. This is confirmed in Table 7.8, where the time impact has the highest rating. Not only is this identified as the highest ranked risk in the precast manufacturing industry but it is regarded as the main reason for *absenteeism* of labourers in the construction environment (Dozzi & AbouRizk, 1993). This type of risk should be mitigated and is considered as the responsibility of management.

Holidays are ranked as the second highest risk in the precast manufacturing industry. Thus, in the case where labourers work during holidays, their productivity is considered to be drastically influenced. The productivity impact is supported by the high time impact rating in Table 7.8.

Stacking of trades and *over-manning* are considered third and fifth highest risks in this industry. It is understandable that inadequate alterations to workforce will result in high productivity loss in the precast manufacturing plant, as the main advantage of a manufacturing plant is its ability to work at optimum efficiency with only the required resources.

Site access is a high ranked risk in the precast industry, as the placement of the concrete precast elements is done by crane. If there is inadequate crane access, delays will occur. The placement of elements is usually a rapid process (31.25m^2/h as shown in) which occurs on the critical path of a project. Therefore, delays due to site access can cause a significant increase in the expected placement time and ultimately on the project schedule.

Late crew build-up and the time spent on teaching basic skills to new labourers (*learning curve*) are both high priority risks in the precast manufacturing environment. These risks occur when the manufacturer employs new labourers, usually when new projects take place which require a higher production rate than produced by the normal workforce (not applicable when using the extrusion process). Another possible reason for the occurrence of these risks is when labourers are absent in critical stages of a project. Reasons for the absenteeism of labourers are discussed in Table 6.6 in the previous chapter.

Poor *logistics* was the lowest ranked high priority risk. The reason this risk is of high priority in this industry is because not only will the delay of material delivery disrupt the flow of work but it can also bring the whole manufacturing process to a halt. It is therefore important to conduct adequate planning and to check up on suppliers on a regular basis.

The subsequent 11 risks (Table 7.8) are considered as medium priority and should be monitored in the precast manufacturing industry to ensure that they do not become high priority risks.

7.3.3.3 Summary and comparison of prioritised risks of both environments

The risk rankings of the two environments are very different. Also, the in-situ construction environment has almost double the number of high priority risks than the precast manufacturing environment. None of the top 3 in-situ construction risks (*rework*, *fatigue* and *overtime*) are considered as high priority risks in the precast manufacturing industry. Due to the nature of the manufacturing process, it is expected that these factors should not have a great effect on the process. The top 3 precast manufacturing risks (*equipment shortage*, *holidays* and *stacking of trades*) were ranked 12th, 9th and 13th in the in-situ construction industry. Thus it is clear that the risk prioritisation differ significantly between these two environments.

Reviewing the type of risks of the three identified categories as shown in Table 7.1, five of the seven risks categorised under labour effectiveness are amongst the top seven ranked risks in the in-situ construction environment. Labour effectiveness as discussed in Section 6.2.2 covers the factors which focus on the labourers as individuals and the influence of their productivity on the project, while the other two categories cover management related factors which also affect the productivity of labourers.

Only one of the direct labour-related (labour effectiveness) risks are considered as high priority in the precast manufacturing environment. This finding reveals that the labourers are considered as a smaller risk in the precast manufacturing environment, while in the in-situ construction environment it is the opposite. This correlates to the different procedures in both environments, as precast manufacturing is a repetitive process which lowers the expectation of unforeseen human-related risks, but the in-situ construction environment always has new, unexpected challenges which influence the workforce. Therefore, in the in-situ construction environment there is more room for human-related errors. The latter argument is supported by the types of high priority risks of both environments as shown in Table 7.7 and Table 7.8.

7.4 Factors and policies to consider when planning risk response strategies

This section discusses factors and legislation which should be considered when planning to mitigate risks caused by the workforce. These factors are prohibiting productivity improvement and by considering these factors up front can enhance the mitigation process. Also, certain labour-related policies and legislation should be considered when planning mitigation strategies. These policies and legislation are discussed in this section.

7.4.1 Factors prohibiting productivity improvement of labour

Bardenhorst (1985) conducted a study on factors prohibiting productivity improvement in construction workers in South Africa. This reference serves as the foundation of this section.

7.4.1.1 The individual as part of the workforce

The individual is considered to be a restricting factor for productivity enhancements. Bardenhorst (1985) mentioned that 12% of the identified factors prohibiting productivity were related to the individual. These factors included the importance of accurate recruitment and selection and also the individual's willingness to be trained (Bardenhorst, 1985). According to the survey conducted, the use of unskilled labourers is ranked second and sixth respectively for the in-situ construction and precast manufacturing industries. These individuals are recruited by a community liaison officer (CLO), as discussed in Chapter 4. Thus it is important to use adequate CLOs who are well informed on labour requirements.

It is the responsibility of the recruiters to inform the labourers about the work environment and what will be expected of them. This is important in preventing disappointment and dissatisfaction when labourers' expectations are not realised (Bell, 1985). The training of individuals is influenced by their willingness to train. Implementing and practicing the newly acquired skills are also essential for the training to be effective (Bardenhorst, 1985).

These prohibiting factors can be improved by setting up a well-defined scope of works and work environment (Bardenhorst, 1985). An integrated training program that is specific and includes induction and skills training should be implemented (Bardenhorst, 1985). Bardenhorst (1985) mentioned that the formation of productivity tracking system can help to set measurable targets so that, in turn, management can give measurable and specific feedback.

7.4.1.2 Training of the workforce

The training of the workforce is considered to be the foundation of labourers' abilities and motivation to strive towards success and higher productivity. According to Bardenhorst (1985) 38% of the productivity-prohibiting factors are training related. Major elements influencing training quality were found to be the training program, quality of the instructors and the method of training. The selection of trainees and the control of the training officers over trainees were also identified as substantial factors influencing the effectiveness of training programs and the effect of training on the productivity of the workforce (Bardenhorst, 1985).

Bardenhorst (1985) suggested that these factors could be improved if foremen provided adequate guidance with the selection of appropriate workers for training. The quality of training is dependent on the quality of the instructor. Therefore, Bardenhorst (1985) suggested that a highly qualified instructor should be used. Another improvement to these factors could be the use of training programs, developed in line with the career path of the workforce.

According to the interviewees from Chapter 4, local labour rarely receive any form of formal training but are rather trained by more skilled permanent labour and supervisors throughout the construction project. This may initially seem as a cost-effective method due to labourers only being employed on a temporary basis. However, providing these labourers with adequate training, as mentioned by Bardenhorst (1985), can ultimately reduce their *learning curve* which is considered as a high priority risk in both the in-situ construction and precast manufacturing environments. Therefore, in a project stretching over a long period, it could be more economical to provide labourers with adequate training. This will not only benefit the project, but also the South African construction environment in the long run, since there is currently a shortage of skilled labour in South Africa (Section 4.4). The trained individual would also experience less difficulty to be employed as he/she will have adequate skills.

7.4.1.3 Management of the workforce

Management of the workforce is the category with the largest number of prohibiting factors for productivity improvement. Research showed that 50% of these factors relate to management, including the lack of management training of line managers, such as foremen. Bardenhorst (1985) suggested that the implementation of a structured development program for foremen could reduce the effect of this inhibiting factor. Other factors, such as neglecting to identify the special abilities of individuals in workforce should also be considered. If labourers' special abilities are effectively identified and utilised they will experience a higher morale, thus improving their productivity and reducing labour related risks. Open communication within management is always essential, especially down the line, as it could help to identify labourers with skill and potential in specific areas or trades (Bardenhorst, 1985).

Bardenhorst (1985) and Dozzi and AbouRizk (1993) mentioned that the lack of managing overtime has a major negative effect on productivity improvement. Management should strive to manage de-motivators which negatively influence the morale of the labourers. Five of the de-motivators of the workforce as shown in Table 6.4 in the previous chapter, are identified as top 10 risks in the in-situ construction and precast manufacturing environments (Tables 7.7 and 7.8). Therefore, by managing these de-motivators, labour and ultimately the project's productivity will be enhanced.. Bardenhorst (1985) also emphasised the importance of measuring the productivity of the workforce in order to improve productivity. This is also identified as an element in the *productivity improvement system* in Figure 6.1 in the previous chapter and can be seen as a tool to identify shortcomings regarding productivity.

7.4.1.4 Summary of productivity prohibiting factors

The individuals themselves, training and management of the workforce are not the only factors that influence productivity in a construction project. These areas are however important to mention, because if productivity improvements are required, these areas should be addressed.. It is also clear from the findings of Bardenhorst (1985) that the area with the highest potential for change is the management of the workforce. This finding of Bardenhorts (1985) is justified by the survey results of the in-situ construction environment, as five of the top seven in-situ construction risks were workforce related. However, the workforce is not considered as such a high risk in the precast manufacturing industry and does not necessarily require a change in the management of the workforce.

7.4.2 Labour policies and legislation

Governmental regulations and policies need to be considered when the employer applies mitigation to the high priority risks shown in Table 7.7 and Table 7.8. According to section 30 of the Basic Conditions of Employment Act (BCEA) 1997 an employer is required to have a summary document that highlights the most important aspects of the act (The South African Department of Labour, 2004).

