THE IMPACT OF PREFABRICATION AND PRE-ASSEMBLY ON CONSTRUCTION HEALTH AND SAFETY IN SOUTH AFRICA

By

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A DISSERTATION PRESENTED TO THE HIGHER DEGREES COMMITTEE OF THE CAPE PENINSULA UNIVERSITY OF TECHNOLOGY IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF TECHNOLOGY: CONSTRUCTION MANAGEMENT

CAPE PENINSULA UNIVERSITY OF TECHNOLOGY

2010

31/10/2010

I dedicate this work to my family and those who helped me reveal my potential.

ACKNOWLEDGMENTS

First and foremost, I wish to thank God for walking with me throughout the process of this research study. He gave me strength on my weaknesses in tough times and the ability to persist till the successful completion of this study.

I also want to thank my supervisor Professor Theodore. C. Haupt for his guidance, support, sacrifices and most of all his patience to make this study comprehensive. His expertise in research was a blessing to me. It inspired me and opened my eyes to see where I never thought I would see in my life.

My thank goes to the Mrs. Zainu Khan for her support and encouragement in my research; she inspired me to believe in myself that I can make it. Mr. Rodriguez also believed in me and kept me going with his expertise in the construction and academic industry, I wish thank him for his support. I wish to acknowledge my family and colleagues, Ruben Ndihokubwayo, Xolani Nghona, Eric Simpheh, Siyabulela Mkaza, students who helped me with observations on site and Methodist church gathering which contributed by feeding me with faith in my studies.

My special gratitude to bursary providers National Research Foundation and Cape Peninsula University of Technology for their funding support which helped me socially and academically during the research process. Without these funds this research would not have commenced. To construction worker, employer and consultants, your contribution to the findings of this research made it comprehensive, thank you.

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LIST OF ABBREVIATIONS

CIDB	Construction Industry Development Board
CSIR	Council for Scientific and Industrial Research
FEMA	Federated Employers' Mutual Assurance Company Limited
HAVS	Hand-arm vibration syndrome
ILO	International Labour Organization
LBT	Labour based technology
MSD	Musculoskeletal disorders
SPSS	Statistical Package for the Social Sciences

ASTRACT

Abstract of Dissertation Presented to the Higher Degrees Committee of the Cape Peninsula University of Technology in Fulfillment of the Requirements for the Degree of Master of Technology in Construction Management

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2010

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The construction industry adopts various methods to bring about the required structure. Typically, in every construction project, health and safety of workers will remain a major concern on site due to accidents, fatalities and illnesses which occur regularly. Despite these incidents raising a concern, construction site activities still involve workers in manual handling of heavy material and repetitive body movements which constitute ergonomic problems. The purpose of this study is to investigate the potential impacts of prefabrication and pre-assembly on the health and safety of construction workers.

The objectives of this study were (1) to examine the health and safety hazards associated with traditional construction methods in South Africa; (2) to investigate the merits of prefabrication and pre-assembly in terms of their impact on overall health and safety improvements when compared with traditional construction methods; and (3) to investigate how construction clients perceive the use of prefabrication and pre-assembly as alternative construction methods that positively impact the overall health and safety of construction workers on site.

Literature pertaining to the content of this research was extensively reviewed. An exploratory study was undertaken to examine the merits of prefabrication and pre-assembly in reducing ergonomic challenges associated with traditional construction methods, where construction workers were observed and interviewed. A self-administered questionnaire survey was used for construction clients, designers and contractors.

The study revealed that 80% of clients in the sample reported that they preferred traditional construction methods instead of prefabrication. It was also found that clients selected prefabrication and preassembly for other reasons which were not associated with particular improvements of health and safety in construction project.

The study found that labour intensive methods also commonly known as traditional construction methods exposed workers to physically demanding activities that posed risks to their health and safety. Reportedly, 76% of workers experienced pain in their waist areas, 70% had pain in their shoulder and 66% had back problems while they were involved in traditional construction. Workers sometimes had to handle heavy material manually, worked at heights and experienced noise caused by heavy construction equipment. However, a case study focused on bricklaying activities and prefabrication insulation wall fixing revealed that prefabrication reduced the exposures of workers to both ergonomic challenges and ergonomic problems. The findings also suggest that traditional construction methods were more hazardous than ones involving prefabrication.

Further research is needed to determine whether the use of other forms of prefabricated and preassembled components would reduce ergonomic and health and safety hazards associated with traditional construction methods.

CHAPTER 1
INTRODUCTION

1.1 Background

The construction industry is one of the most important industrial sectors in South Africa due to it being a major employer of labour (Van Zyl, 2007). According to available South African statistics, in 2004 the construction industry employed about 403,000 workers. This number comprised of about 126,000 employees (31,3%) engaged in the construction of buildings, followed by 89,000 employees (22,1%) employed in the construction of civil engineering structures, 56,000 (13,9%) employed in the construction of other building types and 29,000 (7,2%) engaged in electrical contracting (Statistics South Africa, 2004). The balance of those employed, namely 103,000 (25,5%) was divided into other operations such as site preparation 10,000 (2,5%), construction of other structures 10,000 (2,5%), plumbing 16,000 (3,9%), shop-fitting 3,000 (0,7), installations of other buildings 27,000 (6,7%), renting of construction or demolition equipment with operator 8,000 (2%), painting and decorating 12,000 (3%) and the construction work done by specialist trade constructors 17, 000(4,2%) (Statistics South Africa, 2004). These numbers confirm the role of the construction industry as a major employer of people. However, the construction industry still faces many challenges and many problems despite being tagged with a failure to maintain worker health and safety.

While the working conditions within the construction industry have resulted in large numbers of accidents, illnesses and fatalities among construction workers (U.S. Department of Labour, 2001), in South Africa general workers were still employed off the streets with no health and safety experience, contributing to the increased likelihood of accidents and injuries (Engineering News, 2006). As a result, there is recognition that the construction industry is one where safety and health related risks remain unacceptably high in developing countries like South Africa and in need of minimization (Eppenberger, 2007).

Although, several research studies have been conducted to examine the circumstances surrounding the causes and categories of accidents and injuries, with the aim to minimize their occurrence within the construction industry (Samuels, 2005; Abdelhamid and Everett, 2000;

Perttula *et al.,* 2006), the rate of construction accidents and injuries remains unacceptably high as the volume of construction activities increases within South Africa (Ferreira, 2008). For example, for the period of April 2006 to February 2007, more than 130 construction-related deaths and over 330 injuries were reported in South Africa (Swanepoel, 2007). Consequently, it is recognised that due to involvement in construction, workers lose their lives and companies suffer loss of profit as a result of the poor health and safety performance of the construction sector. The fact that the construction industry still continues to cause death and bring harm to workers, suggests the need for alternative construction methods.

Even worse, the European Union construction sector accounts for about 30% of fatal accidents, but yet employs only 7% of the workforce (Mwankusye, 2005). Further, in 2001, a survey by the Occupation Safety and Health Administration (OSHA) in Tanzania found that on 63 sites, three fatal accidents and 33 accidents involving injuries were identified such as cuts by sharp edges, punctures by nails, hits by hammer and bruises; 27 sites recorded accidents involving fall of objects and tools while about 23 recorded accidents involving handling of tools and equipment and/or plants (Mwombeki, 2005). Evidently, the construction industry continues to fail to learn from previous experiences and the same types of accidents continue to recur throughout the world (Lingard, 2005). This is also true within the context of the South African construction industry. Smallwood and Haupt (2005) reported that during 1999, the latest year for which comprehensive occupational injury statistics were available, a total of 14,418 medical aid cases, 4,587 temporary total disablements, 315 permanent disablements, and 137 fatalities were reported to the Compensation Commissioner in South Africa. Eppenberger (2007) argued that serious injuries and fatalities which have continued to occur unabated on South African construction sites were caused by the mismanagement and underestimation of risk. Furthermore, Smallwood (2007) argued that design influenced construction, and therefore, affected construction health and safety in terms of the hazards and risks on site

Regardless of the efforts by construction teams to improve health and safety, the Construction Industry Development Board (CIDB) (2004) argued that the industry lacks commitment to a culture which actively promotes health and safety. For example, while Holt (2001) found that many construction injuries resulted from failures or falls involving access equipment which had been incorrectly selected, erected, used or maintained, the South African

Department of Labour determined that large numbers of accidents on sites were caused by non-compliance with health and safety legislation (Smallwood and Haupt, 2005). The Construction Regulations were introduced in July 2003 to respond to the poor health and safety record of the sector and create a legislative framework for construction health and safety (Deacon and Kew, 2006). However, the impact of legislation and regulations alone cannot bring about comprehensive improvement on health and safety in construction (Haupt, 2001). Evidently, there is clearly a need for new approaches to construction health and safety (Smallwood and Haupt, 2005).

The construction industry adopts various methods to produce a required structure. For instance, in South Africa, the government through various public sector developments has initiated the use of labour based and intensive construction methods. In-situ, labour based or labour intensive construction methods involve many different critical activities which are labour intensive and unfortunately more hazardous for workers during the construction process (Lingard, 2005). Labour based approaches arguably pose various threats to the health and safety of workers.

In the labour based approach construction activities which would otherwise be carried out by machines are carried out by labour (International Labour Organization, 2006). Unfortunately, where large construction projects such as offices, hotels and complexes utilise large materials in size which may be uneven and impossible to handle, ergonomic problems are highly possible to workers (Smallwood, 2006). This contributes to the prevailing poor health and safety performance within the construction industry. With poor health and safety performance being the order of the day, it is advisable that construction companies should take the effects of the poor health and safety as a cost that needs to be carried out like any other administrative function (Webber, 2007).

1.2 Preliminary literature review

1.2.1 South African construction initiatives

The economies of developing countries such as South Africa have other specific challenges relating, inter alia, to resources, technology and skill scarcity, and high levels of poverty and unemployment (Van Wyk, 2006). As a result, the South African government has focused on Public Works Programmes to either reduce or eliminate poverty and unemployment through support of encouragement of small and medium enterprise.

In November 1997, Minister Jeff Radebe announced that the ANC-led government had initiated programs targeted to develop a more stable delivery environment as a foundation for sustained skills formation, improved quality, productivity, and health and safety. However, the CSIR (2003) reported that the problem of skills in South Africa, particularly at middle management level, was costing the country about R154.4 billion annually, which represented 14,4% of GDP. Additionally, the CIDB (2007) reported that the records of health and safety of Federated Employers' Mutual Assurance Company Limited (FEMA) which accounted for about 50% of construction industry compensation claims for 2006, showed that 9,184 accidents were reported with 73 fatalities which was estimated for a total cost of R124 million. This implies that there is either a weakness relative to the construction method used or the construction industry is taking health and safety requirements for granted. Haupt and Smallwood (2005) argued that the continuing poor health and safety performance of the construction industry in the form of fatalities, injuries, and disease, the number of large-scale construction accidents, and the general non- participation by key project stakeholders such as clients and designers, provided the catalyst for a new approach to construction health and safety.

In consultation with the Advisory Council for Occupation Health and Safety, the government has introduced health and safety regulations in terms of section 43 of the Occupational Health and Safety Act No. 85 of 1993. These regulations apply to employers, self-employed persons and users on permanent or temporary premises with a major hazardous installation which may pose a risk that could affect the health and safety of employees and the public (Gazette, 2001). The enforcement of legislation by government requires compliance with minimum acceptable standards to health and safety and certain environmental considerations. According to Illingworth (2000: 7),

........."the health and safety legislation should influence the method of construction and failing to do so, the party which is liable, may face charges".

The results of accidents and fatalities within the construction industry in South Africa are an indication of health and safety legislation and regulations being poorly understood or followed by construction practitioners. These results also show that adequate monitoring and control within construction have not been achieved yet (Ozumba, 2008). This is strictly because of the continued number of fatalities and accidents that still occur on construction sites. Previous country-specific prescriptive approaches have failed to reduce the number of accidents occurring on construction sites around the world (Haupt, 2001).

1.2.2 Health and safety background

The health and safety planning of any construction project starts in the inception stage where the possibilities of the project plan are evaluated. In the inception stage the importance of health and safety should be prioritised when decisions are reached (Cruickshank, 2005). When feasibility studies are done, they will highlight the responsibilities of the health and safety team in the implementation phase (Brown, 2006). In most cases health and safety planning may be done effectively from the inception stage to the feasibility stage. Unfortunately, the construction stage presents the major challenge relative to illnesses, accidents, diseases, injuries and fatalities as a result of working on site.

The South African Minister of Labour, Membathisi Mdladlana, reported in 2008 that three people were killed and four others seriously injured when a building under construction collapsed in Stellenbosch in the Western Cape Province (Department of Labour, 2008). As a result of accidents, workers with their families and friends believe that involvement in the construction industry leads to unimaginable pain and suffering associated with accidental fatalities or serious injuries (Lingard, 2005). For example, the strain of the loss of a family member from a construction project, particularly if the worker was the bread winner, will be experienced by families and friends (Agumba, 2008).

In the attempt to reduce construction accidents, Rwamamara (2007) argued that management should be well organized with a clear policy for health and safety and strong team management that enforces proper health and safety training. In addition, health and safety performance can be achieved by careful planning and implementing appropriate construction methods (Haupt, 2001). However, construction activities can be challenging for workers on site.

Health and safety performance does not only depend on workers on site but on management to ensure that health and safety precautions are well practiced on site. Health and safety hazards such as injury to people, contracting of chronic diseases by workers and even death have had far reaching effects on the image of the industry (Kikwasi, 2008). Regardless of the impact of labour laws and regulations governing employment, the conditions of health and safety for construction workers on site continue to pose severe occupational health and safety problems (Mwankusye, 2005).

Factors such as carelessness, stress at work, lack of knowledge and skills, long hours working in the same place and lack of co-ordination by team workers affects health and safety on sites. According to Lundholm and Swartz (2006), stress and other mental strain at work can cause a worker to work unprofessionally and carelessly due to their state of mind which may result in accidents. The Department of Public Works stipulated that the promotion of health and safety, productivity, quality and environmental protection and the enhancement of contractor performance in South Africa will be difficult, as long as the division between design and construction continues (Smallwood, 2000).

1.2.3 Construction methods

1.2.3.1 In-situ method of construction

In-situ or traditional construction methods require the overall construction work to be carried out on site as opposed to prefabrication/preassembly or precasting. The traditional construction method is a multi-activity construction process which requires materials handling techniques that will also consider the health and safety of workers. Perttula *et al.*, (2006) found that materials handling processes caused large numbers of serious accidents on construction sites. Evidently, construction processes which involve manual handling of heavy material were found to increase the probability of workers experiencing back pain and musculoskeletal disorders (Coble, 2000).

Site based construction workers experience large amounts of bending or twisting moments of their back while handling heavy equipment and machinery, working while injured and climbing to reach equipment at height. The entire back and lower back, in particular, are the main elements that normally suffer from pain because of working under difficult and challenging conditions (De Looze *et al.,* 2001). Workers contend daily with physically demanding working conditions and tasks which differ from levels of exposure. These exposures differ from trade to trade and job to job on a daily basis (Brunette, 2005). For example, labourers are required to carry 50 kg cement bags, removing these from one place to another. Furthermore, De Looze *et al.,* (2001) indicated that scaffold erection was a physically demanding and awkward posture process since it involves constructing and disassembling components such as props, boards, and pipes in both horizontal and vertical directions.

According to Lundholm and Swartz (2006) the condition of muscle and joints from physical loads and work posture could result in musculoskeletal problems to workers. Musculoskeletal disorders may result in construction workers being disabled and handicapped (Felson, 2000). Smallwood (2006) further argued that several construction tasks which involve heavy equipment handling present ergonomic risks to employees.

Despite site based construction involving many different trades such as, excavating, formwork, concreting, roofing, steel erecting, screeding, bricklaying, and ceiling erecting, each of these trades entails exposure to two or more construction ergonomic problems (Smallwood, 2006). These ergonomic threats and musculoskeletal disorder challenges affect the health and safety performance of the construction industry. Lingard (2005) argued that health and safety improvements will not be achieved unless there is a new approach towards the methods of organising and doing construction. This study will investigate the health and safety related hazards and risks factors associated with construction site processes in order to minimise them.

1.3 Problem statement

While traditional construction methods and materials handling techniques expose construction workers to many hazards and ergonomic challenges with major negative outcomes, there is a perceived resistance on the part of clients to consider alternative construction technologies which potentially reduce the exposure of construction workers to working environments that present threats to the health and safety of construction workers such as, for example, prefabrication and pre-assembly.

1.4 Hypothesis

The hypotheses to be tested in this study are:

- H1: Traditional methods of construction threaten the health and safety of workers on site.
- H2: Prefabrication and preassembly reduce threats to the health and safety of workers when compared with traditional methods of construction.
- H3: Clients undervalue the impact of pre-assembly and pre-fabrication as alternative construction methods that will improve overall health and safety performance.

1.5 Objectives

The primary objectives of the study are:

- To examine the health and safety hazards associated with traditional construction methods in South Africa;
- To investigate the merits of prefabrication and pre-assembly in terms of their impact on overall health and safety improvements when compared with traditional construction methods; and
- To investigate to what extent construction clients perceive the use of prefabrication and pre-assembly as alternative construction methods that positively impact overall health and safety of construction workers on site.

1.6 Research methodology

The research methodology to be employed on this study will include the following, namely:

- An extensive review of relevant literature to establish the nature of construction activities that construction workers are exposed to with respect to the impact of these activities on the overall health and safety.
- The literature review will also include the use of alternative construction methods that potentially reduce or eliminate the risk of exposure of workers to conditions that impact negatively on their health and safety, such as pre-assembly, prefabrication and pre-casting.
- This approach will be complemented by a structured questionnaire survey of a sample of construction stakeholders and workers.
- Case studies, site visits and interviews will be used to gather relevant data to test the study hypotheses and achieve the research objectives.
- Bricklayers, bricklaying assistants, steel fixers, plasterers and their assistants, and prefabricated insulation walls erectors will be observed on site in the Western Cape region.

- Relevant gathered data will be used to test the study hypotheses and achieve the research objectives.
- Both qualitative and quantitative research methodologies will be used.
- Conclusions will be drawn and recommendations formulated from the analysis of the data.

1.7 Limitations

The following limitations will apply to the study, namely:

- Industry restriction: the research will be conducted on a limited number of construction sites;
- Geographical area: The research will be conducted in the Western Cape Province of South Africa; and
- Time constraint: The time available for the research is from February 2008 to June 2010.

1.8 Assumptions

- It is assumed that the proposed participant companies in the study will co-operate and allow access to their sites.
- It is assumed that the selected construction participants will respond honestly and accurately.

1.9 Ethical considerations

In order to comply with internationally accepted standards, the names of participant organisations and individuals will not be recorded on research instruments. No compensation will be paid to any respondent or participant in the study. Quality assurance will be done with respect to the following aspects:

- It is assumed that the proposed participant companies will be identified for survey;
- General conduct and competence of interviewers;
- Quality of data capturing;
- Accuracy in calculation; and
- Correctness and completeness of questionnaires if used, especially where open-ended questions are concerned.

1.10 Definition of key terms and concepts

Prefabrication: is the manufacture of component parts of a building and its service prior to their assembly on site (Wilson and Smith 1999).

Pre-assembly: is the manufacture and assembly of complex units comprising several components prior to the units being installed on site (Wilson and Smith 1999).

Health and safety legislation: Legislative frameworks that effectively address the work environment and procedures (Haupt, 2001).

Construction ergonomics: Ergonomics is a study of human capabilities relating to work demands (Samuels, 2005)

Labour based method: is a process whereby the construction work normally carried out by machines is carried out by labour (International Labour Organization, 2006).

Semi-skilled employee: is an employee who is competent through training and/ or experienced to be employed in specific services (Nicmar Building Centre, 2005).

Skilled employee: is an employee who is competent through training and/ or experienced to be employed in all activities of job description (Nicmar Building Centre, 2005).

1.11 Structure of the Thesis

Chapter One: presents an introduction to the topic and the background to the problem, the hypothesis, objectives and the research methodology.

Chapter Two: comprises of the literature review of previous work in the area of the study.

Chapter Three: describes the research methodology employed in the study to achieve the stated objectives.

Chapter Four: presents the findings of an exploratory study.

Chapter Five: findings of the research study

Chapter Six: discussion of findings

Chapter Seven: presents the conclusion and recommendations for future study.

1.12 Chapter summary

This chapter introduced outlined the framework of the entire research study. The preliminary literature review focused on health and safety background of the construction sector. The identification problem, research objective and methodology for data collection are presented in this chapter.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter critically reviews current and relevant literature on prefabrication and pre-assembly in the construction industry as alternative construction methods with particular reference to their impact on cost, productivity, quality and health and safety. The chapter also reviews the impact of current construction methods and practices on the health and safety of workers on construction sites.