This summary discusses aspects such as working hours, leave, remuneration and termination of employment. These aspects can influence techniques used to enhance labour productivity and it is therefore important to understand the measure of influence of these legislative aspects.

7.4.2.1 Working time

According to the BCEA, a labourer is limited to working a maximum of 45 hours a week and up to 8 or 9 hours per day depending on the days worked in a week. Overtime is allowable but may not be forced onto labourers and should rather be an agreement. In the case of overtime, the maximum allowable workday is 12 hours and no more than 15 hours of overtime per week. This overtime may only be maintained for a period of 2 months every 12 months (The South African Department of Labour, 2004). Another option for employers is to use averaged work periods. These periods allow 45 work hours per week with a maximum of averaged 5 hours overtime per week. This could only be done on agreement by both the employer and the employee. It is also important to consider how ineffective a workforce become if they are working extensive overtime. This is shown an explained in Table 6.2.

Meal intervals are prescribed by the BCEA to be 60 minutes after 5 consecutive working hours. The break may be reduced on agreement to a minimum of 30 minutes and also rejected if employees work less than six hours a day. A consecutive 36 hour break should be provided to employees every week, which should, unless otherwise agreed upon, include Sundays. Employees working night shifts should be informed about the additional safety hazards and the right to undergo a medical examination. Public holidays are considered the same as Sundays; however, employees are still paid even if no work is done (The South African Department of Labour, 2004).

The employer and construction managers should consider these regulations and time limits when they are behind schedule and are trying to make up lost time. Not only can the legal limits be exceeded if not managed correctly but productivity loss can also occur if labourers work more than the optimum hours per week (Table 6.2). Also, reviewing the risks shown in Table 7.7, overtime is ranked as a high priority risk in the in-situ construction environment. Thus this legislative restriction is important to consider in the in-situ construction environment. Research has shown that injuries are also more likely to occur when labourers are overworked, which can result in large compensation fees, especially when accidents occur during non-legal hours (Iwasaki, Takahashi & Nakata, 2006).

7.4.2.2 Leave

Employees are entitled to annual leave which is calculated at 21 consecutive days. Upon arrangement between employer and employee this can be changed to one day leave for every 17 days worked or one hour for every 17 hours worked. Sick leave should also be granted to employees and are calculated to be up to 6 weeks in a 36 month period. This normally works out as one day sick leave per every 26 days worked. Pregnant employees are entitled to maternity leave which consists of a consecutive four month break from work. During pregnancy the employee is not allowed to perform hazardous activities which may bring potential harm to the fetus. Employees are also granted three days paid leave in the case of a family issue such as sickness, death or birth of specified relatives. (The South African Department of Labour, 2004)

The legitimacy of leave should be considered when analysing the number of days a worker was absent. The foreman or person responsible for labourers' leave should try to minimise the absence of labourers during critical periods of a project. Activities which are on the project's critical path should use sufficient labourers to optimally perform the task at hand. Therefore, it is important for construction projects to have a good procurement plan in place.

7.4.2.3 Remuneration

The employee should be informed of details regarding remuneration, whilst the employer is required to possess personal information of the employee's different payment aspects (The South African Department of Labour, 2004). According to the BCEA, overtime work should be granted 1.5 times the normal wage. In the case where an agreement is made between the employer and employee, the employee is allowed to receive paid time-off equivalent to the overtime worked. Work done on Sundays during normal working hours receive 1.5 times the normal wage, whilst in the case of overtime work on Sundays, the wage should be twice the normal wage. Public holidays are considered the same as Sundays. (The South African Department of Labour, 2004)

Employees should be informed about their remuneration to avoid disappointment. According to a study conducted by Bell (1985), labour disappointment results in dissatisfaction, which is a subjective response to anticipated rewards (Bell, 1985). The psychological result of disappointment varies amongst individuals and can result in individuals becoming depressed due to frustration and unhappiness (Ma, 2012). These factors greatly influence the motivation of labourers, which ultimately affects their productivity (Ma, 2012).

7.4.2.4 Termination of employment

Before an employee can be released from his/her duties, notice has to be given in advance by the employee. The notification period is dependent on the period the employee was employed. If more than one year, the notification period should be at least 4 weeks, whereas if the employment period was between six months and a year only 2 weeks' notice is required. Only one week's notice is required if the employment period was less than six months. (The South African Department of Labour, 2004)

This is an important factor to consider when using temporary labour. The fact that the employees working for less than six months are only subject to one week's notice to be released from their duties can be a high risk for foremen who need to manage their crew's productivity and build-up. Managers experiencing a high turnover rate should consider the mitigation of possible turnover causes. Section 6.2.2.6, Table 6.7 shows possible causes for turnover in the construction industry as identified by Dozzi and AbouRizk (1993).

7.4.2.5 Summary of labour policies and legislation

Considering these labour policies and legislation it is evident that they should be taken into account by managers when they want to optimise the productivity of labourers both on site and in the manufacturing industry. Companies which do not comply with these policies and legislation could be prosecuted and fined. Therefore, it is important to consider these labour-related policies and legislation when applying productivity enhancing strategies.

7.5 Conclusion

This chapter has shown the importance of the productivity influential factors (Chapter 6) on both the in-situ construction and precast manufacturing industry. Although not all of these factors are directly related to labour, as mentioned in Section 6.2, they all have an effect, directly or indirectly, on the productivity of the labourers.

The results of the survey in the in-situ construction industry showed that 14 of the 23 identified productivity-influencing factors of a construction project are considered as high priority risks which require action from management. Another important finding which relates to this investigation is that 5 of the top 7 ranked risks were directly related to labour. They were in descending order: *fatigue, learning curve, hazardous working area/safety, absenteeism and turnover,* and *morale and attitude.* Not only are these factors considered high priority risks but they all received a probability rating which suggested that there is a medium to real chance of occurring during a project. Thus, according to the respondents, labourers in the South African construction industry experience fatigue, work overtime and in hazardous environments, have inadequate experience, are absent and have low morale to such an extent that it becomes a threat to the construction projects. These risks suggest that the in-situ construction environment is not ideal for labourers.

The precast manufacturing industry on the other hand only had one direct labour-related factor in the 9 high priority risks, as ranked by the 4 participants. This factor was the *learning curve* which supports the opinion of a number of the interviewees in Chapter 4 who stated that labourers in South Africa have a skills shortage. This risk was ranked as high priority in both environments. However, labourers in the precast industry receive sufficient training; the risk is mitigated, since they use a permanent workforce, whereas the in-situ environment uses new labourers for each project.

The precast manufacturing industry is considered a much more labour-friendly environment, as labourers are not exposed to such high levels of fatigue or such hazardous working areas, since this industry is much more controlled. Also, labourers have higher morale levels which will result in an overall happier and friendlier workforce with a higher productivity rate. Labourers with a higher morale are also considered to have a positive influence on their local community.

Thus, from this chapter it can be concluded that not only does the precast manufacturing industry have less high priority risks than the in-situ construction industry, but the labourers involved in the precast industry experience better living and working conditions without a considerable salary difference. Chapter 4 also mentioned that labourers from the precast manufacturing environment experience better job security and good skills development. Therefore, from these two chapters it seems that labourers from the precast manufacturing industry overall make better living. However, it should be considered that the precast industry cannot exist without the in-situ construction industry, but it does however transfer many activities from the in-situ construction environment to the factory. In the structural building industry a large portion of the work is done at considerable heights, magnifying the labour-related advantage as work is always done at ground level in the precast environment.

CHAPTER 8

8 CONCLUSIONS AND RECOMMENDATIONS

This chapter provides the conclusions and recommendations from this research.

8.1 Problem statement and objectives

Labour is regarded as a key factor in construction projects and also in the choice between in-situ concrete construction and hybrid concrete construction (HCC). This is primarily due to the construction industry's ability to reduce poverty through its labour-intensive nature. The use of HCC is known to reduce labour requirements; therefore it is in contrast with the objectives of the National Development Plan of South Africa.

The goal of this study was to determine the effect of labour in the choice of the most appropriate construction method and also the effect of the construction method on labourers. It was therefore critical to understand both the in-situ and HCC labour environments and the extent and types of labour used in each. For these reasons, the objectives of this study were to:

- Identify and investigate the labour-related factors that influence the utilisation of HCC in South Africa.
- Examine the influence of the NDP and the EPWP on the choice between in-situ and hybrid concrete construction.
- Investigate job creation and skills development in both environments.
- Conduct qualitative (interviews) and quantitative (labour hour comparison) investigations into the effect of both construction methods on the related *socio-economic factors*.
- Investigate the effect of construction productivity-influencing factors on both the in-situ construction and precast manufacturing environments.

The study identified and discussed the following parameters as part of the investigation to provide the reader with relevant information regarding the choice between in-situ and hybrid concrete construction in South Africa.

1. Influence of NDP and EPWP on the choice between in-situ and HCC
2. Job creation
3. Labour skills and skills development
4. Job security
5. Labour environment
6. Labour productivity

A summary of the conclusions regarding these parameters is provided in the following section.