2.2 Traditional construction methods and health and safety

Construction work is performed in two different ways, namely, using either traditional construction processes or offsite construction. Offsite construction refers to prefabricated material and components fabricated and/or pre-assembled in a factory-type working environment followed by transportation to their permanent location on site. Offsite production is also recognized under various names, for example, modularization, pre-assembly, prefabrication or precast (Haas *et al.,* 2000). Conversely, traditional construction work is carried out on site through the combinations of manual labour and raw materials. Traditional construction methods are referred to as labour based, labour intensive or in-situ construction methods. The in-situ construction method is construction work which uses raw materials and involves labour intensity on the building site.

Labour based techniques are an approach where construction activities which would be carried out by machines are instead carried out by labour on site (ILO, 2006). Labour based technology (LBT) has been used in many developing countries (Phoya and Haupt, 2008). Although, labour based methods, labour intensive methods or traditional in-situ construction methods are acknowledged to make use of large amounts of labour in a construction project, Parkikesit (2000) indicated that labour could also be used efficiently or inefficiently. Where large volumes of labour are employed doing construction work, health and safety remains a significant factor that requires consideration during the construction process. Given that the construction process involves physical demanding work, Green (1985) indicated that the fitness of a labour should be checked before engagement to work.

Labour based or traditional construction methods are seen as strategies for creating employment opportunities and alleviating poverty in the construction industry (Phoya and Haupt, 2008). Consequently, Kheni (2008) acknowledged the construction industry as a source of job creation which is encouraged by government policy. In South Africa, for example, the government initiated the Expanded Public Works Programme to increase the labour intensity of construction projects to alleviate poverty and unemployment levels (Biyase, 2005).

According to the CSIR (2003), the labour-intensive provincial and municipal infrastructure projects were expected to create about 500, 000 jobs with 150, 000 jobs from other infrastructure programmes. These labour-intensive jobs were underpinned by government policy which encourages small, medium and emerging contractors to utilize labour intensively to enhance the economic growth in South Africa (Agumba, 2006). Consequently, contractors are bound to use as many local labourers or workers as possible on any government-funded project which provides local job opportunities (Rowlinson, 1999). Typically, such projects engage workers in activities such as, excavation, temporary or permanent formwork erection, concrete work, roofing, steel erection, screeding, ceiling erection, block laying, carpentry, plastering work, reinforcement work, painting work, and bricklaying. While these activities may present opportunities for large numbers of people to be employed within the construction industry, they would also reduce the unemployment rate in South Africa if these jobs are sustained over sufficiently long periods of time. Regrettably, these jobs are, however, intrinsically hazardous in nature and impact negatively the health and safety of workers on construction sites. As a result, Smallwood and Haupt (2007) indicated that, while workers were involved in trade related work such as concreting, reinforcing, formwork, structural steelwork, masonry, roofing, building fabric, plumbing and drainage/pipefitting, suspended ceilings, painting and decorating, paving and other external work, ergonomic problems were highly possible.

Construction site activities are, reportedly the major causes of health problems to workers (Samuels, 2005). Additionally, construction activities and labour intensive methods were fraught with various hazards and risks to workers (Baradan *et al.*, 2006). These risks differ from trade to trade or activity to activity on a daily basis (Bruttene, 2005). The management of risks and the identification of potential causes of accidents during these construction activities will lead to improvement of health and safety on site. Although, Wamuziri (2008) indicated that many construction accidents were caused by human error, Ferreira (2008), however, asserted that many contractors failed to manage or give priority to health and safety risks on the construction site. Consequently, the mismanagement and underestimation of risk have resulted in serious injuries, accidents and fatalities (Eppenberger, 2007). Arguably, the construction site risks and accidental exposures are invited by human performance and insufficient management on site. These factors emphasize pressure on the construction industry to consider alternative construction methods to improve health and safety.

Given that health and safety performance improvement on construction sites is still a goal worth pursuing, Lou *et al.*, (2008) suggested that prefabrication would improve construction site working conditions by reducing significantly work to be done on site. McKay *et al.*, (2005) added that moving work away from construction sites themselves could lead to less hazardous construction activities and, consequently, less risk. According to Pasquire and Connolly (2002) prefabrication and pre-assembly will not only improve health and safety but quality, productivity, performance, profit and the time frame for completion of the contract.

The implementation and realization of health and safety benefits offered by alternative methods are dependent upon the obligation, commitment and motivation of clients of construction projects (Moeti, 2000). Regrettably, there is a lack of consideration for the benefits of prefabrication and pre-assembly in the construction industry in developing countries like South Africa (Tam *et al.*, 2007). Arguably, governments as major construction clients should encourage improved construction that exposes workers to less harmful working conditions such as, for example, prefabrication and preassembly. Unfortunately, in developing countries governments are committed to labour intensive methods. The resistance to the adoption of prefabrication and pre-assembly in the construction sector will restrict the improvement of construction health and safety (McKay *et al.*, 2005).

2.3 Factors leading to poor health and safety on traditionally constructed projects

The construction industry is the most significant industry to people worldwide (Kheni, 2008). For example, on the one hand, workers are involved in construction work to receive a basic income. On the other hand, construction companies anticipate benefiting from the services of these workers. Evidently, both parties expect to benefit from their involvement in the construction industry. However, construction processes confront workers with unsafe conditions which involve many risks and hazards on site.

According to Abdelhamid *et al.*, (2000) unsafe conditions involve the working environment or the working locations associated with tools, equipment and materials. Basically, unsafe conditions bring threats to the health of workers on construction sites (Mwombeki, 2005). Additionally, unsafe conditions can potentially lead to accidents, injuries and fatalities. However, Mantri (2005) found that the occurrences of accidents can be eliminated by the implementation of health and safety codes and practices in all stages of construction processes. Arguably, accidents can be prevented by identifying the problem activities, errors or unsafe conditions. Even though activities that present accidents and fatalities are identified, the construction site, however, does not receive effective management (Eppenberger and Haupt, 2008). A failure to manage construction risks could lead to accidents and fatalities on site.

Accidents and fatalities have earned the construction industry the reputation of being the most dangerous industry among all occupational groups (Deacon *et al.*, 2005). As a result, many research studies have been carried out to demonstrate the main causes and factors which present risks and hazards leading to accidents, injuries or fatalities in the construction industry.

2.3.1 Health hazards on site

Construction work involves physically demanding activities which utilize labour intensive methods in developing countries such as South Africa. Due to construction materials being heavy and irregular in terms of their form or shape (Smallwood and Haupt, 2007), it is not suitable for workers to lift and handle these materials (Smallwood, 2004). As a result, construction project activities and material handling techniques expose workers to high risk of hazards (Teo *et al.*, 2008).

Manually lifting, pulling, pushing or carrying large and heavy material is the most common material handling method performed by construction workers (Lipscomb *et al.*, 2005). To eliminate these exposures, it is the responsibility of the construction planner or designer to determine materials and equipment handling methods for the proposed construction works (Proverbs *et al.*, 1999). Clearly, the decisions during the design stage of designers directly impact on the health and safety of workers on construction sites (Rwamamara and Holzmann, 2007). Notably, the design team tends to focus on the safety of end users, with the expectation of contractors having to find their own ways of working safely (Hinze and Marini, 2008). Consequently, many accidents and fatalities occur during on-site construction processes given that construction work has a high probability to expose workers to hazards (Baradan, *et al.*, 2006).

Designer's decisions, arguably, expose workers to lifting, carrying and pushing heavy materials, which present the risk of musculo-skeletal disorders and ergonomic problems (Samuels, 2005). Within the period of 2005 to 2006, it was found that about 577 major injuries in construction were associated with handling, lifting or carrying of construction material in the United Kingdom (Wright, 2006). Rwamamara (2007) asserted that designers could influence the improvement of construction safety by making better choices in the design and planning stages of a project. Although, the designer may eliminate hazardous activities, material and various trades which expose workers to risks of accidents, injuries and fatalities on site, Pasquire and Connolly (2002) argued that designers, typically, have little understanding to distinguish between designing for manufacturing and assembling and insitu construction methods.

Given their labor-intensive nature, construction trades and activities tend to be a source of either temporary or permanent job creation. Unfortunately, such jobs can cause accidents or injuries to occur, for example, to a temporary worker resulting in permanent disability which may terminate the ability of that worker to secure future job opportunities. In Australia, for example, musculoskeletal disorders have resulted in work-related disability representing 34.0% (237,103 workers aged between 16 and 64 years) of all Disability Support Pension (DSP) recipients About 25.4% DSP recipients, or 177,129 workers had psychological or psychiatric disabilities in June 2004 (Waghorn *et al.*,2006). Moreover, Smallwood and Haupt, (2007) in their study found that, about 90.9% of workers were injured while performing construction work related to lifting an average weight of 20kg or more. Therefore, hazards associated with material handling during the construction process on site are discussed.

2.3.1.1 Ergonomic hazards

As previously stated, the nature of construction generally is a very physically demanding process reliant on manual labour (Samuels, 2005). Previous research papers have shown that construction work activities exposed workers to ergonomic challenges (Smallwood, 2004; 2006; Rwamamara, 2007; Samuels, 2005). These challenges include awkward postures, lifting heavy materials, manual handling of heavy and irregular sized loads, frequent bending and twisting of the body, working above shoulder height, working below knee level, and pushing and pulling of loads (Samuels, 2005; Ajayi and Smallwood, 2008).

The study of ergonomics is concerned with the wellbeing or fitness of workers while they are involved in work. Samuels (2005) indicated that ergonomics was the study of human capabilities relating to work demands. Ergonomics involves the exploration of the impact of work activities on the health of workers. Unfortunately, construction work and related activities have constantly negatively affected the health of workers. Samuels (2005) found ergonomic problems such as, working in the same position for long periods of time, using vibrating tools and equipment, working while injured, and being exposed to noise caused by construction tools, plant and equipment. Given that construction workers are expected to produce a specific amount of work per day, they perform work tasks with varying levels of risks exposure (Bruttene, 2005), and increasing the probability of ergonomic problems. Table 2.1 shows the factors which constitute ergonomic problems in construction.

Table 2.1 Job factors that constitute major ergonomic problems

Job Factors	Response%
Bending and twisting of the body	25.4
Working in same position for long time	21.1
Working while injured	18.7
Handling heavy materials or equipments	17.2
Reaching overhead or away from the body	16.7
Working in different environmental conditions (wet/humid, cold/ hot)	14.9
Working in awkward /cramped position	13.2

Source: (Samuels, 2005)

The job factors identified in Table 2.1 are indicative of construction workers being exposed to problematic working conditions. It is evident that bending and twisting are the leading factors that presented ergonomic problems to workers. These ergonomic problems could result in lifetime pain or disability among workers (United State Department of Labor, 2000). Smallwood (2006), however, asserted that making suitable decisions on design, procurement and construction methods could improve construction ergonomics. Arguably, the ergonomic hazards could be reduced by doing large amounts of construction work outside the construction site environment, which would result in reduction of manual handling hazards. Resultantly, as the construction process takes place in specialized facilities where working conditions can be controlled, construction site work involving awkward posture, heavy material handling, bending and twisting the body for long hours would be reduced or eliminated. Moreover, Smallwood and Haupt (2007) suggested that prefabrication would potentially reduce ergonomic problems. Toole and Gambatese (2008) argued that prefabrication would improve overall health and safety in the construction site.

2.3.1.2 Musculoskeletal disorders (MSD)

The National Institute of Occupational Health and Safety in the U.S.A. has defined

.......'*Musculoskeletal Disorders as a group of conditions around the working place that involve muscles, nerves, tendons, and supporting structure such as inter- vertebral disc'* (Piedrahita, 2003:6).

Musculoskeletal Disorders (MSD) have many different negative effects on the health of workers (Samuels, 2005). In 2001, the Bureau of Labor Statistics in the U.S.A. found that 1, 537, 600 injuries and illnesses were reported in private industrial workplaces. Over 582, 000 musculoskeletal disorders were also reported within the construction industry in the United States (Piedrahita, 2003). Evidently, the construction industry is still one with the highest risks of work-related musculoskeletal disorders (Rwamamara, 2007).

Musculoskeletal disorder injuries and illnesses affect body parts which may result in disability. Although, Badley *et al.*, (1994), found about 40% of chronic conditions and 54% of all long-term disabilities resulted from musculoskeletal disorders, Simons and Rwamamara (2007) suggested that the use of prefabricated or pre-cast elements could reduce risks associated with musculoskeletal disorders on site. Prefabricated or pre-cast operations transfer work hazards on site environment which includes high level of lifting, pulling, pushing and handling heavy to medium equipment, to factory mechanized equipment where work-related musculoskeletal disorders including the ergonomic challenges are likely to be reduced (Rwamamara and Holzmann, 2007). Clearly, the use of pre-fabrication does reduce the hazard level of construction tasks on site (Toole and Gambatese, 2007).

2.3.2 Safety hazards on site

The environment in which the construction work is performed is dynamic with many health and safety hazards that potentially affect workers. The accumulation of rubble and debris, working in trenches and at heights involving ladders, scaffolding, formwork and hand power tools are activities which presents hazards to safety of workers on construction sites (Griffith and Howarth, 2000). Workers performing construction work involving heights are likely to experience falls, slips and trips (Lipscomb *et al.*, 2005). Additionally, construction sites adopt large amount of people performing various activities using equipments and machinery. Consequently, workers work in confined spaces which are hazardous and awkward.

Among the numerous hazards and risks posed by the construction activities to workers, falls are the leading cause of fatalities in construction (Dong *et al.*, 2008). It has further been established that where construction activities involve work at heights, falls are likely due to many operations taking place on site. Construction workers may fall or slip while ascending or descending with heavy equipment when using scaffolds or ladders (Lipscomb *et al.*, 2005). Although, previous studies have shown various ways to prevent these falls, latest studies still show high levels of occupational fall accidents which remain to be dealt with (Lipscomb *et al.*, 2006; Hsiao *et al.*, 2007; Dong *et al.*, 2009). Clearly, there is a major need for alternative construction approaches which reduce the likelihood of falls on construction sites.

Ladders are one of the simplest, quicker and inexpensive construction equipments used on construction activities. Ladders are highly used on height related works such as, panting, plastering, ceiling and many more activities. Although, ladders may be cheaper and simpler to use, the ladder incurred the second highest fall accidents in the United States construction industry with about 164,000 occupational injuries on annual basis (Hsiao *et al.*, 2008).

According to Mthalane *et al.*, (2008) falls from ladders are caused by working on uneven ground surfaces and improper positioning. Moreover, some of ladder falls are caused by improper task selection for ladders, overreaching and slips while climbing due to faulty steps or rungs (United States Department of Health and Human Services, 2000). In the first instance, the use of a scaffold or access platform would have been more appropriate. Pendlebury and Gibb, (2004) suggested that the use of prefabrication as a construction method would reduce the environmental impact relative to unsafe and unhealthy conditions during the construction progress and consequently reduce site hazards. This means that activities where a ladder is needed will be reduced. For a long time, the construction industry has been tagged with being a challenging environment with a high probability for accidents, fatalities and injuries. Therefore, it is worth noting the benefits offered by other construction methods such as, prefabrication and preassembly.

According to the Construction Site Accidents Legal Guide (2006) scaffolding is a temporary framework which is used to support construction workers and their materials during the construction or repair of large structures. Scaffolding is brought on site in individual components that are then assembled for height related construction work, such as, bricklaying, plastering and painting. Since each of these activities involves ascending and descending with materials from point to point, risk of slips and falls while climbing or collapse of the scaffolding itself are likely due to site conditions and human error (Lipscomb *et al.*, 2005). Mthalane *et al.*, (2008) reported that falls while using scaffold were caused by, *inter alia,* absence of guard rails. McKay *et al.*, (2005) argued for alternative methods that would reduce the use of scaffolding on site. Readily made structural components such as cladding walls and precast slabs potentially reduced the need for scaffolding where risks of falls were likely. Although the use of cranes may seem dangerous when lifting these components, they removed the exposure to the impact of manually handling components or constructing these using conventional means.

2.3.2.1 Working in confined space

NIOSH (1986) found that about 60% of the fatalities of workers working in confined spaces could have been prevented. Additionally, according to Safety Corner in Washington (2003) the metal fumes and toxins resulted from welding, cutting and brazing while working in confined spaces could result in brain damage. Clearly, the health and safety risks and challenges transmitted by the construction environment to workers demanded more consideration by designers for the way workers executed construction activities and more advanced construction technologies to reduce the risk of exposure to working in confined spaces. Toole and Gambatese (2006) suggested that the utilization of prefabrication would reduce working at heights including working in confined space and, consequently, reduce exposure to hazards on site, including hazardous materials and activities.

2.4 Origins of prefabrication and preassembly

Rwamamara (2007) defined prefabrication as the manufacturing of structural components which took place at a specialized facility or factory followed by their permanent installation in place on site. Prefabrication had been used for over a century with reference to improvement on performance, schedule and cost implications (Toole and Gambatese, 2008). For example, in 1779, an iron prefabricated bridge at Colebrookdale was built in the United Kingdom (Waskett, 2001). Given that offsite construction methods had been previously extensively used for many years in developed countries such as Australia and the U.K. (Blisman, 2007), there have been many studies that investigated the impact of preassembly and prefabrication within the construction industry. Pasquire *et al.*, (2005) measured prefabrication based on cost, time, quality, health and safety, sustainability and site issues and pointed out that health and safety was of primary importance for all concerned. McKay *et al.*, (2005) found that offsite production managers would be provided guidance in design and planning stage to eliminate certain hazards and create an enabling working environment. Evidently, these studies demonstrated many benefits offered by prefabrication and preassembly in the construction industry.

Although the construction industry has been associated with delays, waste, poor performance and poor health and safety, the use of prefabrication has been shown to reduce construction delays caused by weather conditions on a project (Abdallah, 2007). Moreover, Pasquire and Connolly (2002) reported that the use of prefabrication minimized waste, maximized value and improved overall performance. Gibb (2001) suggested that the construction industry should change its current culture to that of the manufacturing sector to improve the overall construction process. Luo *et al.*, (2005) found that prefabrication was an opportunity to reduce cost. Yeung *et al.*, (2005) found that prefabrication would present the following benefits on projects:

- Higher productivity levels of construction trades;
- Cost savings at every level of the supply chain due to mass production, e.g. labour and materials costs;
- Faster return on investment for the client;
- Reduced programme durations for fixing and erection operations;
- Lower manpower requirement on-site owing to simplified work content at working floor;
- Savings in space allocated to materials storage;
- Better quality control leading to more accurate profiles and dimensions of components;
- Less materials wastage because of fewer defective products;
- Safer working environment at prefabrication factories;
- Enhanced teamwork spirit and manufacturing ethos under a repetitive production process;
- More efficient testing requirements of the products at the manufacturing facility than at the construction site;
- Less influence of site tasks by inclement weather conditions;
- Re-engineered project delivery and supply chain system based on wide scope of prefabrication and preassembly; and
- Application to public and private sector housing, commercial building and road construction projects in collaboration with industry and government partners

From this evidence prefabrication offers opportunities for major improvements in the construction industry. Glass and Pepper, (2006:239) argued that

..... "the worst place to build a building is on a building site, the best place to build a building is in a factory because it is a more controlled environment".

Many authors have demonstrated the benefits associated with prefabrication. It still remains for clients and construction stakeholders to encourage the transformation and transition to a manufacturing culture.

2.4.1 Perception of construction clients on the prefabrication as an alternative method for construction

Given that construction clients bring their idea of a building to construction professionals with a clear definition of its purpose (Schexnayder and Mayo, 2004), they also have their expectations and specific requirements that have to be met regardless of the complexity and nature of construction sites. Consequently, the construction project team meets to prepare a suitable package of strategies to satisfy these requirements. This package may involve the preparation of feasibility studies, drawings and planning, contracts and tenders documents including the selection of a suitable construction method. These activities were governed by the project and client requirements, where time, cost, quality, value, trust and security were mostly considered (Smallwood, 2000).

Cost, time and quality have been the priority of construction clients for many previous decades (Smallwood, 1999; Musonda and Haupt, 2008). Bikitsha and Ndihokubwayo (2009) found that construction clients were still influenced by time, cost and quality when selecting prefabrication as an alternative construction method. However, Pacquire and Gibb (2002) indicated that clients resisted the use of prefabrication and pre-assembly since they were unfamiliar with the benefits associated with off-site manufacturing. Abdallah (2007) compared prefabrication and in-situ construction methods and found that the prefabricated concrete structure was cheaper. Unfortunately, there is little willingness to change from in-situ construction to off-site manufacturing in the form of prefabrication and pre-assembly in the construction industry (Gibb, 2001).