8.2 Conclusions

Influence of NDP and EPWP on the choice between in-situ concrete construction and HCC

Investigations and interviews conducted by other authors regarding the use of HCC, mentioned that tender documentation and programmes such as the *Expanded Public Works Programme* and *National Development Plan* restrict the use of HCC in public projects in South Africa. This is primarily because it is considered that the use of HCC in the place of in-situ concrete construction directly implies job loss.

The NDP, EPWP and tender documentation were investigated through literature and by conducting interviews with suitable individuals. It was found that the programmes only promote labour intensive construction techniques in low-skilled activities, but do not influence the decision to use HCC in the structural building industry.

Job creation

Public clients promote job creation in the construction industry by limiting contractors to the employment of local unemployed, low-skilled labour. These directives are prescribed in tender documentation and failure to comply results in penalties. Low-skilled labourers are considered a threat to construction projects. This is supported by the risk analysis, (Chapter 7) as five of the top seven in-situ construction high priority risks were labour-related.

Literature and interviews suggested that HCC utilizes less labour than the conventional construction method, thus providing less job opportunities. However, these opinions did not incorporate into their comparison the amount of labour utilized at the precast plant. A labour hour comparison between the two techniques, including the precast plant, did show that HCC used 70% of the labour required by the conventional construction method for the specific structural building project described in Chapter 5.

Thus, HCC utilizes less labour for the same project than in-situ construction, justifying the statements that the use of HCC implies job loss. However, it should be considered that HCC projects are expected to be completed sooner than corresponding in-situ projects, therefore, although less job opportunities are created by means of labour hours, the labourers will be available sooner to start with a new project. To an extent this counters the effect of job loss, considering the use of HCC.

Labour skills and skills development

The use of unskilled labourers was ranked as the second highest area of concern in the South African construction environment (Kriel & Wium, 2014). South Africa is currently in a situation where skilled labour is rare and unskilled labour is in abundance. It is part of the goal of the NDP and EPWP to promote skills development in South Africa. This is done by means of the NYC legislation (sub-division of EPWP) and through the directives in tender documentation to employ local, low-graded sub-contractors. These schemes are compatible with both construction methods and pose no threat to the utilization of HCC.

Although in-situ construction creates more job opportunities than HCC (considering labour hours), HCC involved more labourers (considering labour on-site and at precast plant). Thus, more labourers are exposed to the construction environment, which results in a higher number of labourers gaining construction experience.

Also, HCC offers a solution to the lack of skilled labour in the South African construction industry. This is due to HCC's ability to transfer the technical activities from site to the controlled environment of the precast manufacturing plant, but still maintaining the low-skilled activities on-site. This is proven by the types and amounts of labour used in both environments in the case study (Chapter 5). HCC largely makes use of *general labour* on-site (81% of work), where in-situ largely relies on *semi-skilled labourers* (62% of work).

Thus, HCC serves as an ideal solution for the lack of skilled (and semi-skilled) labour in South Africa, since it requires little skilled and semi-skilled labour on-site. Also, the use of HCC has little effect on the number of job opportunities for low-skilled, unemployed local labour, as they are still required on-site, and in similar numbers as in the in-situ construction environment.

Job security

The EPWP consider one permanent job opportunity to be equivalent to two and a half temporary job opportunities. Thus, permanent job opportunities deliver a higher contribution to the job creation schemes in South Africa. Also, better job security means a better living for the employed individuals.

The labour force breakdown of on-site construction (Chapter 4) showed that construction companies use 10-30% permanent labourers, where the labour breakdown of the precast manufacturing environment showed that 100% of the workforce are permanent employees, except in certain exceptional cases.

Thus, considering that HCC utilises permanent labour both off-site (100%) and on-site (10-30%), whereas in-situ only uses permanent labour on-site (10-30%), it is clear that HCC provides a higher percentage of its workforce with permanent job opportunities than in-situ.

Labour-related risks in the construction environment

Labour was identified as one of the important aspects of the construction environment, as it directly influences the project duration, quality and, consequently, the project cost. The risk analysis (Chapter 7) provides relevant information regarding the types of high priority risks influencing productivity in both the in-situ concrete construction and precast manufacturing environment.

Five of the top seven high priority productivity risks in the in-situ construction environment were labour related. Thus, labour is considered as an extreme high risk in this environment. Considering the types of risks, the in-situ environment seems to be physically demanding and unsafe for labourers, which contribute to the low morale of labourers in this environment. The precast manufacturing environment only had one labour related risk amongst the nine high priority risks. This indicates that this environment may be less demanding on labourers, both physically and psychologically, resulting in a healthier and more content workforce.

It is to be noted that the in-situ related risks also have an influence on the on-site activities of the HCC method, although to a lesser extent, as less on-site labour is required in the HCC alternative. Also, most of the technical activities of an HCC project are transferred to the controlled precast environment, reducing the on-site labour-related risks.

Considering the HCC method as a whole (on-site and precast environment), labourers in this environment have better working conditions than labourers in the in-situ environment. Also, according to the survey, labourers in this environment are considered as low-medium priority risk and are therefore easier manageable.

Labour productivity

Labour productivity in the construction environment was ranked as the highest area of concern in the South African construction environment. Thus, it is important to understand which of the considered methods utilizes its labour more effectively.

From the case study, the labour productivity of both techniques was calculated (*activity-orientated model*) by considering the construction of one floor level and its corresponding support system. The HCC method made use of a hollowcore floor system with an in-situ structural topping.

The productivity rates were 0.217 m^2/h and 0.305 m^2/h for in-situ and hybrid concrete construction respectively. These rates indicate that, considering the structure compared in the case study, HCC had higher labour productivity, even though this method utilizes less skilled labour on-site. Thus, HCC utilizes *low-skilled labour* (conduct 81% of work) to greater effect than in-situ utilizes *semi-skilled labour* (conduct 62% of work), considering the productivity rates.

Combined conclusions

Combined conclusions from addressed parameters:

1. The NDP and EPWP do not prevent or hamper the use of HCC in the structural building industry of South Africa.
2. In-situ concrete construction provides more job opportunities than HCC, considering the required labour hours for a specific project.
3. HCC projects have the potential to consume 20% less construction time, thus labourers can be involved in a new project sooner, countering job loss when using HCC.
4. 80% (Section 5.3.2.2, Table 5.7) of HCC activities are done by general labour, serving as an ideal solution for the current low-skilled labour in the South African construction environment.
5. HCC provides labourers with a better working environment considering the method’s physical and psychological demands, and also provides them with better job security.
6. HCC indirectly serves as a mitigation method regarding labour-related risks.
7. Labour is considered a major risk in the in-situ construction environment, whereas in the precast environment labour is of lesser concern. Thus, utilizing HCC over in-situ will provide management with better control over the workforce.

8. HCC utilizes labourers to greater effect, since this method has a higher labour productivity rate considering similar structural buildings, as compared in the case study. Also, this higher productivity is achieved using low-skilled labour.

Thus, from the preceding conclusions, the choice of HCC above in-situ construction seems to be advantageous to both the labourers and the management in the structural building environment.

8.3 Recommendations

This study investigated the choice between in-situ and hybrid concrete construction, considering the labour aspect thereof.

8.3.1 Recommendations from findings

The following recommendations were made for the South African construction industry:

Mind-set change regarding legislative restrictions in public projects

Consultants and contractors should not dismiss the possible use of HCC, thinking that their tender will be penalised owing to the less labour-intensive nature of this construction method.

Current labour environment

The use of HCC is advised due to its ability to use low-skilled labour to great effect. This is an important factor to consider if a project is constructed in a remote area with limited skilled labour, especially in the current South African construction environment, as both skilled and semi-skilled labour are in short supply.

Higher labour productivity

Labourers in the HCC environment are more productive than those in the in-situ environment and can be applied more effectively. This is mainly due to the simplicity and pre-manufactured nature of on-site activities, whilst the technical activities are performed off-site by trained labourers. Thus, the use of HCC is advised in a country which is currently experiencing low labour productivity, as discussed in Section 2.4.5 (The World Bank, 2015).

Less labour-related risks to the contractor

When using HCC, a large portion of the technical work is transferred to the precast manufacturing plant. A large majority of the productivity labour risks related to these activities is also transferred. The contractor therefore experiences less labour-related risks. As a result, better management of workforce is facilitated by HCC. Contractors who experience management problems regarding workforce productivity should consider HCC.

Suggestions to unions and programmes which promote job creation

This study showed that for a specific project, the in-situ construction technique required more labour hours than HCC, which suggests that it is better for job creation. However, HCC projects have a faster turnover than similar in-situ projects, which counters the effect of job loss. Also, job creation is not the only aspect that should be considered. The HCC environment is advantageous to the labourers in the sense that it provides:

- Better job security
- Safer work environment
- Less physical activities
- Better morale
- Exposes more unskilled, unemployed labourers to the construction environment

These factors should all be considered when striving to reduce poverty, since all these factors contribute towards developing an individual who is better equipped for the future, whether it is work-related or personal.

8.3.2 Recommendations for further study

This investigation addressed various labour-related parameters in the choice between in-situ and hybrid concrete construction in South Africa. Further studies in the following fields could contribute to the value of this topic.