The experience of clients in the construction industry could contribute to resistance to prefabrication and pre-assembly. For example, inexperienced clients relied on recommendations of consultants to take most decisions in a project, unlike experienced clients who knew what construction was all about. The resistance of inexperienced construction clients may be attributed to designers not proposing off-site manufacturing processes in their designs. Gibb (2001) argued that these advisors remained the main barrier to further implementation of prefabrication, even though clients had the last say.

Experienced construction clients were familiar with construction methods and therefore made more decisions. Although the designer might advise on particular matters, Bikitsha and Ndihokubwayo (2009) in their study found that designers rarely proposed the use of prefabrication as alternative construction methods. The primary drivers and motivators for or barriers to the adoption of manufacturing include

- Clients and the project team;
- Procurement methods and supply chain relationships;
- Formal/contractual requirements;
- Legislation;
- Changing construction to a manufacturing process;
- Whole life costing,
- Sustainability and waste reduction;
- People issues, skills and training;
- New materials and technologies;
- Information and communications technology;
- Pre-assembly; and
- The measurement of success (Gibb, 2001).

Some authors found that client resistance to the use of prefabrication could be attributed to the following, namely

Initial cost (Glass and Pepper, 2006);

- Inhibition of design creativity (Pasquire and Connolly, 2002);
- Lack of understanding the product by the SMME's (Gibb,2001); and
- Client requirements.

Although clients might reject the use of prefabrication due to negative perceptions about its initial cost implication, the reduction of labour, waste and many construction site operation related cost would enhance profitability in a construction project. Unfortunately, in developing countries like South Africa, the in-situ construction method was regularly a preferred method for project construction. It was possible that the resistance to the use of prefabrication as a construction method might be caused by its perceived reduction of labour since many developing countries have high rates of unemployment.

2.5. Merits of prefabrication and preassembly relative to construction health and safety

2.5.1 Effects of pre-assembly on health and safety

While prefabrication involved the manufacture of building components and services prior to their assembly on site (Wilson *et al.,* 1999), pre-assembly covered the manufacture and complete assembly of building parts or structures earlier and usually off-site before their installation into their final position on site (Gibb, 2001). These two construction processes therefore had on-site installation processes that differed slightly from each other. For example, prefabricated concrete slabs are delivered to site in pre-manufactured components with instructions of how to assemble them. On the other hand, preassembled units will be assembled before transportation to site. Hass *et al.,* (2000) indicated that preassembly could be a combination of prefabrication and modularization. Fredriksson (2006:351) defined modularization as;

"…….the ability to pre-combine a large number of components into modules and for these modules to be assembled off-line and then bought onto the main assembly line and incorporated through a small and simple series of tasks".

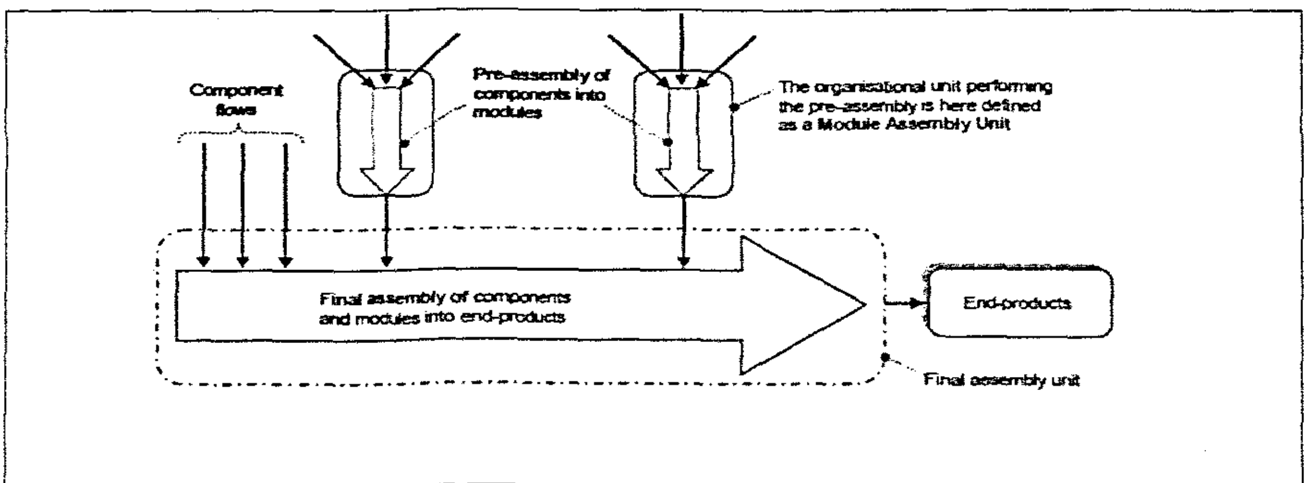

Figure 2.1: Modularity in production (Court *et al.,* 2006)

Figure 2.1 shows the process of modularization of preassembly units. The preassembled components are pre-connected together to form modules as the completed end product. Due to modules being large when joined together, they are often transported in multiple sections (Hass *et al.,* 2000). In countries such as, for example, the UK, China, Netherlands and Malaysia, there have been many studies on the evaluation of the use of off-site construction. Many have recommended it as the best method for construction due to its benefits (Willems, 2003; Thanoon *et al.*, 2003; Pasquire and Collony, 2002; Pendlebury and Gibb, 2004). Consequently, Gibb (2001) argued that there was a need for the construction industry to change from its current culture to offsite manufacturing to improve its overall performance.

Hass *et al.,* (2000) and Court *et al.,* (2006) suggested that the utilization of offsite production would lead to improvements in overall project health and safety. Evidently, the use of preassembly would reduce the possible hazards that could lead to unnecessary accidents and fatalities within the construction industry. For example, McKay *et al.*, (2005) in their study found that the fatality rate and non fatality accidents in the United Kingdom construction industry were reportedly lower than those of the United States. This was one of the testimonials from the utilization of offsite production in the United Kingdom construction industry.

Preassembled building units were well designed and created in a safe working environment where automated tools and material were used. Preassembly could be built in an unprotected environment which required full attention to health and safety of workers. For example, preassembly may be combined with various construction trades where different kinds of risks and hazards during the construction process were often likely to result in injuries and accidents (Baradan *et al.,* 2006). However, Bikitsha and Ndihokubwayo (2009) found that prefabrication was flexible and it would reduce risks associated with on site construction processes. For instance, Figure 2.2 shows risks incurred with slab construction process done on site. Figure 2.2 shows a comparison of slabs built onsite and precast concrete slab installation in site.

The processes in Figure 2.2 clarify that offsite construction reduced many hazards associated with on-site construction activities. For example, worker's involvement in manual material handling onsite associated with huge exposure to twisting, bending and repetitive lifting loads while mixing concrete could result in back injuries (Bust *et al.*, 2005) which would be reduced by offsite processes. Additionally, concrete vibrating involves workers in repetitive hand and arm vibration which could lead to hand and arm vibration syndrome (The Office of Regulatory Services, 2008). Hand-arm vibration syndrome (HAVS) develops an influence on blood vessels, nerves and muscle on hands, arms and wrist which may result in disability if ignored (HSE, 2005). The Office of Regulatory Services (2008) indicated that anti-vibrating gloves reduce vibration. However, offsite precast concrete slab would eliminate the need for concrete vibration on site completely.

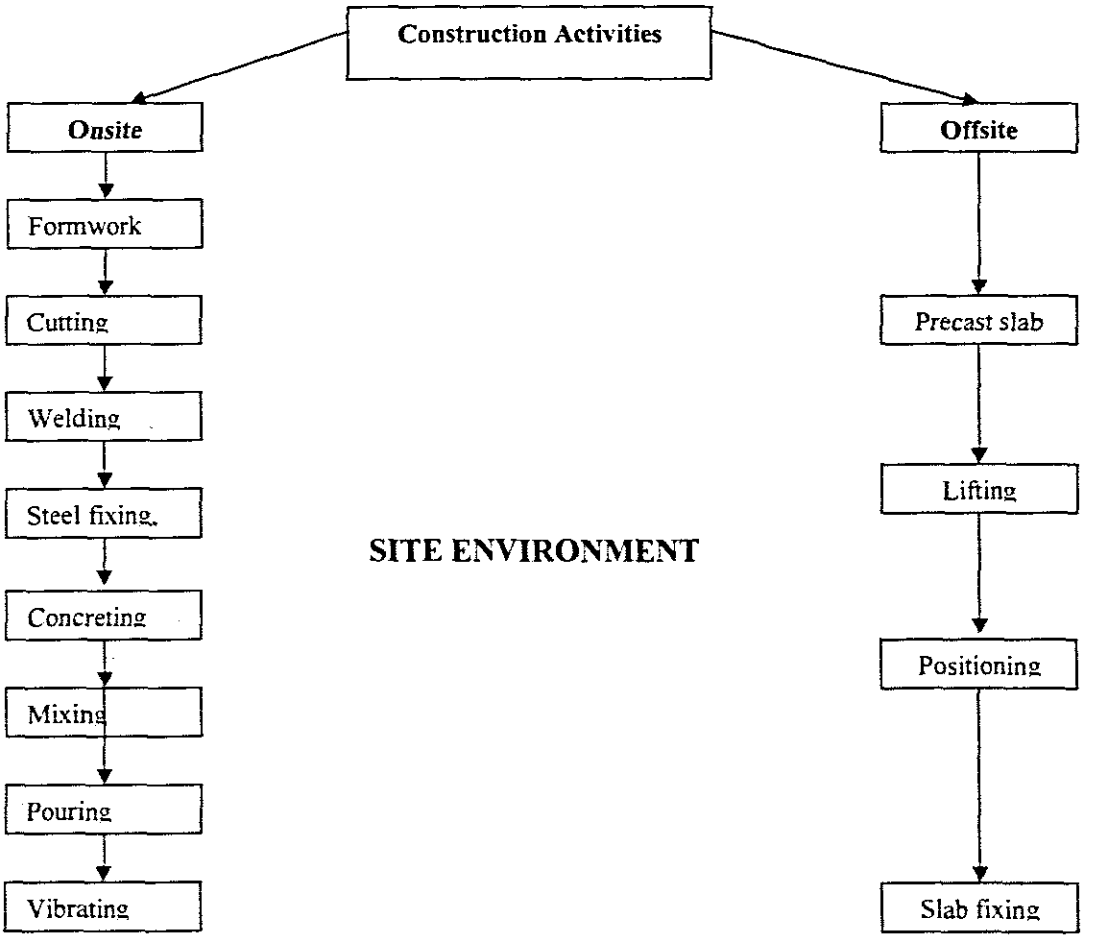

Figure 2.2: A comparison of risks associated with construction processes of precast and insitu concrete slabs on site

Preparation of steel also involves awkward postures and kneeling resulting in back injuries (Construction Safety Association of Anterio, 2008). While steel fixing exposes workers to various health risks, precast concrete reduce the use of formwork and onsite steel fixing, cutting, tying and concrete mixing process which expose workers to health hazards (Smallwood and Haupt, 2007). Arguably, precast concrete would be quicker and easy to erect with less risks compared to traditionally concreting on site. Additionally, McKay *et al.*, (2005) in their study found various health and safety benefits associated with offsite production such as, for example;

- Better control of welding operations;
- Elimination of working on heights eliminate use of scaffolding;
- Less falls, trips and slips;
- Material are mechanically handled right to the workplace;
- Reduction of activities associated with MSD; and
- The work is performed in an open space compared to the confined space on-site.

2.5.2 Measurements of health and safety improvements with prefabrication

The construction process involves complex operations that require the strategic selection of construction methods that do not threaten the health and safety of workers. South African construction sites generally present challenges for contractors and especially those from the underdeveloped sector to maintain health and safety on site (Nair and Haupt, 2008). It is particularly true that anyone can start a construction company regardless of their experience in the industry. Consequently, there is a high probability that health and safety management will be either compromised or ignored.

In South Africa, traditional construction methods are preferred where the overall creation of the desired structure is done on site. This preference involves work processes that demand focus on project requirements and conditions that exclude in most cases health and safety of workers (Smallwood and Haupt, 2008). Despite the health and safety of workers and project efficiency being major concerns during the construction of a project (Choudhry *et al.*, 2008), the construction site activities continue to threaten the health and safety performance of the industry (Kikwasi, 2008). As a result, construction sites are considered to be danger zones compared to other workplaces (Wamuziri, 2008). Many studies that compare in-situ construction to prefabrication off-site (Shen *et al.*, 2008; Pasquire *et al.*, 2005) found that in-situ construction activities were more hazardous (Gibb and Neale, 1997; Rwamamara, 2007; Bikitsha and Ndihokubwayo, 2009).

Court (2009) noted that the industry had 56,000 cases of work-related MSD cases and over 38% of all lost-time material-handling injuries in the period 2004 to 2005. Prefabrication was found to possibly reduce the exposure of workers to physical demanding work related to manual material handling processes (Mckay *et al.*, 2005). Continued resistance to off-site construction methods conceals these potential health and safety benefits. These benefits will be derived from identifying hazards on site which could be eliminated or reduced by off-site processes as shown in Figure 2.3.

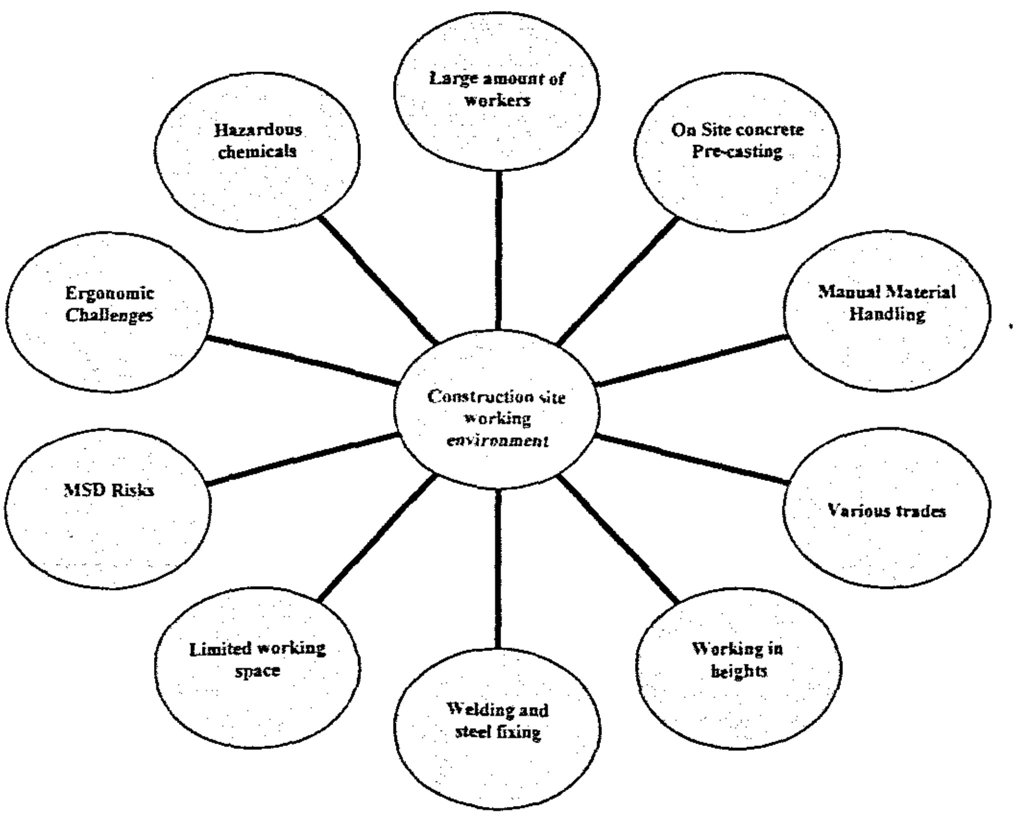

Figure 2.3 The construction site working environment (Haupt, 2001)

This working environment leads to poor health and safety performance (Deacon *et al.*, 2005 and Baradan *et al.*, 2006). Consequently, many injuries and fatalities occur, which Baradan *et al.*, (2006) found that roof works involved the highest risks. Conversely, Gibb, (2003) argued that the use of prefabrication and preassembly was found to be six times safer than the traditional insitu construction in terms of fatalities and accidents in the United Kingdom. This implies that the adoption of prefabrication and preassembly would mean safer working condition, reduction of manual material handling and consequently simplify the ways of managing safety.

Table 2.2 Potential health and safety benefits of prefabrication

Site Activities	Reduction of onsite risk and hazards with prefabrication
1) Hazardous activities	• Reduction of hazardous trades • Eradication of on-site reinforcement concrete, steel fixing, cutting and tying • Reduction of scaffolding and temporary formwork risks. • Reduction of height related works • Reduction of slip, trips and fall • Elimination of bending, twisting, kneeling and working in awkward positions, • Improvement in working conditions
2) Material Handling	• Eliminate handling hazards such as lifting, carrying, pulling and pushing • Reduce physical demanding activities • Reduce hazardous material • Reduction of ergonomic problems and musculoskeletal disorder probabilities. • Reduction of Chronic non-specific respiratory disease/chronic bronchitis
3) Environmental Issues	• Reduction of hazardous waste on site • Eliminate hazards associated with working on confined space • Less construction operations and large equipments • Reduce exposure to dust, weather conditions and vibrating tools health hazards • Reduction equipment noises and hazardous chemicals

Source: (McKay *et al.*, 2005; Bikitsha and Ndihokubwayo, 2009; Smallwood and Haupt, 2007)

From Table 2.2, it is evident that the adoption of prefabrication would lead to major benefits of health and safety on construction site. Material handling hazards entails the involvement of workers to manual lifting, handling, puling and pushing unsuitable material which directly impact their health. While hazardous activities involve height related work and working conditions, environmental hazards refer to noises, weathering conditions and working in the confined space. It is clear that health benefits of prefabrication refer to its potential reduction of material handling hazards, ergonomic problems and musculoskeletal disorder probabilities. Safety benefits involve the reduction of height related works and improvement of working conditions. It can be argued that the use of prefabrication would improve environmental issues, hazardous activities and material handling and also improve health and safety performance on construction site

2.6 Chapter summary

The chapter provides an overview of literature relative to the impact of prefabrication on construction health and safety. The literature argues that the adoption of prefabrication as an alternative construction method would result in less hazards and less risks than where construction work is traditionally done on sites. A traditional construction method presents major threats to health and safety of workers.

The traditional construction method health hazards were material handling hazards, ergonomic and musculoskeletal disorders hazards. Safety hazards were discussed in relation to ladder works, scaffolding and working in confined spaces. The use of prefabrication and preassembly on site could lead to potential reduction of these health and safety hazards since most of construction works would be carried out under factory conditions off site.

The chapter also reviewed the perceptions of clients with regards to the use of prefabrication as an alternative construction method.

CHAPTER 3
RESEARCH METHODOLOGY AND DESIGN

3.1 Introduction

The chapter outlines the research methodology that will be used to obtain the relevant information or data for this study. Oliver (2004) asserted that the methodology describes the steps in a practical way of how the whole research project will be organized. The main purpose of the research methodology is to elucidate the nature and the process of research in order to obtain relevant answers or possible solutions to a particular problem (Welman *et al.*, 2006).

The research problem is underpinned by the reviewed literature to provide clear understanding and a solid background of the problem to be investigated. According to Kothari (2004: 25)

......."a research problem is one which requires a researcher to find out the best solution for the given problem".

The problem investigated is the potential benefits to the health and safety of construction workers of alternative construction methods such as pre-fabrication and pre-assembly. Despite on-site construction methods typically exposing construction workers to many hazards and ergonomic challenges, there is a perceived resistance on the part of clients to consider alternative construction technology.

According to Welman *et al.*, (2006), a hypothesis is a declaration or proposition to be tested by reference to the findings of empirical study. Fellows and Liu (2008) further asserted that it was significant to use hypotheses in research when the study was based on theory and previous work. The research problem and hypotheses guide the gathering of information required to lead the formulation of research objectives. When these are connected together, they form a strategic plan of how to address the research problem.

3.2 Research design

The research design involves preparation and selection of methods of collecting and analyzing a data with aims to fulfill the research purpose. Research design is considered once the researcher has determined the problem to be investigated with clear objectives and measurable hypothesis (Marczyk *et al.*, 2005). The effectiveness of the research design is determined by involving five factors namely,

- The means of obtaining information;
- The availability and skills of the researcher and his staff, if any;
- The objective of the problem to be studied;
- The nature of the problem to be studied; and
- The availability of time and money for the research work (Kothari, 2004).

3.3 Overview of research strategies

The strategies or methods of collecting data should be precise as they could impact on research outcomes (Fellows and Liu, 2008). According to Kothari (2004:8)

........"researchers not only need to know how to develop certain indices or tests, how to calculate the mean, the mode, the median or the standard deviation or chi-square, how to apply particular research techniques, but they also need to know which of these methods or techniques, are relevant and which are not, and what would they mean and indicate and why".

There are two types of research methodologies that can be used to collect data in a research project, namely, qualitative and quantitative methods. Quantitative and qualitative researches differ from each other in many ways while at the same time they can complement each other (Neuman, 2000). The main difference between these two approaches is that, the qualitative approach seeks objective data which consists of findings presented numerically while qualitative method deals with subjective data where respondents express their own opinions. Both qualitative and qualitative approaches were adopted for this study. The figure 3.1 below shows the research strategy which was utilized for this research study.

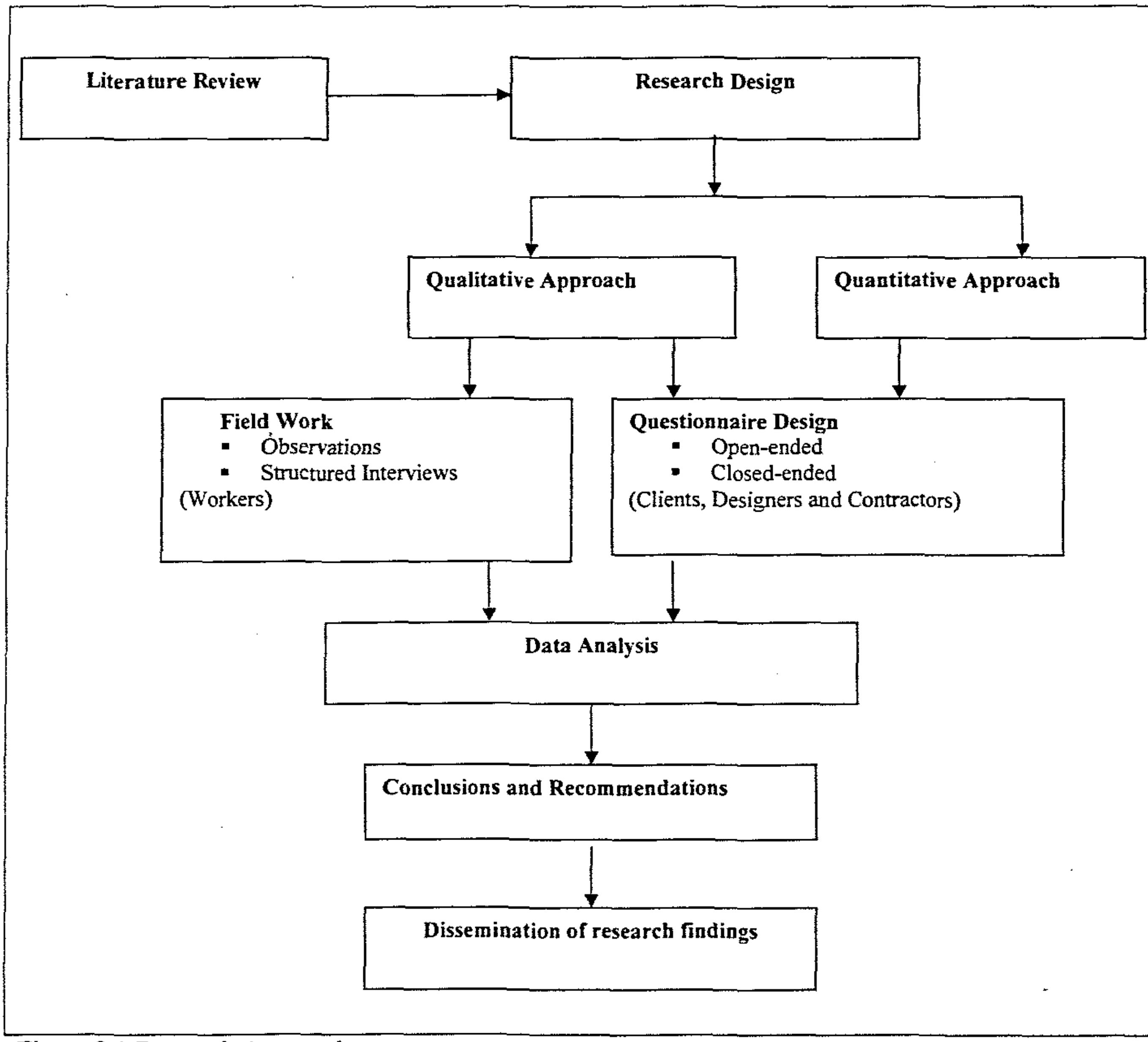

Figure 3.1 Research Approach

3.2.1 Quantitative approach

In quantitative research, researchers make use of statistical analysis to convert their data to a numerical index with the aim of generalizing the findings derived from a sample to a population. This approach depends on the informal understanding that has developed from the experiences of the researcher (Neuman, 2000). The main focus of the quantitative study is to control all components in actions and depictions of the respondents (Henning *et al.*, 2004). Qualitative research typically consists of two research strategies namely experimental and survey research. Survey research involves a sample of population which is studied to determine its characteristics (Kothari, 2004). This could involve interviews or administered questionnaires to samples of research respondents selected to obtain the possible data required. According to (Marczyk *et al.*, 2005:3),

……. *"the experimental research involves comparing two groups on one outcome measure to test some hypothesis regarding causation".*

In the context of this study, the literature suggests that prefabrication and preassembly as alternative construction methods would lead to potential improvements of health and safety on construction sites. The survey approach was useful for this study to determine counts, weight or mass of respondents relative to causes of health and safety problems and the effect of traditional construction methods on the health and safety of workers, measurement of potential benefits of health and safety by prefabrication and preassembly and perceptions of clients with regards to the use of prefabrication and preassembly as alternative construction methods. However, the adoption of a quantitative method alone would not cover all the necessary data required. The qualitative research approach was also utilized to get the true feelings of the outside world relative to the impact of prefabrication and preassembly on construction health and safety.

3.2.2 Qualitative approach

The qualitative approach involves the curiosity of the researcher to discover the true feelings and understanding of the world relative to certain issues. Qualitative research studies do not measure and quantify their results in the same way as the quantitative approach does (Marczyk *et al.*, 2005). Qualitative research uses unchanged logic to get what is real in terms of quality, meanings, contexts, or images of reality based on what people actually do. The aim of qualitative research is to obtain answers from questions based on 'what',' how' or 'why' instead of trying to find out 'how many' or 'how much' (Green and Thorogood, 2004). The advantage of qualitative research is that it recognizes the different experiences of respondents who are free to give their insights in a relatively unrestricted manner. Unfortunately, qualitative methods can be difficult to analyze since respondents may provide so many different opinions that may affect the reliability and validity of the study.

Generally, there are five types of qualitative research, namely:

3.2.2.1 Case study

.... *"is often used to describe a study that involves data from a real setting (in our case often a setting in practice), and is seen as equivalent to an observational study in which only one or very few cases are involved"* (Blessing and Chakrabarti, 2009: 269).

Case study approaches focus on groups, individuals, communities or organizations, depending on the nature of data to be gathered.

3.2.2.2 Phenomenology

.........*"provides an insight into the meanings or essences of experiences that we may previously have been unaware of but recognize"* (Richard and Morse, 2007:52).

3.2.2.3 Grounded theory also known as a philosophical research involves a theory that is developed from the data. According to Singh (2006) philosophical research requires naturally good philosophical thought in general.

3.2.2.4 Ethnography provides the means of exploring cultural groups (Richard and Morse, 2007). When conducting ethnography research it is significant for the researcher to carefully plan how the data will be accessed.

3.2.2.5 Historical research seeks to reveal past related problems or information in order to improve current or future trends. According to (Singh, 2006), historical research involves the collaboration of facts and records of the past.

Qualitative research involves observation of personal experiences of particular issues with aims to generalize and solve them. In the context of this study, the qualitative approach investigates the perceptions of construction stakeholders relative to the impact of prefabrication and preassembly on construction health and safety.

3.3 Data collection method

Researchers typically collect two sets of data for the research, namely, primary and secondary data (Kumar, 1999). Primary data involves practical methods of collecting a data. Secondary data includes reviewing relevant literature which is sourced from the existing theoretical knowledge. This process involves reading, understanding, linking ideas, and constructing the previous theoretical information with aims to identify a research problem. It also includes the use of existing databases and other data that have been collected by other researchers and is in the public domain.

3.3.1 Secondary Data,

3.3.1.1 The literature review

The review of literature provides a clear understanding of, which form of questionnaires will suit the study, participants involved and what research instrument to be adopted. The literature that was reviewed was drawn from various journals, government publications, textbooks, conference proceedings and internet sources of information. Despite the relevance of the information gathered from different literature studies and presented, Welman and Kruger (2003) argued that these studies should link to one another in order to provide a logical flow of an argument.

The literature reviewed for this study addressed the exposure of workers to health and safety hazards when engaged with traditional construction methods. The literature also discussed the potential benefits of health and safety through utilizing alternative construction methods such as prefabrication and preassembly. The reviewed literature focused on clients relative to their use of prefabrication as an alternative method for construction.

3.3.2 Primary Data

The primary data was gathered on limited numbers of construction sites and offices from clients, designers, contractors and workers. Kumar (1999) indicated that several methods can be used to collect primary data depending on nature of the targeted population.

3.4 Population

The population is the study object which involves individuals, groups, organizations, human products and events (Welman and Kruger, 2003). Blanche *et al.*, (2006) further maintained that the population was the larger pool from which sampling elements are drawn and where findings are generalized. The findings may be generalisable only if the sample is representative.

.... *"By "representative" we imply that the sample has the exact properties in the exact same proportions as the population from which it was drawn but in smaller number"* (Welman *et al.*, 2006:55).

Kothari (2004) suggested that the respondents selected for the study should be as representative of the total population as possible in order to produce a small sample. Additionally, the research problem should relate to a specific population before drawing a sample of that population for analysis (Welman *et al.*, 2006). In order to acquire the data relative to the impact of prefabrication and preassembly on construction health and safety, the targeted groups were namely:

- Construction site workers;
- General contractors;
- Private and public sector clients; and
- Architecture and engineering designers.

The targeted population will cover the total collection of all units of analysis and lead the researcher to conclusions (Welman and Kruger, 2003).

3.5 Sampling

According to Kumar (1999) the sample of a population is selected to estimate a certain fact or situation regarding the bigger group (Kumar, 1999). There are two types of sampling, namely probability sampling and non- probability sampling (Kothari, 2004). Each of these two sampling design is divided into sub-sampling as shown in Figure 3.2.

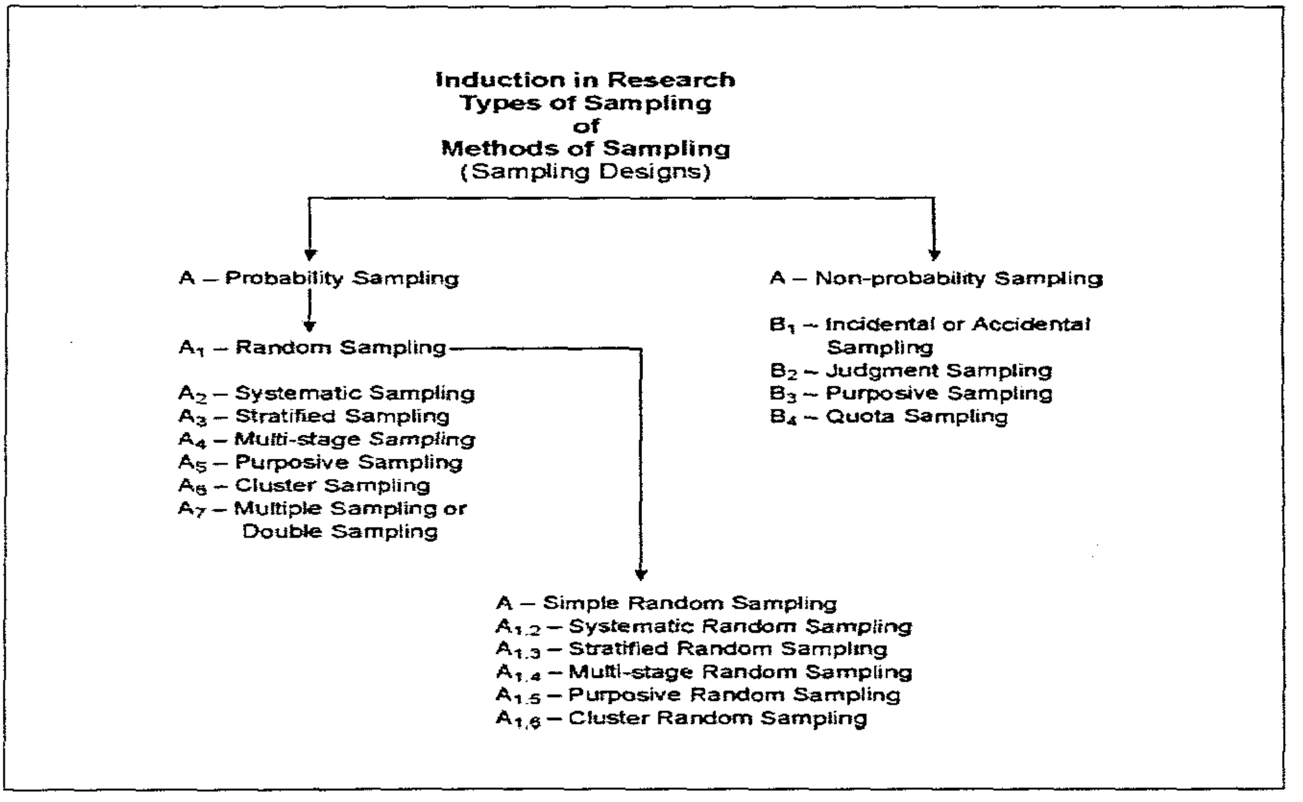

Figure 3.2: Induction in research types of sampling methods
Source: (Singh, 2006)

Non-probability sampling is a procedural sampling approach which does not afford any basis for estimating the probability that each item has in the population (Singh, 2006). Conversely, in probability sampling, it is possible to identify that any element or item of population will be included in the sample (Welman *et al.*, 2006). While, probability sampling is also known as a random sampling, non- probability sampling is referred to as non-random sampling. Stratified random sampling was selected for this research given that the proportional representatives of populations were subgroups of the population. Additionally, representativeness is guaranteed with a stratified random sampling regardless of the sample size since it is built into the sampling strategy from the start (Welman and Kruger, 2003).

3.6 Questionnaire design

De Vos *et al.*, (2002:172) defines a questionnaire as:

……..*"a set of questions on a form which is completed by the respondent in respect of a research project"*.

A questionnaire is issued to respondents to read, interpret and answer the questions in it. Questionnaires seek the views of various groups, individuals or organizations relative to particular issue. A questionnaire could involve two different forms of questions, namely, open ended and closed ended questions (Fellows and Liu, 2008). Both open ended and closed ended forms of questions were adopted for this study.

- In closed ended questions, the respondents are given a range of statements which require respondents to tick the appropriate box (Welman *et al.,* 2006). The respondents are restricted according to the way they should answer the questions. These types of questions are also known as quantitative questions since their data is analyzed statistically.
- Open ended questions acquire the direct thoughts and insight of respondents. In open ended questions, the answers of respondents are not influenced by the researcher inputs (Welman *et al.,* 2006); hence the respondents speak or write what they really feel. Although these questions are easy to ask, they may pose difficulties for respondents to answer given that they require critical thought of mind. Fellows and Liu (2008) further indicated that the responses from these questions could also pose difficulties for the researcher to analyze.

Kothari (2004: 105) argued that

......"the questionnaire method is likely to be very slow since many respondents do not return the questionnaire in time despite several reminders".

Additionally, face- to-face interviews were conducted on construction sites with 53 workers to complement the data from questionnaires. Meetings with the respondents were set up via telephone prior the visit. During these meetings respondents were given questionnaires to complete in the presence of the researcher. However, some respondents indicated that they were busy and would return the questionnaire via mail or the researcher should return and pick them up on a particular day.

A suite of four questionnaires was designed, each targeted at a specific sample. A questionnaire was designed to investigate whether construction workers had any health and safety related threats while involved in their work. This questionnaire was divided into Section A and Section B. Section A was designed to obtain data relative to the impact of traditional construction activities on health and safety of workers. In section B, the improvements of health and safety through utilization of prefabrication were examined. Figure 3.1 below indicates the number of each type of questions in each section.

Table 3.1: Construction worker questionnaire

Questions	Section A	Section B
Closed-ended	8	3

Other questionnaires were designed for contractors, designers and clients to determine their perceptions about the use of prefabrication as an alternative construction method (Section A) and their views relative to the merits of prefabrication and preassembly to improve the health and safety of worker when compared with traditional construction methods (Section B). For most of the questions a 5-point Likert scale was considered apt and scaled answers were posed.

Table 3.2: Construction contractor questionnaire

Questions	Section A	Section B
Closed-ended	8	3
Open-ended	2	1

Table 3.3: Construction designer questionnaire

Questions	Section A	Section B
Closed-ended	7	3
Open-ended	0	1

Table 3.4: Construction client questionnaire

Questions	Section A	Section B
Closed-ended	7	3
Open-ended	2	0

3.7 Interviews

There are three kinds of interviews, namely: structured, semi-structured and unstructured interviews. The method of collecting data in a personal way refers to *"structured interview"*. In *"semi structured"* interviews, the researcher indicates all necessary themes and questions to be covered, while unstructured interviews are relatively informal and adopted to explore a general area of interest (Fellows and Liu, 2008).

Usually, the interview is the process of question and answer between the researcher and a single respondent (Fellows and Liu, 2008). Interviews can be done either telephonically or face-to-face

On construction sites, most of the workers spoke Xhosa. Interviews were undertaken to examine the impact of traditional construction methods on their health and safety and also measure perceived health and safety related benefits associated with prefabrication and preassembly. This was done by exploring material handling hazards and activities that have led to ergonomic problems and illnesses to workers. These interviews accommodated those Xhosa speaking workers which did not understand English given that the questions were written in English. This was an advantage because the researcher understood and also speaks Xhosa.

3.8 Case study/observational approach

Observation is an efficient method to collect a data by means of studying or quantifying behaviors of an individual or group of people (Marczyk *et al.*, 2005). The effectiveness of observation to bring about the desired result for a formulated research purpose is increased when it is systematically planned and recorded and is subjected to checks and controls on validity and reliability by an observer (Kothari, 2004).

The observational design can either be structured or unstructured depending on the nature of the data required. In most cases, structured observations are considered in a descriptive study, while unstructured are considered in an exploratory study (Kothari, 2004). Structured observation refers to an observer having to select particular activities or factors relative to human behavior. For example, if an observer wishes to find out specifically the frequency of the body movement of a worker while engaged at work for a specific time interval recorded on a pro forma, the observer is conducting a structured observation. But if an observer is observing activities generally with no specific factors then he is undertaking unstructured observation. Moreover, when an observer is planning to observe various activities, it is essential to consider

- The site;
- The observation point;
- The study period of time;
- Continuous observation or sampling;
- Numbers and length of sampling periods;
- What to observe;
- Zone divisions;
- Design of the record sheet; and
- Analysis of data (Welman et al., 2006).

A team of four students observed the body movements of construction workers while they were engaged in selected construction activities. An observation sheet was used to record each body movement involved in the activity of each worker for five minute periods with one minute breaks in between. Each activity was observed for 2 hours by the entire team to ensure accuracy in the observation and recording processes. These body movements included bending and twisting of the body, working in same position for long time, handling heavy materials or equipments, working below knee level, kneeling, working above shoulder and reaching overhead or away from the body. Bricklayers and their general worker, steel fixers, plasterers and their general worker, and prefabricated insulation walls erectors were observed for two hours. As previously stated, each activity was observed for two hours in five minute periods with a one minute break after each 5 minute period. Seven activities were observed and analyzed quantitatively using SPSS.

3.9 Data analysis

As shown in figure 3.3, the data analysis process involves various steps that demand the full concentration of the researcher in order to avoid unnecessary errors on the data. Kothari (2004:130) defined the analysis of data as;

......"the computation of certain indices or measures along with searching for patterns of relationships that exist among the data groups".