Labour productivity in both considered construction techniques

In Chapter 6, various productivity-measuring techniques were briefly discussed to aid the explanation of labour productivity in the construction environment. This investigation only used one productivity-measuring technique to compare the productivity of the in-situ and HCC alternatives of the project used in the case study (Chapter 5). Productivity was determined using only the tender execution rates of the labourers and not the real rates as experienced on site. Further studies could measure the on-site labour productivity of both considered techniques and compare them with one another and also with their respective expected productivities as calculated with the tender execution rates. This will provide valuable information regarding the technique with the highest labour productivity (based on real rates), and also the technique where labourers are managed most effectively.

The use of precast elements in other disciplines in the civil construction industry

This study primarily focussed on the utilization of HCC in the structural building industry. However, precast elements are also used in other disciplines in South Africa. The findings of this study are not 100% applicable to other disciplines. Therefore, a similar investigation should be conducted regarding other disciplines which also make use of high volumes of precast elements.

Labour-related risks in the construction environment

Labour has been identified as a high priority risk in the construction environment, based on a risk analysis done according to the guidance of PMBOK. This study used the risk analysis to compare the high priority risk of the in-situ environment with that of the precast environment. However, further investigation could be done into the types of high priority risks in the construction industry and possible mitigation methods which best suit the current South African labour environment.

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10 APPENDICES

APPENDIX A

Table - A.1 shows some of the precast concrete suppliers of elements used in the structural building industry. Considering these manufacturers, precast floor systems are the elements mostly manufactured.

Table - A.1: Some structural building precast concrete suppliers in South Africa

Name of company	Information available	Location	Hollowcore panels	Rib-and-block	Beams	Columns	Staircases
Bobcrete	www.bobcrete.co.za	Cape Town	X	X			X
Cobute	www.cobute.co.za	Cape Town		X	X	X	X
Concrete Units	www.concreteunits.co.za	Cape Town		X			
Corestruc	www.corestruc.co.za	Polokwane	X		X	X	X
Echo	www.echo.co.za	Johannesburg, Durban	X				
Elematic SA	www.elematic.co.za	Johannesburg	X				
Ital Concrete Design	www.italconcrete.co.za	Johannesburg		X	X		
Neat Contech	www.neatcontec.co.za	Humansdorp		X			
Portland Hollowcore	www.portland.co.za	Cape Town	X				
Shukuma	www.shukumaflooring.co.za	Port Elizabeth	X				
Stabilian	www.stabilan.co.za	Bloemfontein	X	X			
Topfloor	www.topfloor.co.za	Cape Town	X				

APPENDIX B – SEMI-STRUCTURED INTERVIEW TRANSCRIPTS

The following figures show the semi-structured transcripts used in the interviews. These transcripts were used to guide the conversations and to prevent deviation. These transcripts also ensured that all the required fields were covered in the conversations.

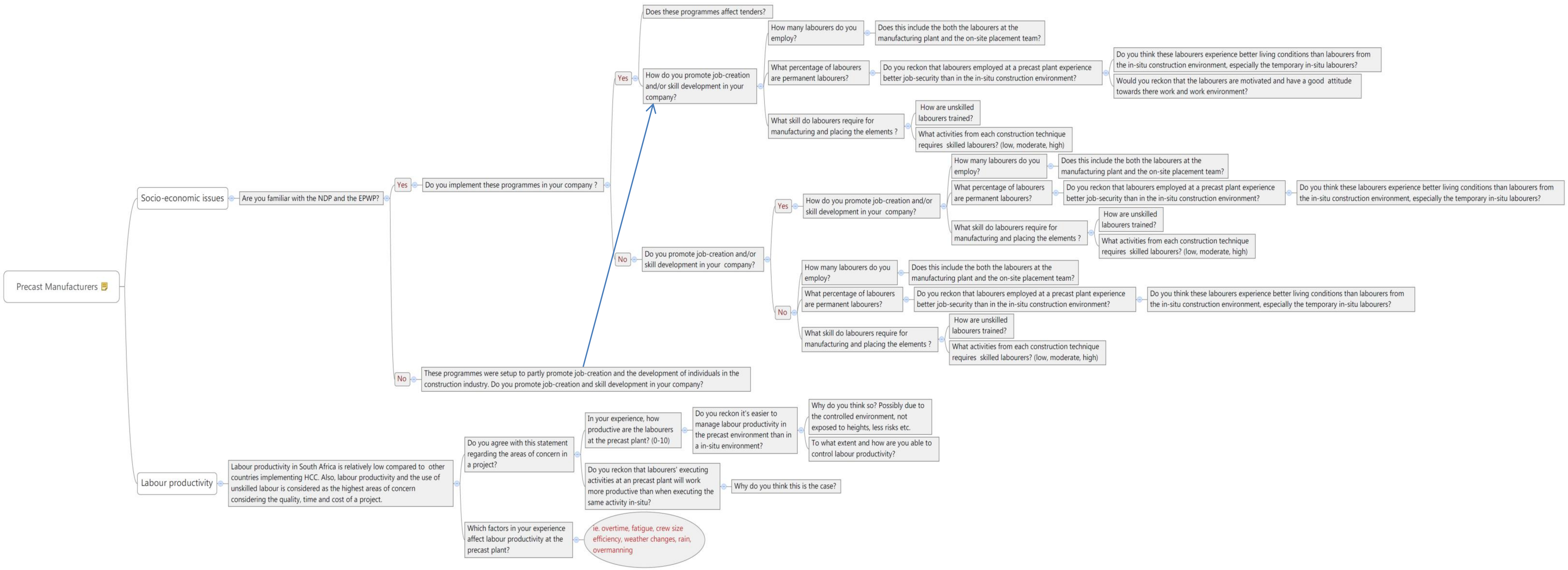

Figure - B.1: Semi-structured interview transcripts used for the precast manufacturing plants

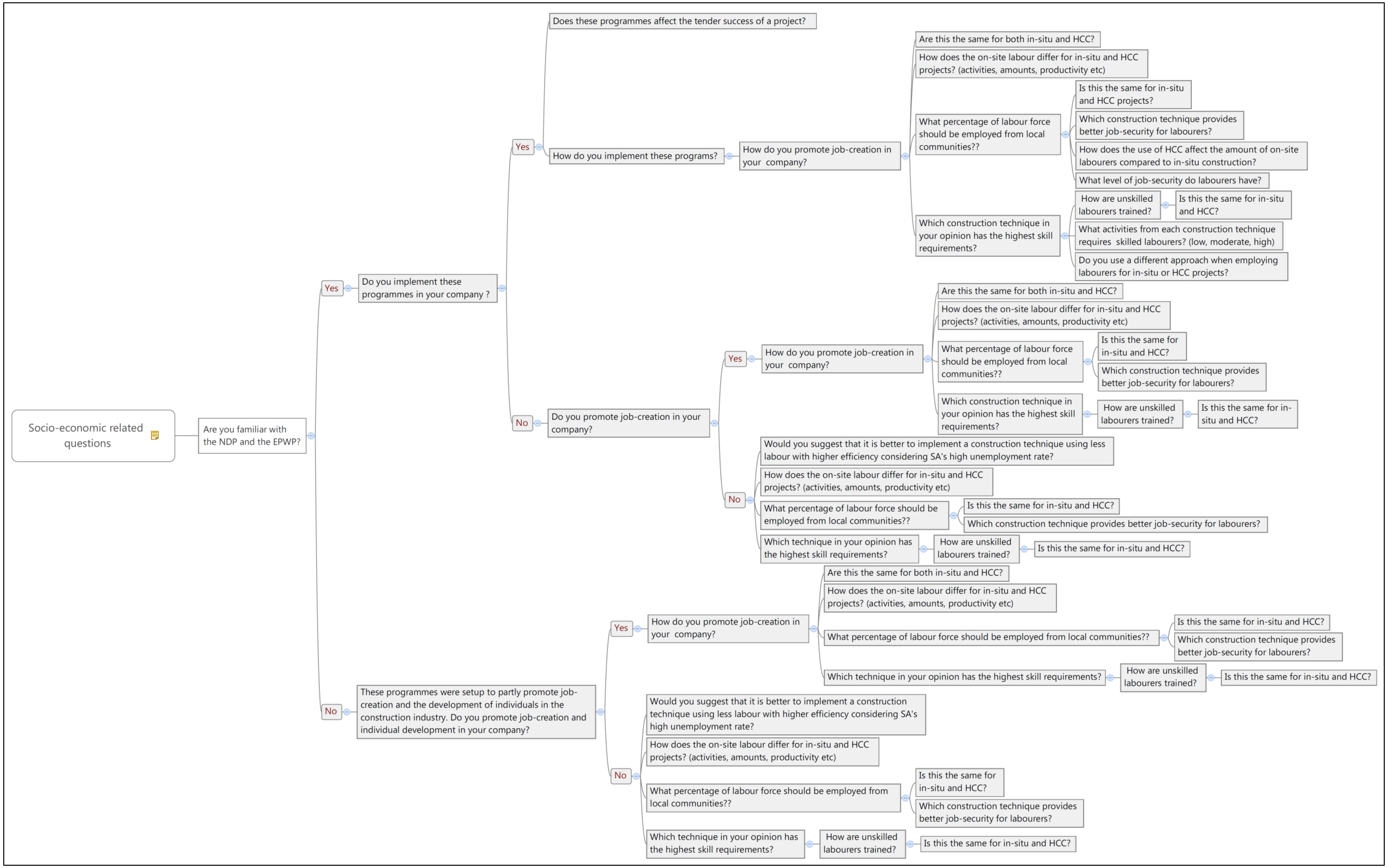

Figure - B.2: Semi-structured interview transcripts regarding the socio-economic issues used for the contractors and for the public client