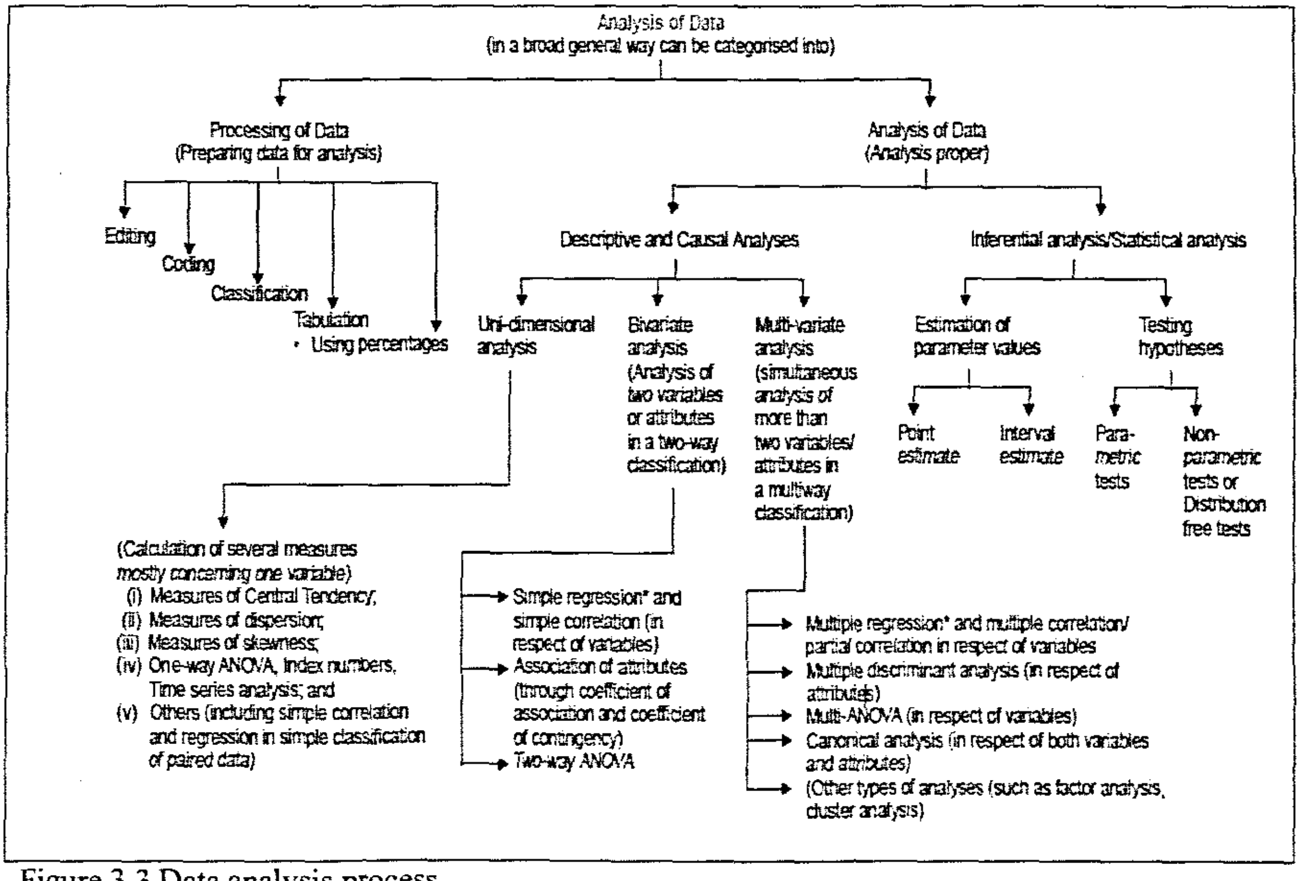

Figure 3.3 Data analysis process
Source: (Kothari, 2004)

Two sources of data namely; qualitative and quantitative were collected and analyzed accordingly. Despite the nature of the data collected, Fellows and Liu (2008) suggest that it was appropriate to start the analysis by examining the raw data using broader understanding. This indeed includes a review of theory and literature which leads to problem identification and assumptions (hypothesis) of problem causes which remain to be investigated. The acceptability or unacceptability of the original formulated research hypothesis depends on the data collected for the study (Welman *et al.*, 2006). The data to be analyzed on this research focused on three major objectives which aimed at testing three hypotheses.

3.9.1 Quantitative analysis

Quantitative analysis involves mathematical operations which quantifies the results into numerical values. This involves statistical analysis such as, for example; descriptive statistics and inferential statistics. Descriptive refers to the description or summary of data gathered for a group of individual unit of analysis (Welman *et al.*, 2006). On the other hand inferential statistics refers to a variety of tests to determine the validity of data with aims to come to conclusions (Kothari, 2004). Quantitative data extracted from closed ended questionnaires was encoded using Statistical Package for the Social Science (SPSS) and the results were carefully interpreted.

3.9.2 Qualitative analysis

Qualitative analysis involves different kinds of personal experiences and theoretical opinions. This form of analysis measures in-depth unstructured individual interviews and group interviews (Welman *et al.*, 2006). The qualitative data for this study was categorized in Microsoft Excel and analyzed manually.

3.10 Reliability and validity

Reliability refers to the source of consistency, dependability and stability of the instrument used for data collection. The reliability of the research instrument is determined by the consistency of the research results. The higher the reliability the more valid the conclusions will be.

Cronbach's alpha coefficient of reliability was determined for scaled questions. According to Fellows and Liu (2008), Cronbach's alpha is a measure of the internal reliability of statements and ranges from 0 to 0.1. The reliability of scaled responses was analyzed using Statistical Package for the Social Science (SPSS).

Validity is concerned with accuracy, effectiveness or trustworthiness of the interpreted data. According to Kothari (2004) validity is the extent to which differences found with a measuring instrument reflect true differences among those being tested. Therefore, it is significant to the researcher to be as concise and as clear as possible when designing research instruments To test the validity of the research instrument, four sets of questionnaires were developed and distributed to lecturers, general contractor, workers, designers and clients to test whether the data would address the hypothesis The validity of hypothesis will be tested through *t*-test. *T-test*

……….. *applies only in case of small sample(s) when population variance is unknown*…(Kothari, 2004).

The *t*-test was performed using SPSS to determine the validity of this study.

3.11 Testing of hypothesis

A hypothesis is an assumption, suspicion or a supposition about the causes of or factors which constitute to a defined problem area. In a given research study, the hypothesis are interlinked to the problem and provides an approach of how to investigate the proposed problem area. When the data is collected and interpreted, the hypothesis will be tested to check its validity or truthfulness. Conversely, Fellows and Liu (2008) argued that not all research projects would require testing of hypotheses which may either be rejected or not be rejected depending on the findings of the study. The process of hypothesis testing is shown in Figure 3.4.

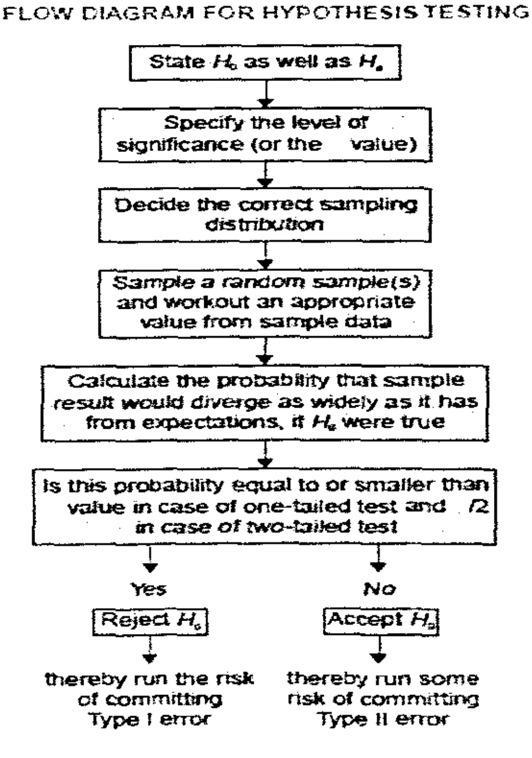

Figure 3.4 Hypothesis testing flow diagram
Source: (Kothari, 2004)

3.12 Chapter summary

In this chapter, various scientific research methodologies and a selected methodological instrument for the data acquisition are discussed. These methods involved qualitative and quantitative investigation approaches. Methods of collecting secondary and primary data were demonstrated. Data analysis methods and hypothesis testing procedures were then discussed.

CHAPTER 4

ANALYSIS OF THE EXPLORATORY STUDY

4.1 Introduction

The chapter presents analysis of findings emanating from an exploratory study. The study focused on examination of construction methodologies on South African construction sites. Given that construction methods involve various activities and processes, an instrument was developed which looked at bricklaying activities and prefabricated wall fixing processes. The data was gathered through structured interviews with bricklayers and their assistants. The observations were also conducted with prefabrication wall fixers and bricklayers with their assistants. Results were obtained and interpreted accordingly.

4.2 Exploratory study

The construction activities of bricklayers, bricklaying assistants and prefabricated board fixers were observed. This study examined prefabrication and pre-assembly as means to reducing ergonomic challenges associated with traditional construction methods. The individual body movements were carefully observed and recorded on an observation sheet in five minute intervals. A team of five observers watched and recorded each activity for a total of two hours per activity. Structured interviews were also conducted with a sample of workers on sites where the observations were made.

4.3 Interviews

From Table 4.1, the sample comprised mostly general workers (58%). The median years of experience in the construction industry was 6.0 years ranging from 1 to 30 years.

Table 4.1 Occupation

Respondents	**Number**	**Percentages**
General workers	14	58.3
Bricklayers	10	41.7
Total	**24**	**100**

4.4 Involvement in ergonomic problem activities

Table 4.2 indicates the frequency at which ergonomics problem activities were encountered by workers on a 5-point Likert scale where 1= Never; 2=Seldom; 3=Sometimes; 4 =Often; and 5 =Always. It was possible to rank the ergonomic problem activities by comparing their mean scores.

Table 4.2 Involvement in ergonomic problem activities

Situation	N	1 %	2 %	3 %	4 %	5 %	Mn	Std Dev	Rank
Working in awkward posture	24	4.2	0.0	66.7	24.9	4.2	3.3	0.7	1
Manual handling of heavy material	24	0.0	33.3	41.7	16.7	8.3	3.0	0.9	2
Noise caused by construction material	24	16.7	0.0	66.7	16.7	0.0	2.8	0.9	3
Working in same place for a long time	24	20.8	8.3	62.5	8.3	0.0	2.8	0.9	3
Vibrating equipments	24	25.0	33.3	29.2	12.5	0.0	2.3	1.0	5
Height related activities	24	4.2	20.8	45.8	25.0	4.2	2.0	0.9	6
Hazardous materials	24	41.7	29.2	8.3	8.3	0.0	2.0	1.0	7

From Table 4.2, it is evident by ranking the means that workers sometimes had to do work involving awkward postures (mean=3.3) and experienced manual handling of heavy material and working in the same place for lengthy periods (mean=3.0). Lastly, respondents were seldom to sometimes exposed to other situations (means=2.0 to 2.8).

These findings indicate that workers are involved in working situations that threaten their health due to exposure to ergonomic challenges. However, arguably, the use of prefabrication and preassembly would reduce these activities and consequently reduce ergonomic problems on site during the construction process.

4.5 Involvement on project where prefabricated components were utilized

Table 4.3 Involvement on projects where prefabricated components were utilized

	Respondents %
Yes	54.0
No	46.0
Total	**100.0**

From Table 4.3 it is evident that slightly more than half (54%) of workers had been involved in projects where prefabricated components had been used. Consequently, they would have recognized the health and safety benefits associated with its use.

4.6 Ergonomic problems encountered while involved in traditional methods and prefabrication erection

Respondents were asked whether they had experienced any physical health hazards while they were involved in traditional construction activities and prefabricated components erection.

Table 4.4 Ergonomic problems associated with various construction methods

Ergonomic Problems	Traditional construction		Prefabrication	
	Yes%	No%	Yes%	No%
Waist pains	96.0	4.0	54.0	46.0
Backaches	88.0	12.0	8.0	92.0
Shoulder pains	79.0	21.0	46.0	54.0
Wrist pains	75.0	25.0	39.0	61.0
Lung problems	33.0	67.0	8.0	92.0
Bone problems	21.0	79.0	23.0	77.0
Muscle and joint pains	21.0	79.0	15.0	85.0
Headaches	25.0	75.0	23.0	77.0

From Table 4.4, it is evident that almost all respondents (96%) had experienced pain in their waist area and 88% had experienced backache pains while they were involved in traditional construction activities. However, noticeably less respondents (54%) reported that they experienced pain in their waist areas and 8% felt backache pains when involved in the erection of prefabricated or preassembled components.

While 79% of respondents experienced shoulder pains and ailments and 75% experienced wrist pains when involved in traditional construction activities, only 46% reported that they experienced pain in their shoulders when involved in the erection of prefabricated components. Further 85% and 61% of the workers reported that they did not experience any muscular pains and any wrist pain respectively w hen involved in the erection of prefabricated components.

These results suggest that prefabrication significantly reduced ergonomic hazards to workers when compared with traditional construction methods.

4.7 Impact of prefabrication and preassembly on health and safety of workers

Table 4.5 Impact of prefabrication and preassembly on health and safety of workers

Statement	N	Yes%	No%
Prefabrication / pre-assembly or precast reduces hazards related to material handling activities on site	13	92.0	8.0
Reducing a need for scaffolding by prefabricated /pre-assembly or precast components would lead to less falls on sites	13	92.0	8.0
When work is done offsite large amount of noise is reduced on site	13	85.0	15.0
Doing more work offsite would lead to reduction of many health and safety risks on site	13	85.0	15.0

From Table 4.5, it is evident that the majority of respondents (92%) reported that the use of prefabrication/ preassembly and precast would reduce hazards related to material handling on site and that the reduction of scaffolding through the use of prefabricated /pre-assembly or precast components would lead to less falls on sites. Slightly less respondents (85%) reported that doing more work offsite would lead to the reduction of many health and safety risks and would reduce noise levels on site

4.8 Observations

A team of five graduate research assistants directly observed, counted and recorded body movements associated with bricklaying, bricklaying assistants and prefabricated wall fixing activities on site. The research group observed workers simultaneously over periods of five minutes. Body movements namely, bending and twisting the body while working, lifting heavy material manually, working below knee level, kneeling, working above shoulder and reaching away from the body were carefully counted, recorded and reported.

4.8.1 Bricklaying observation

Fifteen bricklayers were observed during the construction process. It was noted that bricklayers bent their bodies when preparing mortar, scooping mortar and while picking up bricks and often twisted their body on their way to stand up and place mortar and a brick. While they bent their bodies to scoop mortar, they had to take one step to reach the wall and place the brick. It was also observed that they seldom knelt while laying bricks from the seventh brick course and above. However, bricklayers had to kneel when laying bricks on the second course from the floor or ground level and sometimes twisted their body in the process.

Table 4.6 Bricklaying body movements

Body Movements	N	Min	Max	Mean/hr
Bending the body	15	89.0	182.0	145.0
Twisting the body	15	60.0	149.0	103.0
Working below knee level	15	19.0	149.0	77.0
Reaching away from the body	15	19.0	120.0	53.0
Lifting heavy material manual	15	0.0	94.0	48.0
Working above shoulder	15	0.0	79.0	33.0
Kneeling	15	0.0	84.0	29.0

From Table 4.6, it is evident that bricklayers bent their bodies a mean of 145 times per hour while working. It was noted that every time they moved their body to execute work, they had to bend as shown in Figure 4.1. They twisted their body a mean of 103 times and worked below knee level a mean of 77 times per hour during bricklaying work progress. Bricklayers reached away from their bodies a mean of 53 times and lifted heavy material manually a mean of 48 times while working. They worked above shoulder height a mean of 33 times and knelt for a mean of 29 times.

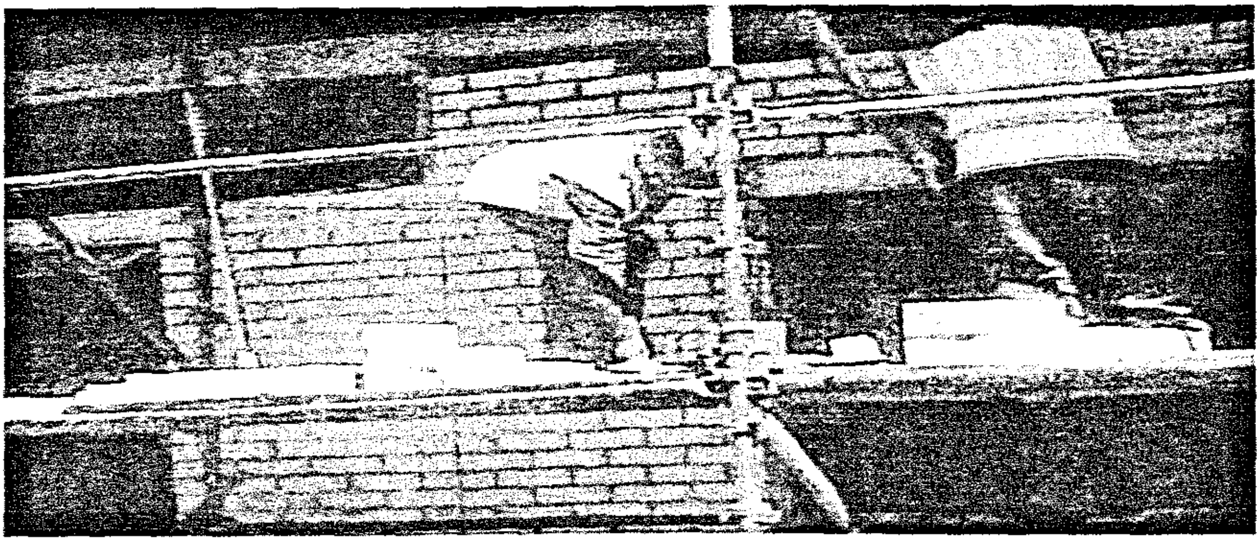

Figure 4.1 Bricklaying, Bending and twisting while working

4.8.2 Bricklayer assistants

4.8.2.1 Manual mixing and supply of mortar

Fifteen bricklaying assistant were observed while they were working. However, bricklaying assistants were divided into two categories, namely manual mixing and supply of mortar (10 workers) and supply of bricks to bricklayer (5workers). During the work process, bricklayer assistants performed repetitive bending, twisted their bodies when loading wheelbarrows with bricks, preparing mortar and, sorting bricks for a bricklayer. They bent and twisted their bodies when mixing mortar manually and also reached away from body when tossing mortar for bricklayer on the first floor. Bricklayer assistants performed repetitive bending, twisting and forceful body movements when mixing the mortar. This was followed by working above shoulder height when tossing the concrete to scaffolding or first floor.

Table 4.7 Bricklayer assistants body movements (Manual mixing and supply of mortar)

Body Movements	N	Min	Max	Mean/hr
Bending the body	10	151.0	305.0	248.0
Twisting the body	10	148.0	278.0	208.0
Working below knee level	10	31.0	190.0	117.0
Reaching away from the body	10	0.0	153.0	71.0
Working above shoulder	10	0.0	117.0	27.0
Lifting heavy material manual	10	0.0	38.0	17.0
Kneeling	10	0.0	92.0	11.0

From Table 4.7, it is evident that bricklayer assistants bent their bodies a mean of 248 times in one hour while mixing cement and supplying concrete. They twisted their bodies a mean of 208 times, worked below knee a mean of 117 times and reached away from the body a mean of 71 times per hour. It was noted they worked above shoulder level a mean of 27 times and lifted heavy material manually for a mean of 17 times.

4.8.2.2 Supply of bricks to bricklayer

Bricklayer assistants performed repetitive bending, twisting and forceful body movements when tossing bricks to different levels where they were caught by another general worker and stacked. This exercise occurred until there were sufficient bricks for the bricklayer.

Table 4.8 Bricklayer assistants body movements (supply of bricks to bricklayer)

Body Movements	N	Min	Max	Mean/hr
Bending the body	5	300.0	619.0	429.0
Twisting the body	5	163.0	562.0	373.0
Reaching away from the body	5	0.0	439.0	135.0
Working above shoulder	5	0.0	321.0	117.0
Working below knee level	5	8.0	189.0	62.0
Lifting heavy material manual	5	3.0	67.0	23.0
Kneeling	5	0.0	16.0	6.0

From Table 4.8, it is evident that bricklayer assistants bent their bodies a mean of 429 times per hour. Twisting of body occurred for a mean of 373 times while tossing bricks to the upper floor. It was noted that they reached away from their bodies a mean of 135 times and also worked above shoulder height for 117 times when tossing the bricks to the floor above.

4.8.3 Prefabricated insulation wall fixers observation

Fifteen prefabricated insulation wall fixers were observed using five minutes intervals while they were erecting walls. Five construction workers were involved in the erection of each prefabricated insulation board. Each board was 4m x 1.5m x 200mm in size. Body movements namely, bending the body, twisting the body, working below knee level, kneeling, reaching away from the body, working above should and lifting heavy material manual were carefully counted and recorded on the observation sheet.

Table 4.9 Prefabricated insulation wall fixers observation

Body Movements	N	Min	Max	Mean/hr
Bending the body	15	43.0	103.0	67.0
Twisting the body	15	24.0	84.0	58.0
Working below knee level	15	3.0	79.0	53.0
Working above shoulder	15	0.0	110.0	49.0
Reaching away from the body	15	5.0	84.0	45.0
Kneeling	15	0.0	74.0	35.0
Lifting heavy material manual	15	0.0	52.0	18.0

From Table 4.9, it is evident that workers bent their bodies a mean of 67 times per hour. Twisting the body occurred for a mean of 58 times and working below their knee level a mean of 53 times per hour. Working above shoulder height occurred for a mean of 49 times and reaching away from body occurred for a mean of 45 times while workers were fixing prefabricated insulated walling. Kneeling while working occurred at a mean of 35 times and lifting of heavy material manually occurred for a mean of 18 times only.

4.9 Summary of findings

Ergonomics challenges are one of the silent but long term health problems facing construction workers. Despite its invisibility to public, it threatens the health of workers who are involved in repetitive body movements while working. Evidently, the findings suggest that almost all workers experienced pain in their waist areas, shoulders and wrist and back areas while engaged in traditional construction methods. Less workers reported pain in the same area while constructing prefabricated insulation walls. It is likely that prefabrication could reduce exposure to the ergonomic problems associated with the traditional construction methods.

Despite the construction environment typically involving working conditions that present ergonomic challenges, a major concern is the lack of consideration for the impact of these on the health of workers on site. The study suggests that allowing more work to be done offsite would lead to major health and safety benefits to workers. Offsite construction significantly reduces onsite construction processes and consequently leads to elimination of ergonomic problems to workers. This choice would lead to healthier and safer working environments and better ways to control and improve health and safety performance on site.

CHAPTER 5

DATA ANALYSIS, INTERPRETATION AND FINDINGS

5.1 Introduction

The aim of this chapter is to present the relevant data which involved the participation of workers, contractors, construction clients and designers. The data was gathered through questionnaire surveys, interviews and observations. The interviews and observations were conducted with workers and a questionnaire survey was done of contractors, construction clients and designers. Results were obtained and interpreted accordingly.

5.2 Contractor survey

5.2.1 Section A: Client perceptions of prefabrication and preassembly

This section presents the analysis of data which was obtained from a survey of contractors relative to how clients perceived the use of prefabrication as an alternative method of construction. The analysis examines how informed clients were, relative to improvements of the health and safety through utilizing prefabrication.

5.2.1.1 Occupation of the respondents

Table 5.1 Occupation

Occupation	**Number of respondents**	**Percentage**
Site agent	3	23.1
Site manager	2	15.4
Health and safety representatives	5	38.4
Site foreman	3	23.1
Total	**13**	**100.0**

Of 20 distributed questionnaires, 13 (65%) were duly completed and returned. From Table 5.1, it is clear that most respondents were health and safety representatives (38.4%). The median years of experience in construction of contractors was 9.1 years ranging from 2 through 40 years.

5.2.1.2 Construction projects which have involved prefabrication or preassembly

Table 5.2 Projects involving prefabrication or preassembly

Projects involving prefabrication or preassembly	
Respondents	**Projects**
23.0	10%
15.0	20%
15.0	30%
15.0	40%
15.0	50%
0.0	60%
8.0	70%
8.0	80%
0.0	90%
0.0	100%

From Table 5.2, it is evident that the respondents have utilized prefabricated components on approximately 80% of their construction projects. Of these construction projects,

- 23% of respondents reported that they had adopted prefabricated components on 10% of their construction projects;
- 15% of respondents reported that they had adopted prefabricated components on 20% of their construction projects;
- 8% of respondents reported that they had adopted prefabricated components on 70% of their construction projects; and
- 8% of respondents reported that they adopted prefabricated components on 80% of their construction projects;

This finding suggests that to a greater or lesser degree the use of prefabrication is familiar to the South African construction industry. However, arguably, its potential has not been widely recognized with respect to the reduction of exposure to health threatening conditions on construction workers.

5.2.1.3 Benefits obtained from the utilization of prefabrication and preassembly

The benefits derived from utilizing prefabrication and preassembly were reported as shown in Table 5.3.

Table 5.3 Benefits derived from the utilization of prefabrication/pre-assembly

Benefits	Percentage %
Cost reduction	31.0
Increased productivity	23.0
Improved health and safety	23.0
Reduction of time frame	23.0

The benefits derived from the utilization of prefabrication and preassembly are shown in Table 5.3, as follows, namely

- 31% of the respondents reported that they had derived cost reduction benefits; and
- 23% of the respondents had derived health and safety improvements on construction projects.

5.2.1.4 Benefits associated with the use of prefabrication and preassembly

Respondents were asked to rate the extent to which the clients and designers recognized the benefits associated with the use of prefabrication as indicated in Table: 5.3.

Table 5.4 Benefits associated with prefabrication and preassembly

Benefit in %	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Respondents %	31%	23%	23%	8%	15%	0%	0%	0%	0%	0%

As indicated in Table 5.4,

- 23% of respondents reported that 20% of clients and designers were aware of the benefits associated with the utilization of prefabrication and preassembly.
- 31% of respondents reported that only 10% of clients and designers recognized the benefits associated with the utilization of prefabrication and preassembly.

This suggests that to lesser extent clients and designers were aware of the benefits associated with the utilization of prefabrication and preassembly. Further, it was noted that only 15 % of respondents reported that 50% of clients and designers were aware of the benefits associated with the utilization of prefabrication and preassembly.

5.2.1.5 Perception of clients relative to the use of prefabrication and preassembly

Respondents were asked to rate the perception of clients relative to the use of prefabrication and preassembly on a 5-point Likert scale where 1= Strongly Disagree; 2=Disagree; 3=Neutral; 4 =Agree; and 5 =Strongly Agree.

Table 5.5 Perception of clients relative to the use of prefabrication

Statement	N	SD %	D %	N %	A %	SA %	Mn	Std dev	Rank
Prefabrication / pre-assembly or precasting reduce material wastage on site	13	0.0	0.0	15.4	53.8	30.8	4.2	0.7	1
Designers are aware of the potential benefits of prefabrication and/or pre-assembly relative to worker health and safety	13	0.0	7.7	23.1	53.8	15.4	3.8	0.8	2
Prefabrication and/or pre-assembly leads to a reduction of labor on site	13	0.0	23.1	0.0	61.5	15.4	3.7	1.0	3
Public sector contracts encourages the use of prefabrication within the construction industry in South Africa	13	7.7	7.7	15.4	46.1	23.1	3.7	1.1	4
The use of prefabricated /pre-assembled or precast will change the structure of the industry	13	0.0	7.7	23.1	69.2	0.0	3.6	0.7	6
The use of prefabricated and/or pre-assembled or precast construction will improve the overall performance of the construction in terms of cost, time and health and safety	13	0.0	15.4	23.1	46.1	15.4	3.6	1.0	5
Clients tend to focus mostly on time, quality and cost instead of worker health and safety	13	7.7	23.1	7.7	53.8	7.7	3.3	1.2	7
Designers do not consider worker health and safety in their designs	13	0.0	23.1	38.4	30.8	7.7	3.2	0.9	8
The use of prefabrication and/or pre-assembly will reduce the skills shortage in construction	13	0.0	32.1	38.5	30.7	7.7	3.2	0.9	8
Designers do not consider prefabrication and/or pre-assembly because they are unfamiliar with this method of construction	13	0.0	38.5	23.1	30.8	7.7	3.1	1.0	10
Designers do not have enough knowledge about prefabrication to propose it to clients as an alternative	13	0.0	38.5	30.8	23.1	7.7	3.0	1.0	12
Construction clients prefer traditional construction methods instead of prefabrication and preassembly	13	7.7	30.8	15.4	46.1	0.0	3.0	1.1	11
Lack of knowledge by designers leads to resistance to the use of alternative construction methods such as prefabrication and/or pre-assembly	13	15.4	23.1	7.7	53.8	0.0	3.0	1.2	13
Designers rarely propose the use of prefabrication and/or pre-assembly to clients in their design	13	7.7	23.1	38.5	30.8	0.0	2.9	0.9	14
Construction clients are not informed about the benefits of prefabricated/ preassembled or precast	13	7.7	38.4	23.1	30.8	0.0	2.8	1.0	15
The use of prefabricated /pre-assembled or precast will create employment opportunities	13	0.0	53.8	23.1	23.1	0.0	2.7	0.9	16

From Table 5.5 above, it is evident that:

- 84. 6% of respondents reported that the use of prefabrication would lead to reduction of material waste;
- 69. 2% of respondents reported that designers were aware of the potential benefits of prefabrication and/or pre-assembly relative to worker health and safety;
- 69. 2% of respondents reported that public sector contracts supported the use of prefabrication;
- 61.5% of respondents reported that the use of prefabricated and/or pre-assembled or precast construction would improve the overall performance of the construction in terms of cost, time and health and safety;
- 61.5% of respondents reported that construction clients tended to focus mostly on time, quality and cost instead of worker health and safety;
- 46. 1% of respondents reported that construction clients preferred traditional construction methods to prefabrication and preassembly; and
- 38. 5% of respondents reported that designers did not consider worker health and safety in their designs.

5.2.2 SECTION B: Health and safety improvements by prefabrication and preassembly

5.2.2.1 Comparison of hazards between traditional construction and prefabrication processes

The results of measuring and comparing the extent to which traditional construction process and prefabrication process expose workers to hazards are as shown in Table 4.5 where 0% referred to no exposure and 100% referred to maximum exposure.

Table 5.6 Comparison of hazards

Traditional method		Prefabrication	
Hazards	**Respondents %**	**Hazards**	**Respondents %**
0%	0.0	0%	15.0
10%	0.0	10%	31.0
20%	23.0	20%	23.0
30%	31.0	30%	31.0
40%	15.0	40%	0.0
50%	31.0	50%	0.0
60%	0.0	60%	0.0
70%	0.0	70%	0.0
80%	0.0	80%	0.0
90%	0.0	90%	0.0
100%	0.0	100%	0.0

From Table 5.6 above, it is evident that:

- 31% of respondents reported that traditional construction process exposed workers to 50% hazards;
- 31% of respondents reported that prefabrication construction process exposed workers to 30% hazards;
- 15% of respondents reported that traditional construction process exposed workers to 40% hazards; and
- 15% of respondents reported that workers were not exposed to any hazards during the prefabrication construction process whereas no one reported that the traditional construction process exposed them to no hazards.

5.2.2.2 Health and safety benefits of prefabrication

Relative to the health and safety benefits from prefabrication compared to on-site construction method, respondents reported as evidenced in Table 4.6.

Table 5.7 Health and safety benefits of prefabrication compared to on-site construction

Benefits	**Percentage %**
Reduction of environmental hazards	31.0
Reduction of material handling hazards	31.0
Reduction of mechanical noise	15.0
Reduction of chemical hazards	8.0
Safe working conditions	23.0
Less risk	8.0

From Table 5.7, it is evident that:

- 31% of respondents opined that the use of prefabrication would lead to reduction of environmental hazards;
- 31% of respondents opined that the use of prefabrication would reduce material handling hazards on site; and
- 23% of respondents opined that the use of prefabrication would lead to safer working conditions.

5.2.2.3 Reduction of hazards by prefabrication

Respondents were asked to indicate to what extent they agreed with statements on hazard reduction using prefabrication on a 5-point Likert scale where 1= Strongly Disagree; 2=Disagree; 3=Neutral; 4 =Agree; and 5 =Strongly Agree.

Table 5.8 Hazard reduction using prefabrication

Statement	N	SD %	D %	N %	A %	SA %	Mn	Std dev	Rank
The use of prefabrication and/or pre-assembly will reduce the need for formwork	13	0.0	0.0	0.0	69.2	30.8	4.3	0.5	1
The use of prefabrication and/or pre-assembly will reduce the exposure of workers to steel reinforcement hazards	13	0.0	0.0	7.7	61.5	30.8	4.2	0.6	2
The use of prefabrication and/or pre-assembly will reduce the need for scaffolding	13	7.7	7.7	23.1	38.4	23.1	3.6	1.2	3
Prefabrication and/or pre-assembly reduces the exposure of workers to chemical hazards on site	13	7.7	15.4	7.7	53.8	15.4	3.5	1.2	4
Reduction of construction activities through prefabrication will reduce health and safety threats associated with confined spaces on site	13	0.0	30.8	23.1	30.8	15.3	3.3	1.1	5
The use of prefabrication and/or pre-assembly will reduce the prospect of contract dermatitis	13	0.0	15.4	38.4	46.2	0.0	3.3	0.8	6
The use of prefabrication and/or pre-assembly will reduce construction falls by reducing working at height related activities	13	7.7	23.1	30.7	30.8	7.7	3.1	1.1	7

From Table 5.8, it was noted that:

- All respondents reported that the use of prefabrication and/or pre-assembly would reduce the need for formwork;
- 93.3% of respondents reported that the use of prefabrication and/or pre-assembly would reduce the exposure of workers to steel reinforcement hazards;

- 69.2% of respondents reported that prefabrication and/or pre-assembly would reduced the exposure of workers to chemical hazards on site; and
- 61.5% respondents reported that the use of prefabrication and/or pre-assembly would reduce the need for scaffolding.

5.2.2.4 Impact of prefabrication and preassembly on health and safety

Respondents were asked to indicate to what extent they agreed with statements on the impact of prefabrication and preassembly on worker health and safety using prefabrication on a 5-point Likert scale where 1= Strongly Disagree; 2=Disagree; 3=Neutral; 4 =Agree; and 5 =Strongly Agree.

Table 5.9 Impact of prefabrication and preassembly on worker health and safety

Statement	N	SD %	D %	N %	A %	SA %	Mn	Std dev	Rank
The use of prefabrication and/or pre-assembly will reduce ergonomic hazards on site	13	0.0	0.0	15.4	69.2	15.4	4.0	0.6	1
Off-site construction processes reduce environmental hazards	13	0.0	0.0	23.1	61.5	15.4	3.9	0.6	2
Prefabrication and/or pre-assembly reduces hazards related to material handling activities on site	13	7.7	7.7	0.0	61.5	23.1	3.8	1.1	1
Off-site construction processes reduce the risks associated with on-site construction methods	13	0.0	7.7	23.1	53.8	15.4	3.8	0.8	4
Increasing the number of workers on a project site potentially leads to difficulties in managing construction worker health and safety	13	0.0	15.4	7.7	61.5	15.4	3.8	0.9	5
Labour intensive projects expose construction workers to physically demanding activities that pose risks to their health and safety	13	7.7	7.7	15.4	53.8	15.4	3.6	1.1	6
Reduction of labour through prefabrication will lead to improvement of health and safety on site	13	0.0	7.7	38.5	38.5	15.4	3.6	0.9	7
Quality is improved through the use of prefabrication and/or preassembly	13	7.7	7.7	23.1	53.8	7.7	3.5	1.1	8
Prefabrication and/or pre-assembly reduces the exposure of workers to health and safety risks	13	0.0	15.4	7.7	61.5	15.4	3.3	1.1	9
The use of prefabrication and/or pre-assembly will lead to improvement of construction health and safety performance	13	7.7	7.7	38.5	38.5	7.7	3.3	1.0	10

From Table 5.9, it is evident that:

- 84.6% of respondents reported that the use of prefabrication and/or pre-assembly would reduce ergonomic hazards on site;
- 84.6% of respondents reported that prefabrication and/or pre-assembly would reduce hazards related to material handling activities on site;
- 76.9 % of respondents reported that off-site construction processes would reduce environmental hazards;
- 76.9 % of respondents reported that increasing the number of workers on a project site would potentially lead to difficulties in managing construction worker health and safety;
- 69.2% of respondents reported that off-site construction processes would reduce the risks associated with on-site construction methods and;
- 69.2% of respondents reported that labour intensive projects exposed construction workers to physically demanding activities that posed risks to their health and safety.

5.2.3 Reliability

When findings or outcomes of the research are repeatable and uniform, they are considered reliable (Wellman et al., 2005). The Cronbach's alpha coefficient for scaled responses was 0.8 which satisfied the criteria for reliability.

5.3 Designer survey

5.3.1 Section A: Client perceptions of prefabrication and preassembly

This section presents the findings of a survey of designers relative to how clients perceived the use of prefabrication as an alternative method of construction. The analysis further examines how informed clients were, relative to improvements of the health and safety through utilizing prefabrication.

5.3.1.1 Occupation of the respondents

Table 5.10 Occupations

Occupation	Number of respondents	Percentage
Architectural designer	6	60.0
Structural engineering designer	4	40.0
Total	**10**	**100.0**

Of the 20 questionnaires that were distributed to designers, ten (50%) were duly completed and returned. As indicated in Table 5.10, it is evident that most respondents were architectural designers (60%). The median years of experience in construction of designers was 15.0 years ranging from 3 through 47 years.

5.3.1.2 Responsibility for selecting construction method

Table 5.11 Responsible party for selecting construction method

Responsible person	**Percentage**
Designers	90.0
Contractors	10.0
Total	**100.0**

From Table 5.11, it is evident that:

- 90% of respondents reported that designers should be responsible for selecting the construction method; and
- 10% of respondents reported that contractors should be responsible for selecting the construction method.

5.3.1.3 Projects which involved prefabrication and preassembly

Table 5.12 Projects including prefabrication

Projects involving prefabrication or preassembly	
Respondents	**Projects**
23.0	10%
15.0	20%
15.0	30%
8.0	40%
8.0	50%
0.0	60%
8.0	70%
0.0	80%
0.0	90%
0.0	100%

From Table 5.12, it is evident that:

- 8% of respondents reported that they utilized prefabricated components on 70% of their construction projects.
- 8% of respondents reported that they had utilized prefabricated components on 50% of their construction projects;
- 15% of respondents reported that they had utilized prefabricated components on 20% of their construction projects; and
- 23% of respondents reported that they had utilized prefabricated components on 10% of their construction projects.

5.3.1.4 Benefits derived from the utilization of prefabrication and preassembly

From Table 5.13, it is evident that:

- 40% of respondents reported that they had derived increased productivity benefits;
- 30% of respondents reported that they had derived health and safety improvements benefits; and
- 30% of respondents reported that they had derived cost reduction benefits from the utilization of prefabrication and prefabrication.

Table 5.13 Benefits derived from the utilization of prefabrication and preassembly

Benefits	Percentage
Increased productivity	40.0
Cost reduction	30.0
Improved health and safety	30.0

5.3.1.5 Factors which influenced the consideration of prefabrication and preassembly

From Table 5.14, it is clear that:

- 80% of respondents reported that time was the most influential factor when considering prefabrication and preassembly;
- 40% of respondents reported that ease of installation was influential when considering prefabrication and preassembly;
- 30% of respondents reported that health and safety was influential when considering prefabrication and preassembly; and

- 20% of respondents reported that waste reduction was influential when considering prefabrication and preassembly.

Table 5.14 Factors which influenced the consideration of prefabrication and preassembly

Factors	Respondents%
Time	80.0
Installation is easy	40.0
Safety	30.0
Less wastage	20.0
Durability	20.0
Cost	10.0
Quality	10.0
Access	10.0

5.3.1.6 Reasons for resistance to prefabrication and preassembly

From Figure 5.15, it is evident that:

- 30% of respondents reported that they did not resist the use of prefabrication and preassembly;
- 30% of respondents reported that they resisted the use of prefabrication and preassembly due to possessing insufficient experience with the approach; and
- 20% of respondents reported that they resisted the use of prefabrication and preassembly due to cost implications.

Table 5.15 Reasons for resisting the use of prefabrication and preassembly

Reasons	Respondents %
Insufficient experience	30.0
None	30.0
Cost	20.0
Different forms of detail	20.0
It is not good for external use	20.0
Quality	10.0

5.3.1.7 Recognition of benefits of prefabrication and preassembly

From Table 5.16, it is evident that:

- 10% of respondents opined that 30% of clients and designers were aware of benefits associated with the use of prefabrication and preassembly; and
- 60% of respondents opined that 20% of clients and designers were aware of benefits associated with the use of prefabrication and preassembly.