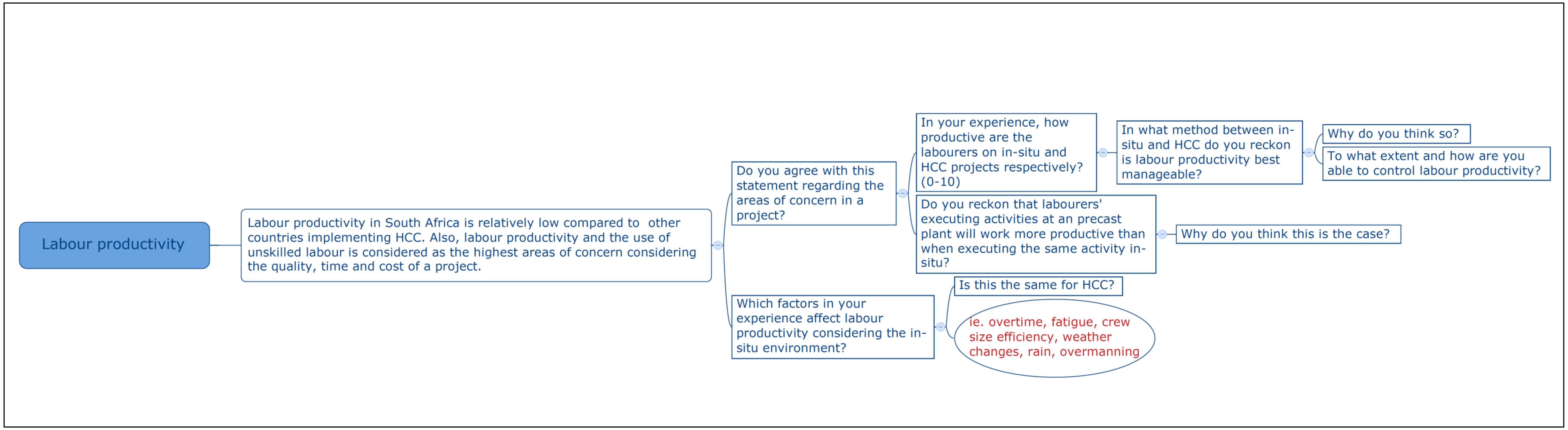

Figure - B.3: Semi-structured interview transcripts regarding labour productivity used for the contractors and for the public client

APPENDIX C – INTERVIEW SUMMARY

Interviewees

Ten interviews were conducted of which five were with representatives from the construction industry, three from precast manufacturing and one was a public client. Table - C.1 below shows all the interviewees and their corresponding abbreviations. These abbreviations will be used in this section to refer to statements made by that individual.

Table - C.1: Interviewees and their corresponding abbreviations

CONTRACTORS				
Name		**Company**	**Profile**	**Email Address**
Morkel Stofberg	MS	Power Construction Group	Human Resource Manager	mstofberg@powergrp.co.za
Craig Hoskins	CH	NMC	Project Manager	craig@nmc.co.za
Johan Bezuidenhout	JB	NMC	Project Manager	johan@nmc.co.za
Tony Byleveldt	TB	ASLA Construction	Divisional Director	tonyb@asla.co.za
Kylan Stone	KS	Stefanutti Stocks Marine	Senior Quantity Surveyor	Kylan.stone@stefstocks.com
Grant Bergh	GB	Group 5 Construction	Engineer	gbergh@groupfive.co.za
PRECAST MANUFACTURERS				
Nico Heyns	NH	Portland Hollowcore	Director	nico@portland.co.za
Attilio Angelucci	AA	Cobute	Director	attilio@cobute.co.za
Anonymous	AN	Anonymous	Manager	-
PUBLIC CLIENT				
Jan Van Rensburg	JR	Department of Public Works – Western Cape	Capital Works Program Manager	Jan.VanRensburg@westerncape.gov.za

This section summarises the interviews into sub-divisions, since the interviews were semi-structured and the conversations were guided where possible by a set of questions. The interviews will be summarised under certain questions that were asked of the interviewees.

Interviewees' opinions of various knowledge areas

National Development Plan and the Expanded Public Works Programme

Contractors

- Certain construction projects are regarded as purely EPWP projects which require redesigning to increase the labour intensity of certain activities. (MS)
- EPWP projects require of contractor to comply with legislation to prevent fines. (CH)
- During certain EPWP projects the client provides the contractor with a certain amount of money to train local unskilled labourers. (MS)

- EPWP projects require of the contractor to supply the number of jobs created (in hours) in the tender. These hours are measured and the contractor is fined when he does not meet the required labour hours. (MS)
- The main goal of the EPWP in construction is to promote job creation. However, only certain projects are subject to the EPWP legislation. (JR)

Precast Manufacturers

- In this industry the NDP and EPWP has not played a significant role. (NH)
- In certain projects where the precast manufacturers have been employed as the main contractors they have been held responsible to comply with these types of legislation. (AN)

Labour intensive construction

Contractors

- The conventional construction method (in-situ) is already labour-intensive and cannot be adjusted to accommodate more labourers and still be effective. (MS, JR)
- Both in-situ and hybrid concrete construction require the same activities to produce the same end product. However, HCC transfers certain activities to a manufacturing plant which reduces time spent on site and ultimately reduces project risk. (JB)
- In most cases the initial tender requires an in-situ design, where after value engineering (VE) is applied, in which certain in-situ sections are replaced with precast elements. The choice between in-situ and HCC is then usually based on the most cost-effective technique, irrespective of the amount of labour loss. Clients will very rarely choose the more expensive technique because of its socio-economic benefits. (JB)
- There is no legislative directive which states that in-situ concrete construction should be used in place of other modular construction techniques such as HCC. (JR)
- In general public projects, contractors cannot really be limited to in-situ construction if it is not cost-effective. (JR)
- Public Works do strive to intensify labour usage in certain activities which is still cost-effective even when labour-intensive construction is used. (JR)

Precast Manufacturers

- The type of labour intensity used in precast manufacturing is dependent on the manufacturing technique used. (NH)

Permanent labour

Contractors

- It is best to try to keep permanent labour constant as they serve as the supervisors and trainers during a construction project. (MS, TB)

Precast Manufacturers

- All the labourers are employed on a permanent basis. (NH,AA)

Local labour

Contractors

- During public projects contractors are required to employ local labour and/or local sub-contractors as far possible. (MS, TB, JB, KS, JR)
- Employing so much local labour is not always positive, since these labourers are paid decent wages for the duration of the project, but after the project they again experience unemployment, since it is rare that consecutive construction projects occur in the same area in a short period of time. (MS)
- When employing local labour a CLO is used to recruit these labourers from the appropriate surrounding communities, to prevent conflict and riots. (MS, JB)
- Around 40% of labour used in public projects is local labour. (MS)
- 30% of labourers are of local origin and are employed through a CLO. (CH)
- The contractor must prove to the client that they have strived to employ local labour as far possible. (TB, JB)
- In poor communities the community expects general activities to be assigned to local labour. If this is not implemented, the site is in danger of sabotage by the community through riots etc. In the case where HCC is used the surrounding community acknowledges that less general activities are present and therefore understand if less local labour are used. (JB)
- Contractor has little management over local labour. (JB)
- In-situ concrete construction can accommodate more unskilled labour than HCC. (JB)

Precast Manufacturers

In certain projects the precast manufacturers are required to employ temporary local labour but it is not a normal occurrence. (AN)

Sub-contractors

Contractors

- When work is sub-contracted to local subbies, they often make use of local labour. However, in these cases these labourers are required to be competent to perform the job at hand and not only low skill activities. (MS, KS)
- 20-40% of workforce in public projects are subcontractors which are usually of local origin as prescribed by the client. (MS, CH, TB)
- The sub-contractors' workforce usually consists of 70-80% local labour during public projects. (TB)

Certain public projects require of the contractor to employ local sub-contractors with a low CIDB *rating. (JR)*

Precast Manufacturers

- In the case where the precast manufacturer is required to provide a client with more elements he they can provide in the required time he employs sub-contractors to conduct certain activities. (AN)

Job creation

Contractors

- In the case where contractors use HCC instead of in-situ concrete construction they tend to use around 30% less labour. (CH)
- There are cases where local labourers have been permanently employed by the company; however this is a rare occurrence. (CH)
- The idea with job creation is not to replace productive and cost-effective construction with labour-intensive, uneconomical construction. It is rather to use labour-intensive construction methods on projects where it poses the same economical and productive benefits as other construction techniques. (JR)

Precast Manufacturers

- There are no temporary labourers working at the manufacturing plant. (NH,AA)
- When the precast manufacturers tender for certain projects which not only require of them to provide standard concrete elements, they can be subject to legislation which requires of them to employ temporary local labour. (AN)

Skills development

Contractors

- After completion of projects, local labourers disappear and it is hard to trace these labourers again, which results in all the training to be redone, consuming valuable time during each project. (MS)
- Local labourers are trained in-house by skilled labourers and supervisors. Labourers with potential will be identified and trained to become semi-skilled or skilled labourers. (MS, CH)
- Permanent labourers are sent on a four week skills development course where they are trained in a specific construction-related trade. (CH)
- In certain projects where the main contractor is required to employ law graded CIDB sub-contractors, this contractor serves as a supervisor who is effectively training the sub-contractor and his labourers. (JR)
- The Department of Public Works provides contractors with a CIDB rating of 3-5 with free training and skills development. (JR)

Precast Manufacturers

- Training and skill development is done in-house by skilled labourers and supervisors. (NH, AA, AN)
- Labourers are shifted between various activities and trades to give them exposure to and experience in all the trades. (AA)
- Local labourers are placed in certain activities which best suit their skill sets and interests. (AN)

Skills requirements and activities conducted by unskilled labour

Contractors

- Only around 20% of labour force is skilled labour. They are mostly operators and skilled labourers in certain trades who supervise the unskilled labourers. (MS)
- Local labourers usually do lowest level of work, except if it seems as if the unskilled labourer has potential. (MS, CH)
- Certain modular methods make it possible to use low-skilled labour to a greater effect. (TB)
- In-situ projects require less on-site labour than HCC projects. To bring this into perspective, consider that to set up an in-situ floor requires 4 teams where, with the use of precast floor slabs, only 2-teams are required. (CH)
- In the case where local labourers acquire the required skills to perform certain activities, it is more economical to assign local labourers to these tasks rather than using permanent skilled labour. (TB)

Precast Manufacturers

- A large part of the manufacturing process is done by machines. The operators of these machines need to have high skill levels. There are also other trades which require skilled labour. Unskilled labourers are used to perform basic activities. (NH)
- All activities are performed in a labour-intensive manner. Certain activities have been modified to enhance productivity but the physical work is done by manual labour rather than machinery. (AA)

Job security

Contractors

- Local labourers working for a subcontractor experience better job security than local labourers directly employed by the main contractor. (MS)

Precast Manufacturers

- Job security in this industry is much higher than in the construction industry, since labourers do not operate from project to project but rather as a continuous production line or factory. (NH, AA)
- Because labourers acquire experience in all the different trades it is easy for them to apply for other construction jobs if they are needed to be dismissed due to an economical low in the company. (AA)
- Job security is better in the precast manufacturing industry than in the construction industry. Migrant labour is one of the biggest social problems in South Africa and is the result of construction labourers having to travel along with construction projects. (AN)

APPENDIX D – CASE STUDY

The following tables show the labour rates as received from the respective interviewees from both considered construction projects as explained in Chapter 5.

Table - D.1: Labour rates for in-situ construction with PT-deck as received from relevant interviewees

	Description/ Activity	**Hours required**	**Quantity ***	**Rate (h/unit)**	**Real quantity ****	**Formwork**						**Re-bar**				**PT-cables**				**Concrete**					
						Supervisor	Hours***	Semi-skilled	Hours***	General labour	Hours***	Supervisor	Hours***	Fixers	Hours***	Supervisor	Hours***	Fixers	Hours***	Supervisor	Hours***	Floaters	Hours***	General labour	Hours***
1	**Columns**		**No**																						
	Erect Formwork	**5**	16	0.31	61	1	19.06	2	38.13	4	76.25		0.00		0.00		0.00		0.00		0.00		0.00		0.00
	Re-bar	**8**	16	0.50	61		0.00		0.00		0.00	1	30.50	3	91.50		0.00		0.00		0.00		0.00		0.00
	Cast concrete	**3**	16	0.19	61		0.00		0.00		0.00		0.00		0.00		0.00		0.00	1	11.44		0.00	3	34.31
	Dismantle formwork	**4**	16	0.25	61	1	15.25		0.00	4	61.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
2	**Formwork to deck**		**m2**																						
	Erect formwork	**32**	500	0.06	1152	1	73.73	5	368.64	8	589.82		0.00		0.00		0.00		0.00		0.00		0.00		0.00
	Stop-ends	**10**	500	0.02	1152		0.00	2	46.08		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
			m2																						
3	**Re-bar**	**24**	500	0.05	1152		0.00		0.00		0.00	1	55.30	10	552.96		0.00		0.00		0.00		0.00		0.00
			No																						
4	**Install PT-cable**	**16**	42	0.38	138		0.00		0.00		0.00		0.00		0.00	1	52.57	6	315.43		0.00		0.00		0.00
5	**Cast concrete**		**m2**																						
	Placement	**5**	500	0.01	1152		0.00		0.00		0.00		0.00		0.00		0.00		0.00	1	11.52		0.00	8	92.16
	Powerfloating	**6**	500	0.01	1152		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	3	41.47		0.00
	Place curing compound	**3**	500	0.01	1152		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	2	13.82
6	**Stressing of PT cables**																								
	Remove stop-ends/ construction joints	**8**	500	0.02	1152		0.00		0.00	4	73.73		0.00		0.00		0.00		0.00		0.00		0.00		0.00
	Preparing and stressing of PT-cables	**10**	42	0.24	138		0.00		0.00		0.00		0.00		0.00	1	32.86	3	98.57		0.00		0.00		0.00
7	**Stripping of deck**																								
	Strip formwork	**24**	500	0.05	1152	1	55.30		0.00	6	331.78		0.00		0.00		0.00		0.00		0.00		0.00		0.00

* = The quantity as given by the interviewees is a function of the hours required.

** = The real quantity is the quantity applied to the rate to determine the labour hours represented by ***.

*** = The labour hours for the individuals from the respective trades

Table - D.2: Labour rates for in-situ construction with conventional reinforced deck as received from relevant interviewees

	Description/ Activity	Hours required	Quantity*	Rate (hr/unit)	Real quantity**	Formwork						Re-bar				Concrete					
						Supervisor	Hours***	Semi-skilled	Hours***	General labour	Hours***	Supervisor	Hours***	Fixers	Hours***	Supervisor	Hours***	Floaters	Hours***	General labour	Hours***
1	**Columns (16 No)**		**No**																		
	Erect Formwork	**5**	16	0.3125	61	1	19.06	2	38.13	4	76.25		0.00		0.00		0.00		0.00		0.00
	Re-bar	**8**	16	0.5	61		0.00		0.00		0.00	1	30.50	3	91.50		0.00		0.00		0.00
	Cast concrete	**3**	16	0.1875	61		0.00		0.00		0.00		0.00		0.00	1	11.44		0.00	3	34.31
	Dismantle formwork	**4**	16	0.25	61	1	15.25		0.00	4	61.00		0.00		0.00		0.00		0.00		0.00
2	**Formwork to deck**		**m2**																		
	Erect formwork	**32**	500	0.064	1152	1	73.73	5	368.64	8	589.82		0.00		0.00		0.00		0.00		0.00
	Stop-ends	**10**	500	0.02	1152		0.00	2	46.08		0.00		0.00		0.00		0.00		0.00		0.00
			m2																		
3	**Re-bar**	**56**	500	0.112	1152		0.00		0.00		0.00	1	129.02	10	1290.24		0.00		0.00		0.00
4	**Cast concrete**		**m2**																		
	Placement	**5**	500	0.01	1152		0.00		0.00		0.00		0.00		0.00	1	11.52		0.00	8	92.16
	Powerfloating	**6**	500	0.012	1152		0.00		0.00		0.00		0.00		0.00		0.00	3	41.47		0.00
	Place curing compound	**3**	500	0.006	1152		0.00		0.00		0.00		0.00		0.00		0.00		0.00	2	13.82
5	**Stripping of deck**																				
	Remove stop-ends/ construction joints	**8.00**	500	0.02	1152		0.00		0.00	4	73.73		0.00		0.00		0.00		0.00		0.00
	Strip formwork	**24**	500	0.048	1152	1	55.30		0.00	6	331.78		0.00		0.00		0.00		0.00		0.00

Table - D.3: Labour rates HCC on-site activities conducted by the contractor as received from relevant interviewees