Table 5.16 Recognition of benefits associated with the use of prefabrication and preassembly

Benefit in %	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Respondents	10%	60%	10%	10%	10%	0%	0%	0%	0%	0%

5.3.1.8 *Perception of clients relative to the use of prefabrication and preassembly*

Respondents were asked to rate the perception of clients relative to the use of prefabrication and preassembly on a 5-point Likert scale where 1= Strongly Disagree; 2=Disagree; 3=Neutral; 4 =Agree; and 5 =Strongly Agree.

Table 5.17 Perception of clients relative to the use of prefabrication

Statement	**N**	**SD %**	**D %**	**N %**	**A %**	**SA %**	**Mn**	**Std dev**	**Rank**
The use of prefabricated and/or pre-assembled or precast construction will improve the overall performance of the construction in terms of cost, time and health and safety	10	0.0	10.0	30.0	50.0	10.0	3.6	0.8	1
Prefabrication and/or pre-assembly leads to a reduction of labor on site	10	0.0	20.0	10.0	60.0	10.0	3.6	0.9	2
The use of prefabrication and/or pre-assembly will reduce the skills shortage in construction	10	10.0	0.0	20.0	60.0	10.0	3.6	1.1	3
Construction clients prefer traditional construction methods instead of prefabrication and preassembly	10	0.0	20.0	10.0	70.0	0.0	3.5	0.8	4
Prefabrication / pre-assembly or precast reduce material wastage on site	10	10.0	20.0	0.0	70.0	0.0	3.3	1.2	5
Construction clients are not informed about the benefits of prefabricated/ preassembled or precast	10	0.0	30.0	20.0	50.0	0.0	3.2	0.9	6
Designers are aware of the potential benefits of prefabrication and/or pre-assembly relative to worker health and safety	10	0.0	20.0	50.0	30.0	0.0	3.1	0.7	7
Clients tend to focus mostly on time, quality and cost instead of worker health and safety	10	10.0	30.0	0.0	60.0	0.0	3.1	1.2	8
Designers rarely propose the use of prefabrication and/or pre-assembly to clients in their design	10	10.0	30.0	10.0	40.0	10.0	3.1	1.2	8
The use of prefabricated /pre-assembled or precast will change the structure of the industry	10	0.0	40.0	30.0	20.0	10.0	3.0	1.1	10
Public sector contracts encourages the use of prefabrication within the construction industry in South Africa	10	10.0	30.0	30.0	20.0	10.0	2.9	1.2	11
Lack of knowledge by designers leads to resistance to the use of alternative construction methods such as prefabrication and/or pre-assembly	10	10.0	50.0	0.0	40.0	0.0	2.7	1.2	12
The use of prefabricated /pre-assembled or precast will create employment opportunities	10	30.0	30.0	0.0	40.0	0.0	2.5	1.4	13

From Table 5.17, it is clear that:

- 70% of respondents reported that prefabrication and/or pre-assembly led to a reduction of labor on site;
- 70% of respondents agreed that construction clients preferred traditional construction methods instead of prefabrication and preassembly;
- 60% of respondents agreed that the use of prefabricated and/or pre-assembled or precast construction would improve the overall performance of the construction in terms of cost, time and health and safety;
- 60% of respondents reported that clients tended to focus mostly on time, quality and cost instead of worker health and safety;
- 50% of respondents reported that construction clients were not informed about the benefits of prefabricated/ preassembled or precast
- 50% of respondents reported that designers rarely proposed the use of prefabrication and/or pre-assembly to clients in their design

5.3.2 SECTION B: Health and safety improvements by prefabrication and preassembly

5.3.2.1 Comparison of hazards between traditional construction and prefabrication processes

The frequency of comparison of hazards between traditional construction and prefabrication processes were ranked by mean percentage as shown in Table 5.18 where 0% referred to no exposure and 100% referred to maximum exposure.

Table 5.18 Comparison of hazards

Traditional method		Prefabrication	
Hazards	**Respondents %**	**Hazards**	**Respondents %**
0%	10.0	0%	20.0
10%	20.0	10%	40.0
20%	0.0	20%	10.0
30%	50.0	30%	20.0
40%	10.0	40%	10.0
50%	10.0	50%	0.0
60%	0.0	60%	0.0
70%	0.0	70%	0.0
80%	0.0	80%	0.0
90%	0.0	90%	0.0
100%	0.0	100%	0.0

From Table 5.18, it is evident that:

- 10% of respondents reported that traditional construction process exposed workers to 50% hazards while no respondents reported that prefabrication exposed workers to 50% hazards;
- 50% of respondents reported that prefabrication construction process exposed workers to 30% hazards;
- 20% of respondents reported that traditional construction process exposed workers to 10% hazards;
- 40% of respondents reported that prefabrication construction process exposed workers to 10% hazards.

5.3.2.3 Reduction of hazards by prefabrication

Respondents were asked to indicate to what extent they agreed with statements on hazard reduction using prefabrication on a 5-point Likert scale where 1= Strongly Disagree; 2=Disagree; 3=Neutral; 4 =Agree; and 5 =Strongly Agree.

Table 5.19 Hazard reduction using prefabrication

Statement	N	SD %	D %	N %	A %	SA %	Mn	Std dev	Rank
The use of prefabrication and/or pre-assembly will reduce construction falls by reducing working at height related activities	10	0.0	10.0	20.0	70.0	0.0	3.6	0.7	1
The use of prefabrication and/or pre-assembly will reduce the need for scaffolding	10	0.0	10.0	20.0	70.0	0.0	3.6	0.7	2
The use of prefabrication and/or pre-assembly will reduce the prospect of contract demartitis	10	0.0	20.0	10.0	70.0	0.0	3.5	0.8	3
The use of prefabrication and/or pre-assembly will reduce the exposure of workers to steel reinforcement hazards	10	0.0	30.0	0.0	70.0	0.0	3.4	1.0	4
The use of prefabrication and/or pre-assembly will reduce the need for formwork	10	0.0	20.0	20.0	60.0	0.0	3.4	0.8	5
Reduction of construction activities through prefabrication will reduce health and safety threats associated with confined spaces on site	10	0.0	30.0	20.0	50.0	0.0	3.2	0.9	6
Prefabrication and/or pre-assembly reduces the exposure of workers to chemical hazards on site	10	0.0	40.0	60.0	0.0	0.0	2.6	0.5	7

From Table 5.19, it is evident that:

- 70% of respondents (mean=3.6) reported that the use of prefabrication and/or pre-assembly would reduce construction falls by reducing working at height related activities and reduce the need for scaffolding;
- 70% of respondents (mean=3.4) reported that the use of prefabrication and/or pre-assembly would reduce the exposures of workers to steel reinforcement hazards;
- 60% of respondents (mean=3.4) reported that the use of prefabrication and/or pre-assembly would reduce the need for formwork; and
- 50% of respondents (mean=3.2) reported that the reduction of construction activities through prefabrication would reduce health and safety threats associated with confined spaces on site.

5.3.2.4 Impact of prefabrication and preassembly on health and safety

Respondents were asked to indicate to what extent they agreed with statements on the impact of prefabrication and preassembly on worker health and safety using prefabrication on a 5-point Likert scale where 1= Strongly Disagree; 2=Disagree; 3=Neutral; 4 =Agree; and 5 =Strongly Agree.

From Table 5.20, it is evident that:

- All respondents (mean=4.2) reported that the use of prefabrication and/or pre-assembly would lead to improvements of construction health and safety performance, reduce ergonomic hazards on site (mean=4.1) and that off-site construction processes would reduce environmental hazards (mean=5.0);
- 90% of respondents (mean=3.9) reported that labour intensive projects exposed construction workers to physically demanding activities that posed risks to their health and safety;
- 80% of respondents (mean=3.8) reported that off-site construction processes would reduce the risks associated with on-site construction methods; and
- 70% of respondents (mean=3.6) reported that prefabrication and/or pre-assembly would reduce hazards related to material handling activities on site and exposure of workers to health and safety risks.

Table 5.20 Impact of prefabrication and preassembly on worker health and safety

Statement	N	SD %	D %	N %	A %	SA %	Mn	Std dev	Rank
The use of prefabrication and/or pre-assembly will lead to improvement of construction health and safety performance	10	0.0	0.0	0.0	80.0	20.0	4.2	0.4	1
The use of prefabrication and/or pre-assembly will reduce ergonomic hazards on site	10	0.0	0.0	0.0	90.0	10.0	4.1	0.3	2
Off-site construction processes reduce environmental hazards	10	0.0	0.0	0.0	100.0	0.0	5.0	0.0	1
Labour intensive projects expose construction workers to physically demanding activities that pose risks to their health and safety	10	0.0	0.0	10.0	90.0	0.0	3.9	0.7	4
Increasing the number of workers on a project site potentially leads to difficulties in managing construction worker health and safety	10	0.0	0.0	10.0	90.0	0.0	3.9	0.3	5
Off-site construction processes reduce the risks associated with on-site construction methods	10	0.0	0.0	20.0	80.0	0.0	3.8	1.4	6
Prefabrication and/or pre-assembly reduces hazards related to material handling activities on site	10	0.0	10.0	20.0	70.0	0.0	3.6	0.7	7
Quality is improved through the use of prefabrication and/or preassembly	10	0.0	0.0	40.0	60.0	0.0	3.6	0.5	8
Prefabrication and/or pre-assembly reduces the exposure of workers to health and safety risks	10	0.0	20.0	10.0	60.0	10.0	3.6	1.0	9
Reduction of labour through prefabrication will lead to improvement of health and safety on site	10	0.0	10.0	30.0	60.0	0.0	3.5	0.7	10

5.3.3 Reliability

The Cronbach's alpha coefficient for scaled responses was 0.8 which satisfied the criteria for reliability.

5.4 Client survey

5.4.1 Section A: Client perceptions of prefabrication and preassembly

This section analyzes the data which was obtained from a survey of clients relative to how they perceive the use of prefabrication as an alternative method of construction. The analysis further examines how informed clients are, relative to improvements of the health and safety through utilizing prefabrication.

5.4.1.1 Occupation of the respondents

Table 5.21 Occupation

Occupation	Number of respondents	Percentage %
Public sector clients	8	53.0
Private sector clients	7	47.0
Total	**15**	**100.0**

Of 20 distributed questionnaires, 15 (75%) were duly completed and returned. The median years of experience in the construction industry of clients was 20.0 years ranging from 1 to 40 years.

5.4.1.2 Responsibility for selecting construction method

Table 5.22 Responsible parties for selecting construction method

Responsible person	Percentage %
Clients	40.0
Contractors	33.0
Designers	27.0
Total	**100.0**

As shown in Table 5.22,

- 40% of respondents reported that clients should be responsible for selecting the construction method;
- 33% of respondents reported that designers should be responsible for selecting the construction method; and
- 27% of respondents reported that contractors should be responsible for selecting the construction method.

5.4.1.3 Project which involved prefabrication and preassembly

From Table 5.23, it is evident that:

- 13% of respondents reported that they utilized prefabricated components on 50% of their projects;
- 27% of respondents reported that they utilized prefabricated components on 30% of their projects; and

- 40% of respondents reported that they utilized prefabricated components on 10% of their projects.

Table 5.23 Projects which involved prefabrication

Projects involving prefabrication or preassembly	
Respondents	**Projects**
40.0	10%
7.0	20%
24.0	30%
13.0	40%
13.0	50%
0.0	60%
0.0	70%
0.0	80%
0.0	90%
0.0	100%

These finding suggests that construction clients do involve prefabrication and preassembly in the projects. However, it was noted that they involved prefabrication and preassembly to a greater or lesser degree on their projects.

5.4.1.4 Benefits derived from the utilization of prefabrication and preassembly

Respondents were asked what benefits they had derived from the utilization of prefabrication and preassembly.

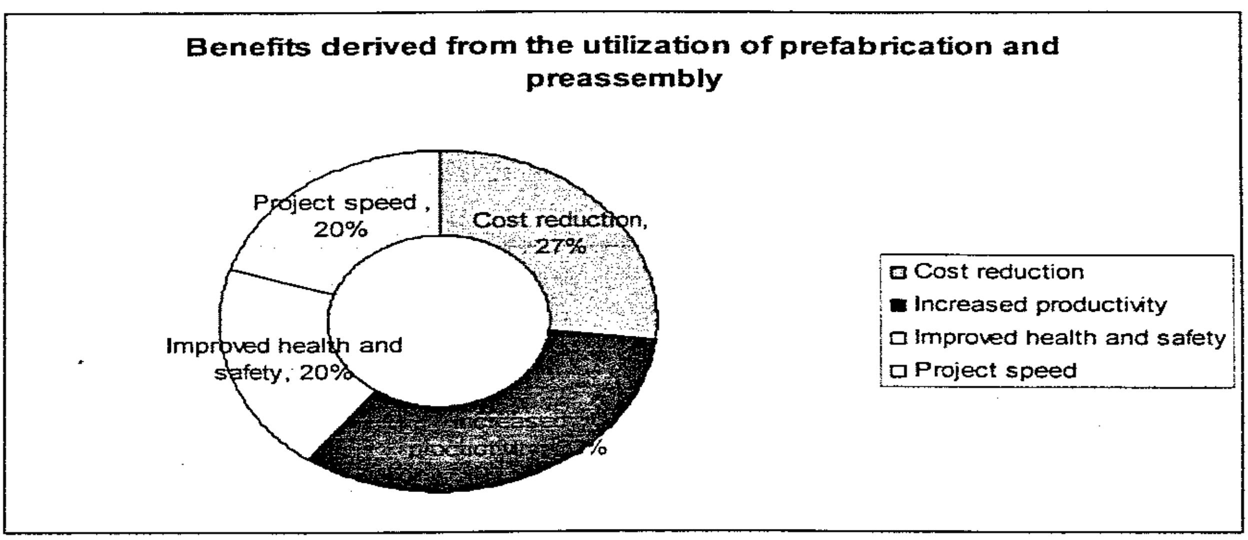

Figure 5.1 Benefits derived from the utilization of prefabrication and preassembly

From Figure: 5.4, it is evident that:

- 33% of respondents reported that they had derived increased productivity benefits;

- 27% of respondents reported that they had derived their benefits from cost reduction; and
- 20% o f respondents reported that they had derived their benefits from the improvements of health and safety.

5.4.1.5 Factors which influenced the consideration of prefabrication and preassembly

From Table 5.24, it is evident that:

- 73% of respondents regarded that time was the most influential factor when considering the prefabrication and preassembly;
- 35% of clients respondents reported that quality was influential factor when considering the prefabrication and preassembly; and
- 21% of respondents regarded that cost reduction was influential factor when considering the prefabrication and preassembly.

Table 5.24 Factors which influenced the consideration of prefabrication and preassembly

Factors	Respondents %
Time	73.0
Quality	35.0
Reduce cost	21.0
Reduce rework	21.0
Reduce labour	14.0
Easy to install	14.0
Reduce delays	14.0
Manufacturing process	14.0
Reduce trades	7.0
Reduce formwork	7.0
Reduce scaffolding	7.0

5.4.1.6 Reasons for resisting prefabrication and preassembly

From Table 5.25, it is evident that:

- 42% of respondents did not resist prefabrication and preassembly; and
- 21% of respondents reported that they resisted prefabrication and preassembly due to contractors' poor performance.

Table 5.25 Reasons for resisting prefabrication and preassembly

Reasons	Respondents %
No resistance	42.0
Cost	21.0
Geometric change (curves)	14.0
Client requirements	14.0

Quality	7.0
Different from the details	7.0

5.4.1.7 Recognition of benefits associated with the use of prefabrication and preassembly

From Table 5.26, it is evident that 50% of clients and designers recognized the benefits associated with the use of prefabrication and preassembly. However, it was noted that respondents reported that the clients and designers did not recognized the benefits associated with the use of prefabrication and preassembly.

Table 5.26 Recognition of benefits associated with the use of prefabrication and preassembly

Benefit in %	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Respondents	40%	14%	14%	33%	7%	7%	0%	0%	0%	0%	0%

5.4.1.8 Perception of clients relative to the use of prefabrication and preassembly

Respondents were asked to rate the perception of clients relative to the use of prefabrication and preassembly on a 5-point Likert scale where 1= Strongly Disagree; 2=Disagree; 3=Neutral; 4 =Agree; and 5 =Strongly Agree.

From Table 5.27, it is evident that:

- All respondents (mean=4.5) reported that prefabrication and/or pre-assembly led to a reduction of labor on site;
- 93.3% of respondents (mean=4.5) reported that lack of knowledge by designers led to resistance to the use of alternative construction methods such as prefabrication and/or pre-assembly;
- 86.7% of respondents (mean=4.3) reported that the use of prefabricated /pre-assembled or precast would change the structure of the industry;
- 80.0% of respondents (mean=4.2) reported that designers did not consider prefabrication and/or pre-assembly because they were unfamiliar with this method of construction, construction clients preferred traditional construction methods instead of prefabrication and preassembly (mean=4.0) and the public sector contracts encouraged the use of prefabrication within the construction industry in South Africa with (mean=3.9);

- 66.7% of respondents (mean=3.7) reported that designers did not have enough knowledge about prefabrication to propose it to clients as an alternative and designers rarely proposed the use of prefabrication and/or pre-assembly to clients in their design; and
- 66.6% of respondents (mean=3.7) reported that the use of prefabricated and/or pre-assembled or precast construction would improve the overall performance of the construction in terms of cost, time and health and safety.

Table 5.27 Perception of clients relative to the use of prefabrication

Statement	N	SD %	D %	N %	A %	SA %	Mn	Std dev	Rank
Prefabrication and/or pre-assembly leads to a reduction of labor on site	15	0	0.0	0%	46.7	53.3	4.5	0.5	1
Lack of knowledge by designers leads to resistance to the use of alternative construction methods such as prefabrication and/or pre-assembly	15	0	0	6.7	33.3	60.0	4.5	0.6	2
The use of prefabricated /pre-assembled or precast will change the structure of the industry	15	0	0	13.3	40.0	46.7	4.3	0.7	3
Designers do not consider prefabrication and/or pre-assembly because they are unfamiliar with this method of construction	15	0	0	20.0	40.0	40.0	4.2	0.8	4
Construction clients prefer traditional construction methods instead of prefabrication and preassembly	15	0	6.7	13.3	53.3	26.7	4.0	0.8	5
Prefabrication / pre-assembly or precast reduce material wastage on site	15	6.7	6.7	6.7	40.0	40.0	4.0	1.2	6
Public sector contracts encourages the use of prefabrication within the construction industry in South Africa	15	0	6.7	13.3	60.0	20.0	3.9	0.8	7
Designers do not have enough knowledge about prefabrication to propose it to clients as an alternative	15	0	13.3	20.0	46.7	20.0	3.7	1.0	8
Designers rarely propose the use of prefabrication and/or pre-assembly to clients in their design	15	6.7	6.7	20.0	46.7	20.0	3.7	1.1	9
The use of prefabricated and/or pre-assembled or precast construction will improve the overall performance of the construction in terms of cost, time and health and safety	15	6.7	6.7	20.0	53.3	13.3	3.6	1.1	10
The use of prefabrication and/or pre-assembly will reduce the skills shortage in construction	15	6.7	13.3	20.0	46.7	13.3	3.5	1.1	11
Designers do not consider worker health and safety in their designs	15	0	13.3	26.7	60.0	0	3.5	0.7	12
Designers are aware of the potential benefits of prefabrication and/or pre-assembly relative to worker health and safety	15	0	20.	26.6	46.7	6.7	3.4	0.9	13
Construction clients are not informed about the benefits of prefabricated/ preassembled or precast	15	6.7	26.7	33.3	26.7	6.7	3.0	1.1	14
The use of prefabricated /pre-assembled or precast will create employment opportunities	15	13.3	33.3	33.3	20.0	0	2.9	1.3	15

5.4.2 SECTION B: Health and safety improvements by prefabrication and preassembly

5.4.2.1 Comparison of hazards between traditional construction process and prefabrication Processes

The frequency of comparison of hazards between traditional construction and prefabrication processes were ranked by mean percentage as shown in Table 5.28 where 0% referred to no exposure and 100% referred to maximum exposure.