	Description/ Activity	Hours required	Quantity*	Rate (hr/unit)	Real quantity**	Formwork						Re-bar				Concrete					
						Supervisor	Hours***	Semi-skilled	Hours***	General labour	Hours***	Supervisor	Hours***	Gneral labour	Hours***	Supervisor	Hours***	Floaters	Hours***	General labour	Hours***
1	**Formwork to deck**		**m2**																		
	Formwork to edges of precast	**10**	**500**	0.02	1152	1	23.04	2	46.08	4	92.16		0.00		0.00		0.00		0.00		0.00
	Props	**8**	**500**	0.02	1152	1	18.43		0.00	4	73.73										
			m2																		
2	**Mesh installment**	**11.71**	**241**	0.05	1152		0.00		0.00		0.00	1	55.97	4	223.90		0.00		0.00		0.00
3	**Cast concrete**		**m3**																		
	Placement	**3.5**	**43.5**	0.08	69.12		0.00		0.00		0.00		0.00		0.00	1	5.56		0.00	8	44.49
	Powerfloating	**6**	**500**	0.01	1152		0.00		0.00		0.00		0.00		0.00		0.00	3	41.47		0.00
	Place curing compound	**3**	**500**	0.01	1152		0.00		0.00		0.00		0.00		0.00		0.00		0.00	2	13.82
4	**Stripping of formwork**																				
	Strip formwork	**10**	**500**	0.02	1152	1	23.04		0.00	4	92.16		0.00		0.00		0.00		0.00		0.00
	remove props	**8**	**500**	0.02	1152		0.00		0.00	4	73.73										

Table - D.4: Labour rates for precast manufacturing at plant as received from relevant interviewees

Description/ Activity	Quantity*	Hours required	Rate (hr/m2)	Real Quantity**	Manufacturing							
Placement on-site (250-300m2)	**m2**				Supervisor	Hours***	Operator	Hours***	Semi-skilled	Hours***	General labour	Hours***
Placement	250	**8**	0.03	1152	1	36.86	1	36.86		0.00	4	147.46
Production (130m2)	**650**	**8**	0.01	1152	**1**	14.18		0.00		0.00		0.00
Cable stressing	130	**1.5**	0.01	1152		0.00	1	13.29	2	26.58		0.00
Casting	130	**1**	0.01	1152		0.00	4	35.45		0.00	4	35.45
Stripping	130		0.00	1152		0.00		0.00		0.00		0.00
Measure & Cutting	130	**1**	0.01	1152		0.00	2	17.72	4	35.45		0.00
Removal from cast bed	130	**2**	0.02	1152		0.00	1	17.72		0.00	4	70.89
Move from stockyard onto trucks	130	**2**	0.02	1152		0.00	1	17.72		0.00	4	70.89

Table - D.5: Masonry brick wall rates for in-situ conceptual design

Description/ Activity	Quantity*	Hours required	Rate (hr/brick)	Real Quantity**	Masonry walls					
	No (bricks)			**No (bricks)**	Supervisor	Hours***	Brick layers	Hours***	General labour	Hours***
Outside walls	6000	8	0.0013	45260.80	1	60.35	10	603.48	6	362.09
Inside single walls (1)	6000	8	0.0013	22011.60	1	29.35	10	293.49	6	176.09
Inside single walls (2)	6000	8	0.0013	16477.76	1	21.97	10	219.70	6	131.82

Table - D.6: Masonry brick wall rates for HCC design

Description/ Activity	Quantity*	Hours required	Rate (hr/brick)	Real Quantity**	Masonry walls					
	No (bricks)			**No (bricks)**	Supervisor	Hours***	Brick layers	Hours***	General labour	Hours***
Outside walls	6000	8	0.0013	45260.80	1	60.35	10	603.48	6	362.09
Inside support walls	6000	8	0.0013	44023.20	1	58.70	10	586.98	6	352.19
Inside single walls	6000	8	0.0013	16477.76	1	21.97	10	219.70	6	131.82

APPENDIX E – SURVEY QUESTIONNAIRE

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Stellenbosch Engineering Department - Risk Analysis on Labour Productivity

1. Personal Information

1. Which of the following best describes your current occupation?

- Client
- Consultant
- Contractor
- Precast Concrete Element Manufacturer
- Other (please specify)

2. How many years of experience do you have in the civil engineering industry?

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Stellenbosch Engineering Department - Risk Analysis on Labour Productivity

2. Factors influencing labour productivity

In this section you are required to assign a rating to both the impact and probability of the respective factors. The impact is described as the influence of the occurrence of the factor on the cost, time and quality of a project as shown in the impact description table. The probability is the chance of occurrence as shown in the probability description table.

Impact Description

	Very low/1	Low/2	Moderate/3	High/4	Very high/5
Cost	Insignificant cost increase	<10% cost increase	10-20% cost increase	20-40% cost increase	>40% cost increase
Time	Insignificant time increase	<5% time increase	5-10% time increase	10-20% time increase	>20% time increase
Quality	Quality barely affected	-	Quality reduction requires client's approval	-	Significant affect to Quality

Probability Description

	Very low/1	Low/2	Moderate/3	High/4	Very high/5
Probability (P)	Occurs rarely	Improbable	Medium	Real Chance	Almost Certain

*** 3. Overtime - Working extended work days or weeks.**

	1	2	3	4	5
Time (Impact)	◯	◯	◯	◯	◯
Cost (Impact)	◯	◯	◯	◯	◯
Quality (Impact)	◯	◯	◯	◯	◯
Probability	◯	◯	◯	◯	◯

*** 4. Fatigue - This can be caused by prolonged or unusual physical exertion.**

	1	2	3	4	5
Time (Impact)	◯	◯	◯	◯	◯
Cost (Impact)	◯	◯	◯	◯	◯
Quality (Impact)	◯	◯	◯	◯	◯
Probability	◯	◯	◯	◯	◯

*** 5. Morale and attitude - Spirit of workers can influence their productivity.**

	1	2	3	4	5
Time (Impact)	◯	◯	◯	◯	◯
Cost (Impact)	◯	◯	◯	◯	◯
Quality (Impact)	◯	◯	◯	◯	◯
Probability	◯	◯	◯	◯	◯

*** 6. Learning curve - This refers to the period of orientation when new labourers are employed or when unskilled labour is used.**

	1	2	3	4	5
Time (Impact)	◯	◯	◯	◯	◯
Cost (Impact)	◯	◯	◯	◯	◯
Quality (Impact)	◯	◯	◯	◯	◯
Probability	◯	◯	◯	◯	◯

*** 7. Crew size inefficiency - This is when the optimal crew size is altered by adding or removing crew members.**

	1	2	3	4	5
Time (Impact)	◯	◯	◯	◯	◯
Cost (Impact)	◯	◯	◯	◯	◯
Quality (Impact)	◯	◯	◯	◯	◯
Probability	◯	◯	◯	◯	◯

*** 8. Over-manning - This occurs where to many labourers are assigned to one task.**

	1	2	3	4	5
Time (Impact)	○	○	○	○	○
Cost (Impact)	○	○	○	○	○
Quality (Impact)	○	○	○	○	○
Probability	○	○	○	○	○

*** 9. Late crew build-up - This occurs when the planned project labour teams are altered due to required labourers not being available. This can result in the employment of inadequate labourers.**

	1	2	3	4	5
Time (Impact)	○	○	○	○	○
Cost (Impact)	○	○	○	○	○
Quality (Impact)	○	○	○	○	○
Probability	○	○	○	○	○

*** 10. Reassignment of manpower - When workers are reassigned to another activity or project.**

	1	2	3	4	5
Time (Impact)	○	○	○	○	○
Cost (Impact)	○	○	○	○	○
Quality (Impact)	○	○	○	○	○
Probability	○	○	○	○	○

*** 11. Hazardous working area / Safety - This occurs where labourers work in a hazardous area that requires special safety equipment and clothing. Restrictions can limit workers and the setup of special safety requirements can consume valuable time.**

	1	2	3	4	5
Time (Impact)	○	○	○	○	○
Cost (Impact)	○	○	○	○	○
Quality (Impact)	○	○	○	○	○
Probability	○	○	○	○	○

*** 12. Start/stop - Stops in the project such as public holidays can affect labourers' productivity.**

	1	2	3	4	5
Time (Impact)	○	○	○	○	○
Cost (Impact)	○	○	○	○	○
Quality (Impact)	○	○	○	○	○
Probability	○	○	○	○	○

*** 13. Errors and omissions / Rework - Increases in errors and omissions affects labour productivity because changes are then usually performed on a crash basis, out of sequence, cause dilution of supervision, etc.**

	1	2	3	4	5
Time (Impact)	○	○	○	○	○
Cost (Impact)	○	○	○	○	○
Quality (Impact)	○	○	○	○	○
Probability	○	○	○	○	○

*** 14. Stacking of trades - This occurs when operations take place within physically limited space with other contractors, resulting in congestion of personnel.**

	1	2	3	4	5
Time (Impact)	○	○	○	○	○
Cost (Impact)	○	○	○	○	○
Quality (Impact)	○	○	○	○	○
Probability	○	○	○	○	○

*** 15. Concurrent operations -This is the effect of adding operations to any sequence of operations that has already been planned, without a gradual and controlled implementation of additional operations.**

	1	2	3	4	5
Time (Impact)	○	○	○	○	○
Cost (Impact)	○	○	○	○	○
Quality (Impact)	○	○	○	○	○
Probability	○	○	○	○	○

*** 16. Absenteeism and turnover - Absenteeism during project, new labourers are required. New labourers are usually not familiar with work area, takes time to obtain required experience.**

	1	2	3	4	5
Time (Impact)	○	○	○	○	○
Cost (Impact)	○	○	○	○	○
Quality (Impact)	○	○	○	○	○
Probability	○	○	○	○	○

*** 17. Site access / Site layout - This is a result of interferences to the convenient or planned access to work areas. This can be due to blocked stairways, roads, walkways, insufficient man-lifts, or congested work sites.**

	1	2	3	4	5
Time (Impact)	○	○	○	○	○
Cost (Impact)	○	○	○	○	○
Quality (Impact)	○	○	○	○	○
Probability	○	○	○	○	○

*** 18. Logistics - Inefficient planning can cause material delivery problems. This can disrupt the flow of workers due to forced stoppages. Labourers struggle to find rhythm again.**

	1	2	3	4	5
Time (Impact)	○	○	○	○	○
Cost (Impact)	○	○	○	○	○
Quality (Impact)	○	○	○	○	○
Probability	○	○	○	○	○

*** 19. Security check - This could be caused by workers entering or leaving the area, or from "brassing" in and out, toolbox checks, transport of labour to secure area, etc.**

	1	2	3	4	5
Time (Impact)	○	○	○	○	○
Cost (Impact)	○	○	○	○	○
Quality (Impact)	○	○	○	○	○
Probability	○	○	○	○	○

*** 20. Ripple effect - This is caused when changes in other trades' work then affects other work, such as the alteration of schedule.**

	1	2	3	4	5
Time (Impact)	○	○	○	○	○
Cost (Impact)	○	○	○	○	○
Quality (Impact)	○	○	○	○	○
Probability	○	○	○	○	○

*** 21. Dilution of supervision - This occurs when the supervision is required to manage unforeseen events and is distracted from productive, planned, and scheduled work.**

	1	2	3	4	5
Time (Impact)	◯	◯	◯	◯	◯
Cost (Impact)	◯	◯	◯	◯	◯
Quality (Impact)	◯	◯	◯	◯	◯
Probability	◯	◯	◯	◯	◯

*** 22. Holidays - Working on holidays affects labour productivity.**

	1	2	3	4	5
Time (Impact)	◯	◯	◯	◯	◯
Cost (Impact)	◯	◯	◯	◯	◯
Quality (Impact)	◯	◯	◯	◯	◯
Probability	◯	◯	◯	◯	◯

*** 23. Weather and season changes - Performing work in a change of season, temperature zone, or climate change resulting in work performed in either very hot or very cold weather.**

	1	2	3	4	5
Time (Impact)	◯	◯	◯	◯	◯
Cost (Impact)	◯	◯	◯	◯	◯
Quality (Impact)	◯	◯	◯	◯	◯
Probability	◯	◯	◯	◯	◯

*** 24. Shift work - This is when work is performed at any time other than the first shift or the morning shift of a work day. Work on second and third shifts are less efficient and may even be based on a shorter work period.**

	1	2	3	4	5
Time (Impact)	◯	◯	◯	◯	◯
Cost (Impact)	◯	◯	◯	◯	◯
Quality (Impact)	◯	◯	◯	◯	◯
Probability	◯	◯	◯	◯	◯

*** 25. Tool and equipment shortage - This is caused when there is insufficient quantity or quality of tools and equipment to meet the needs of the amount of labourers on a project.**

	1	2	3	4	5
Time (Impact)	○	○	○	○	○
Cost (Impact)	○	○	○	○	○
Quality (Impact)	○	○	○	○	○
Probability	○	○	○	○	○

APPENDIX F – SURVEY DATA

The following tables give relevant information and comparisons to justify the decision to ignore one of the respondents. Table - F.1 shows the results of the risk analysis of the precast manufacturing industry. This can be compared to Table 7.8 to show the respondent's influence on the final results. Table - F.2 provides a comparison between the results of the four considered respondents and that of the ignored respondent. From this comparison it is clear that the ignored respondent had a higher ranking for the vast majority of the probabilities and impacts of the respective risks.

Table - F.1: Prioritised and ranked risks in the precast industry, considering the ignored respondent

Rank	Risk	Probability		Cost		Time		Quality		Effect
		(P_d)	Std. dev (σ)	C_d	Std. dev (σ)	T_d	Std. dev (σ)	Q_d	Std. dev (σ)	
1	Tool and equipment shortage	0.70	0.35	0.52	0.27	0.60	0.28	0.34	0.31	0.42
2	Holidays	0.70	0.35	0.44	0.33	0.54	0.36	0.27	0.33	0.38
3	Stacking of trades	0.62	0.27	0.46	0.33	0.58	0.32	0.29	0.32	0.36
4	Over-manning	0.62	0.33	0.52	0.27	0.22	0.18	0.28	0.33	0.32
5	Learning curve	0.58	0.30	0.46	0.33	0.52	0.27	0.51	0.40	0.30
6	Site access / Site layout	0.58	0.33	0.40	0.37	0.52	0.27	0.19	0.13	0.30
7	Late crew build-up	0.58	0.30	0.38	0.27	0.46	0.33	0.44	0.35	0.27
8	Logistics	0.54	0.36	0.44	0.22	0.48	0.30	0.23	0.33	0.26
9	Overtime	0.66	0.33	0.28	0.29	0.37	0.39	0.11	0.08	0.24
10	Absenteeism and turnover	0.54	0.36	0.30	0.31	0.40	0.37	0.45	0.34	0.24
11	Errors and omissions / Rework	0.58	0.23	0.41	0.27	0.37	0.28	0.34	0.31	0.24
12	Dilution of supervision	0.54	0.30	0.16	0.13	0.38	0.27	0.19	0.13	0.21
13	Morale and attitude	0.78	0.18	0.26	0.13	0.25	0.15	0.19	0.13	0.20
14	Hazardous working area / Safety	0.70	0.20	0.28	0.29	0.11	0.08	0.11	0.15	0.20
15	Start/stop	0.62	0.30	0.29	0.29	0.26	0.31	0.26	0.33	0.18
16	Reassignment of manpower	0.50	0.37	0.28	0.29	0.26	0.30	0.24	0.32	0.14
17	Weather and season changes	0.54	0.33	0.13	0.15	0.24	0.32	0.10	0.06	0.13
18	Security check	0.46	0.36	0.12	0.04	0.27	0.30	0.05	0.00	0.12
19	Concurrent operations	0.46	0.17	0.22	0.16	0.26	0.13	0.24	0.32	0.12
20	Ripple effect	0.42	0.44	0.28	0.29	0.28	0.29	0.21	0.33	0.12
21	Crew size inefficiency	0.54	0.26	0.20	0.12	0.13	0.07	0.11	0.08	0.11
22	Fatigue	0.50	0.24	0.20	0.18	0.14	0.15	0.14	0.08	0.10
23	Shift work	0.42	0.36	0.14	0.15	0.14	0.15	0.09	0.07	0.06

Table - F.2:Comparison between opinion of four considered respondents and ignored respondent

Rank	Risk	Probability		Cost		Time		Quality	
		Avg	Individual	Avg	Individual	Avg	Individual	Avg	Individual
1	Tool and equipment shortage	0.65	0.90	0.45	0.80	0.55	0.80	0.23	0.80
2	Holidays	0.65	0.90	0.35	0.80	0.48	0.80	0.14	0.80
3	Stacking of trades	0.55	0.90	0.38	0.80	0.53	0.80	0.16	0.80
4	Site access / Site layout	0.60	0.30	0.45	0.20	0.45	0.80	0.19	0.20
5	Over-manning	0.60	0.70	0.45	0.80	0.18	0.40	0.15	0.80
6	Learning curve	0.55	0.70	0.38	0.80	0.45	0.80	0.44	0.80
7	Overtime	0.50	0.70	0.28	0.80	0.38	0.80	0.35	0.20
8	Late crew build-up	0.45	0.90	0.35	0.80	0.40	0.80	0.09	0.80
9	Logistics	0.55	0.90	0.31	0.80	0.26	0.80	0.23	0.80
10	Errors and omissions / Rework	0.65	0.70	0.15	0.80	0.26	0.80	0.09	0.80
11	Morale and attitude	0.75	0.90	0.23	0.40	0.21	0.40	0.19	0.20
12	Absenteeism and turnover	0.45	0.90	0.18	0.80	0.30	0.80	0.36	0.80
13	Dilution of supervision	0.50	0.70	0.10	0.40	0.28	0.80	0.19	0.20
14	Hazardous working area / Safety	0.75	0.50	0.15	0.80	0.09	0.20	0.09	0.05
15	Concurrent operations	0.40	0.70	0.18	0.40	0.28	0.20	0.25	0.20
16	Start/stop	0.60	0.70	0.16	0.80	0.13	0.80	0.13	0.80
17	Crew size inefficiency	0.50	0.70	0.15	0.40	0.11	0.20	0.09	0.20
18	Fatigue	0.45	0.70	0.15	0.40	0.08	0.40	0.13	0.20
19	Reassignment of manpower	0.40	0.90	0.15	0.80	0.13	0.80	0.10	0.80
20	Security check	0.40	0.70	0.10	0.20	0.14	0.80	0.05	0.05
21	Shift work	0.35	0.70	0.15	0.10	0.15	0.10	0.06	0.20
22	Weather and season changes	0.50	0.70	0.06	0.40	0.10	0.80	0.08	0.20
23	Ripple effect	0.30	0.90	0.15	0.80	0.15	0.80	0.06	0.80