Table 5.28 Comparison of hazards

Traditional method		Prefabrication	
Hazards	**Respondents %**	**Hazards**	**Respondents %**
0%	7.0	0%	20.0
10%	13.0	10%	47.0
20%	27.0	20%	13.0
30%	40.0	30%	13.0
40%	7.0	40%	13.0
50%	7.0	50%	7.0
60%	0.0	60%	0.0
70%	0.0	70%	0.0
80%	0.0	80%	0.0
90%	0.0	90%	0.0
100%	0.0	100%	0.0

From Table 5.28 above, it is evident that:

- 7% of respondents reported that traditional construction process exposed workers to 50% hazards;
- 40% of respondents reported that prefabrication construction process exposed workers to 30% hazards;
- 27% of respondents reported that traditional construction process exposed workers to 20% hazards;
- 47% of respondents reported that prefabrication construction process exposed workers 10% hazards

5.4.2.3 Reduction of hazards by prefabrication

Respondents were asked to indicate to what extent they agreed with statements on hazard reduction using prefabrication on a 5-point Likert scale where 1= Strongly Disagree; 2=Disagree; 3=Neutral; 4 =Agree; and 5 =Strongly Agree.

Table 5.29 Reduction of hazards by prefabrication

Statement	N	SD %	D %	N %	A %	SA %	Mn	Std dev	Rank
Prefabrication and/or pre-assembly reduces the exposure of workers to chemical hazards on site	15	0	0	0	60.0	40.0	4.4	0.5	1
The use of prefabrication and/or pre-assembly will reduce the need for formwork	15	0	0	13.3	46.7	40.0	4.2	0.7	2
Reduction of construction activities through prefabrication will reduce health and safety threats associated with confined spaces on site	15	0	0	20.0	53.3	26.7	4.1	0.7	3
The use of prefabrication and/or pre-assembly will reduce the prospect of contract demartitis	15	0	0	33.4	33.3	33.3	4.0	0.7	4
The use of prefabrication and/or pre-assembly will reduce the exposure of workers to steel reinforcement hazards	15	6.7	0	20.0	40.0%	33.3	3.7	1.0	5
The use of prefabrication and/or pre-assembly will reduce the need for scaffolding	15	0	13.3	26.7	40.0	20.0	3.9	1.1	6
The use of prefabrication and/or pre-assembly will reduce construction falls by reducing working at height related activities	15	13.3	6.7	33.3	26.7	20.0	3.3	1.3	7

From Table 5.29, it is evident that:

- All respondents (mean=4.4) reported that prefabrication and/or pre-assembly would reduce the exposure of workers to chemical hazards on site;
- 86.7% of respondents (mean=4.2) reported that the use of prefabrication and/or pre-assembly would reduce the need for formwork;
- 80.0% of respondents (mean=4.1) reported that reduction of construction activities through prefabrication would reduce health and safety threats associated with confined spaces on site;
- 73.3% of respondents (mean=3.7) reported that the use of prefabrication and/or pre-assembly would reduce the exposure of workers to steel reinforcement hazards; and
- 60.0% of respondents (mean=3.9) reported that the use of prefabrication and/or pre-assembly would reduce the need for scaffolding.

5.4.2.4 Impact of prefabrication and preassembly on health and safety

Respondents were asked to indicate to what extent they agreed with statements on the impact of prefabrication and preassembly on worker health and safety using prefabrication on a 5-point Likert scale where 1= Strongly Disagree; 2=Disagree; 3=Neutral; 4 =Agree; and 5 =Strongly Agree.

Table 5.30 Impact of prefabrication and preassembly on worker health and safety

Statement	N	SD %	D %	N %	A %	SA %	Mn	Std dev	Rank
Off-site construction processes reduce the risks associated with on-site construction methods	15	6.7	0	13.3	46.7	33.3	4.0	1.1	1
The use of prefabrication and/or pre-assembly will reduce ergonomic hazards on site	15	0	6.7	13.3	73.3	6.7	3.8	0.7	2
Reduction of labour through prefabrication will lead to improvement of health and safety on site	15	6.7	6.7	6.6	60.0	20.0	3.8	1.1	3
Off-site construction processes reduce environmental hazards	15	0	13.3	13.3	60.0	13.3	3.7	0.9	4
Prefabrication and/or pre-assembly reduces hazards related to material handling activities on site	15	0	13.3	13.3	66.7	6.7	3.7	0.8	5
The use of prefabrication and/or pre-assembly will lead to improvement of construction health and safety performance	15	0	6.7	26.7	60.0	6.7	3.7	0.7	6
Increasing the number of workers on a project site potentially leads to difficulties in managing construction worker health and safety	15	6.7	6.7	20.0	40.0	26.7	3.7	1.2	7
Quality is improved through the use of prefabrication and/or preassembly	15	0	13.3	20.0	53.3	13.4	3.7	0.9	8
Prefabrication and/or pre-assembly reduces the exposure of workers to health and safety risks	15	6.7	13.3	20.0	26.7	33.3	3.7	1.3	9
Labour intensive projects expose construction workers to physically demanding activities that pose risks to their health and safety	15	0	6.7	40.0	40.0	13.3	3.6	0.8	10

From Table 5.30, it is evident that:

- 80.0% of respondents (mean=4.0) reported that off-site construction processes would reduce the risks associated with on-site construction methods,
- 80.0% of respondents (mean=3.8) reported that the use of prefabrication and/or pre-assembly would reduce ergonomic hazards on site and that the reduction of labour through prefabrication would lead to improvement of health and safety on site;

- 73.3% of respondents reported that off-site construction processes would reduce environmental hazards;
- 73.4% of respondents (mean=3.7) reported that prefabrication and/or pre-assembly would reduces hazards related to material handling activities on site;
- 66.7% of respondents (mean=3.7) reported that the use of prefabrication and/or pre-assembly would lead to improvement of construction health and safety performance; increasing the number of workers on a project site potentially had led leads to difficulties in managing construction worker health and safety; quality would be improved through the use of prefabrication and/or preassembly;
- 60.0% of respondents (mean=3.7) reported that prefabrication and/or pre-assembly would reduce the exposure of workers to health and safety risks

From Table 5.31, it is evident that:

- Public sector clients tend to be neutral on the fact that the use of prefabrication and preassembly would reduce the exposure of workers to health and safety risks (mean=3.8), ergonomic hazards (mean=3.6), hazards related to material handling (mean=3.6).
- Private sector clients only agreed that offsite construction processes would reduce risks associated with on-site construction methods (mean=4.3), environmental hazards (mean=4.1) and that the use of prefabrication and preassembly would reduce ergonomic hazards on site (mean=4.0).

These findings suggest that clients undervalue the potential improvements of health and safety through utilization of prefabrication and preassembly despite private sector clients having shown recognition of few particular health and safety benefits.

5.4.3 Reliability

The Cronbach's alpha coefficient for scaled responses was 0.7 which satisfied the criteria for reliability.

Table 5.31 Perceptions of clients relative to the impact of prefabrication and preassembly on worker health and safety

Which of the following best describes your position?	Mean value for each activity									
	Off-site construction processes reduce environmental hazards	The use of prefabrication and/or pre-assembly will reduce ergonomic hazards on site	The use of prefabrication and/or pre-assembly will lead to improvement of construction health and safety performance	Quality is improved through the use of prefabrication and/or preassembly	Prefabrication and/or pre-assembly reduces hazards related to material handling activities on site	Off-site construction processes reduce the risks associated with on-site construction methods	Prefabrication and/or pre-assembly reduces the exposure of workers to health and safety risks	Reduction of labour through prefabrication will lead to improvement of health and safety on site	Increasing the number of workers on a project site potentially leads to difficulties in managing construction worker health and safety	Labour intensive projects expose construction workers to physically demanding activities that pose risks to their health and safety
Public Sector Client Mean	3.4	3.6	3.8	3.3	3.6	3.8	3.5	3.8	3.5	3.8
Private Sector Client Mean	4.1	4.0	3.6	4.1	3.7	4.3	3.9	3.9	4.0	3.2

5.5 Worker interviews

This section presents the analysis of data which was obtained through structured interviews with construction workers relative to the impact of traditional construction methods to health and safety of workers on site. This analysis further reports on the measurements of health and safety improvements by prefabrication and preassembly.

5.5.1. Impact of traditional construction method activities on health and safety of workers

From Table 5.32, most workers interviewed were general workers (48%). The median years of experience in the construction industry of workers was 6.0 years ranging from 1 to 40 years.

Table 5.32Occupation

Occupation	Number of Respondents	Percentages %
General labour	24	48.0
Carpenter	3	6.0
Bricklayer	8	16.0
Painter	4	8.0
Plasterer	5	10.0
Shutter hander	2	4.0
Tiller	4	8.0
Total	**50**	**100.0**

5.5.1.1 Ergonomic problems encountered while involved traditional methods and prefabrication erection

Respondents were asked whether they had experienced any physical health hazards while they were involved in traditional construction activities and prefabricated components erection.

Table 5.33 Ergonomic problems associated with various construction methods

Ergonomic Problems	Traditional construction		Prefabrication	
	Yes%	No%	Yes%	No%
Waist pains	76.0	24.0	66.0	34.0
Backaches	68.0	32.0	46.0	54.0
Shoulder pains	70.0	30.0	42.0	58.0
Wrist pains	25.0	75.0	46.0	54.0
Lung problems	54.0	46.0	24.0	76.0
Bone problems	8.0	92.0	15.0	85.0
Muscle and joint pains	46.0	54.0	39.0	61.0
Headaches	23.0	77.0	20.0	80.0

From Table 5.33, it is evident that:

- 76% of respondents reported that they had pains in their waist area while involved in traditional method activities;
- 70% of respondents reported that they experienced shoulder pains and ailments while involved in traditional method activities; and
- 66% of respondents reported that they experienced backache pains while involved in traditional method activities.

These results suggest that prefabrication significantly reduces ergonomic hazards to workers when compared with traditional construction methods.

5.5.1.2 Frequency of involvement in ergonomic problem activities

Table 5.34 indicates the frequency at which ergonomics problem activities were encountered by workers on a 5-point Likert scale where 1= Never; 2=Seldom; 3=Sometimes; 4 =Often; and 5 =Always. It was possible to rank the ergonomic problem activities by comparing their means scores.

From Table 5.34, it is evident by ranking the means that: workers:

- Sometimes (mean=3.3) encountered noise caused by heavy construction equipment close to their working areas;
- Sometimes (mean=3.0) experienced manual handling of heavy material and working at height; and
- Seldom to sometimes (means=2.1 to 2.5) other exposures.

Table 5.34 Frequency of involvement in ergonomic problem activities

Ergonomics problem activities	N	1 %	2 %	3 %	4 %	5 %	Mean	Std Dev	Rank
Noise caused by construction equipments	50	4.0	2.0	66.0	18.0	10.0	3.3	0.8	1
Manual handling of heavy material	50	6.0	16.0	52.0	22.0	4.0	3.0	0.9	2
Height related activities	50	8.0	8.0	60.0	24.0	0.0	3.0	0.8	3
Working in same place for a long time	50	16.0	34.0	36.0	10.0	4.0	2.5	1.0	4
Working in awkward posture	50	24.0	12.0	58.0	6.0	0.0	2.5	0.9	5
Hazardous materials	50	36.0	20.0	38.0	6.0	0.0	2.1	1.0	6
Vibrating equipments	50	38.0	24.0	30.0	8.0	0.0	2.1	1.0	7

These findings indicate that workers are involved in working situations that threaten their health due to exposure to ergonomic challenges. However, arguably, the use of prefabrication and preassembly would reduce these activities and consequently reduce ergonomic problems on site during the construction process.

Table 5.35 Comparison of trades relative to exposure to ergonomic problem activities

Which of the following best describes your trade?	Mean value for each activity						
	Working in awkward posture	Height related activities	Manual handling of heavy material	Noise caused by construction material	Working in same place for a long time	Vibrating and equipment	Hazardous material
Bricklayer	3.1	3.1	2.34	3.6	3.0	1.9	2.
Carpenter	2.3	3.7	4.0	3.0	2.7	2.7	2.3
General worker	2.4	2.9	3.4	3.2	2.8	2.4	2.4
Plaster	2.8	3.0	3.0	3.2	2.2	2.2	1.8
Painter	1.8	3.0	1.8	2.5	1.8	1.3	1.0
Tiler	2.5	2.78	2.8	4.0	1.3	1.0	1.5
Shutter hand	1.0	3.5	3.0	3.5	1.5	2.0	2.5

From Table 5.35, it is clear that;

- Carpenters were often (mean = 4.0) exposed to manual handling of heavy material, sometimes (mean = 3.0-3.7) and seldom exposed to other ergonomic challenging activities;
- Tilers were often (mean = 4.0) exposed to noise caused by construction material, seldom (mean = 3.0-3.7) to other ergonomic challenging activities;
- Bricklayers were sometimes (mean = 3.0-3.7) exposed to noise caused by construction material and other activities, and seldom exposed to other ergonomic challenging activities; and
- General workers were sometimes (mean = 3.2-3.4) exposed to manual handling of heavy material and other activities, and seldom exposed to other ergonomic challenging activities.

5.5.1.3 Feelings about the job

Respondents were asked whether they sometimes felt like changing jobs due to heavy physical workloads.

Table 5.36 Involvement on projects where prefabricated components were utilized

	Respondents %
Yes	78.0
No	22.0
Total	**100.0**

From Table 5.36, it is clear that:

- Most (78%) workers reported that they sometimes felt like changing their current jobs due to heavy workloads.

5.5.2 Section B: Measurements of health and safety improvements by prefabrication and preassembly

5.5.2.1 Involvement on project where prefabricated components were utilized

Table 5.37 Involvement on projects where prefabricated components were utilized

	Respondents %
Yes	54.0
No	46.0
Total	**100.0**

From Table 5.37, it is evident that:

- Slightly more than half (52%) of workers had been involved in projects prefabricated components had been used.

Evidently, construction workers have been involved in projects which had adopted prefabricated components. Consequently, they might have recognized health and safety benefits associated with its use as indicated in Figure 5.28 below.

5.5.2.2 Impact of prefabrication and preassembly on health and safety of workers

Table 5.38 Impact of prefabrication and preassembly on health and safety of workers

Statement	N	Yes %	No %
Reducing a need for scaffolding by prefabricated /pre-assembly or precast components would lead to less falls on sites	26	85.0	15.0
When work is done offsite large amount of noise is reduced on site	26	85.0	15.0
Prefabrication / pre-assembly or precast reduces hazards related to material handling activities on site	26	85.0	15.0
Doing more work offsite would lead to reduction of many health and safety risks on site	26	69.0	31.0

From Table 5.38, it is evident that:

- 85% of respondents reported that, reduction of scaffolding through prefabricated /pre-assembly or precast components would lead to less falls on sites, the use of prefabrication/ preassembly and precast would reduce hazards related to material handling on site and noise on site; and that offsite construction process would reduce large amount of noise occurring on site;
- 69% of respondents reported that, doing more work offsite would lead to reduction of many health and safety risks on site.

5.6 Observations

A team of five graduate research assistants directly observed, counted and recorded the body movements associated with plasterers and their assistance and steel fixers on site. Each activity was observed for two hours using five minute intervals and one minute break in between the observations.

5.6.3 Plasterers observation

Fifteen plasterers were observed for two hours using five minutes interval while they were bulking and striping the plaster on the wall and smoothening the surface. Body movements namely, bending the body, twisting the body, working below knee level, kneeling, reaching away from the body, working above should and lifting heavy material manual were carefully counted and recorded on the observation sheet.

Table 5.39 Plasterer body movements

Body Movements	N	Min	Max	Mean/hr
Bending the body	15	50.0	232.0	175.0
Working below knee level	15	0.0	199.0	136.0
Kneeling	15	0.0	208.0	119.0
Twisting the body	15	10.0	206.0	115.0
Working above shoulder	15	31.0	154.0	86.0
Lifting heavy material manual	15	0.0	122.0	75.0
Reaching away from the body	15	38.0	113.0	71.0

From Table 5.39, it is evident that plasterers were subjected to bend their bodies for a mean 175 times and work below knee level for 136 times per hour. It was observed that they knelt for a mean 119 times while at the same time they twisted their body for a mean 115 times during the plastering process. Plasterers worked above shoulder level for 86 times and lifted heavy material for 75 times per hour. Reaching away from the body occurred for a mean 71 times while they were plastering per hour.

5.6.4 Plasterer assistants observation

Fifteen assistants of plasterer were observed for two hours using five minutes interval while they were mixing and supplying the concrete to plasterers. Body movements namely, bending the body, twisting the body, working below knee level, kneeling, reaching away from the body, working above should and lifting heavy material manual were carefully counted and recorded on the observation sheet.

Table 5.40 Plasterer assistant body movements

Body Movements	N	Min	Max	Mean/hr
Bending the body	15	120.0	269.0	192.0
Twisting the body	15	62.0	216.0	124.0
Working below knee level	15	0.0	201.0	115.0
Reaching away from the body	15	12.0	73.0	180.0
Working above shoulder	15	0.0	62.0	27.0
Lifting heavy material manual	15	0.0	67.0	17.0
Kneeling	15	0.0	22.0	4.0

From Table 5.40, it is evident that plastering assistants bent their bodies for 192 times while they twisted the body for 124 times per hour. Working below knee level occurred for a mean 115 times and reached away from the body for a mean 73 times. It was observed that they worked above shoulder height for a mean 27 times per hour.

5.6.5 Steel fixing observation

Fifteen steel fixers were observed for two hours using five minutes interval while they were measuring space between steel, cutting wire and fixing steel preparing for concrete pouring on site. Body movements namely wrist twisting, bending the body, reaching away from the body, twisting the body, kneeling and working below knee level were counted and recorded on the observation sheet.

Table 5.41 Steel fixing observations

Body Movements	N	Min	Max	Mean/hr
Wrist twisting	15	218.0	321.0	268.0
Bending the body	15	0.0	312.0	204.0
Reaching away from the body	15	101.0	62.0	152.0
Twisting the body	15	43.0	235.0	14.0
Kneeling	15	62.0	149.0	94.0
Working below knee level	15	163.0	257.0	108.0

From Table 5.41, it is evident that workers twisted their wrists while fixing steel a mean 268 times per hour while at the same time they bent their bodies for 204 times in one hour. They worked below the knee level for a mean 152 times per hour. They twisted their bodies for a mean 108 times per hour while cutting and fixing wires. Kneeling occurred for a mean 94 times per hour and reaching away from the body occurred for a mean 14 times per hour.

5.7 Summary of findings

This chapter presented analysis of findings emanating from a survey of construction workers, construction clients, constructors and designer. Observations of plasterers and structural steel workers with their assistants were also presented. The findings suggest that construction workers are likely to experience ergonomic problems when involved in traditional construction work. However, prefabrication/ preassembly and precasting were identified as technological construction methodologies that would reduce these problems.

Construction clients and designers were slightly aware of potential benefits associated with prefabrication and preassembly. Some clients acknowledged the improvements of health and safety by prefabrication and preassembly. Given their acknowledgement of involving prefabrication and preassembly on few project they have completed, it can be argued that most of the clients undervalue this method as an alternative construction.

CHAPTER 6
DISCUSSION OF FINDINGS

6.1 Introduction

This chapter discusses the findings of the surveys of contractor, clients and designers as well as the findings of interviews and observations of construction workers on site.

6.2 Perception of clients relative to the use of prefabrication and preassembly

The selection of construction methods as relative to health and safety is a crucial factor given that any construction project is unique. Since contractors are responsible for the execution of construction work, the question might be asked whether they should be responsible for selecting the construction method. The study suggests that designers should decide on which construction method should be adopted for construction projects. Arguably, this view may be underpinned by designers being obligated to select construction materials as part of formulating the design of the building or structure. Moreover, in the case of inexperienced clients and possibly the absence of a project manager, designers may be responsible for selecting the construction method. On the other hand construction clients who have experience in and knowledge of the construction industry might be responsible for selecting the construction method themselves. The review of the literature suggested that designers and clients remained drivers and motivators for, or barriers to, the selection of prefabrication, preassembly and precast technologies.

The findings of this study indicate that construction clients and their advisors had previously adopted prefabrication, preassembly and precasting on their construction projects. Evidently, only one respondent reported that prefabrication was adopted on most of his projects. However, almost all respondents had adopted prefabrication on their projects to a greater or lesser degree. That this alternative construction method is not considered on every project suggests that construction clients and designers resist the utilization of prefabrication. Furthermore, the literature suggests that such resistance stems from their unfamiliarity of the benefits associated with prefabrication (Gibb, 2001).

However, the findings reported that to varying degrees, clients and designers were aware of the benefits associated with the utilization of prefabrication. Increased productivity was perceived as the optimum benefit derived from the utilization of prefabrication including cost reduction, time and health safety improvements. Similarly, some of their reasons for adopting prefabrication were as follows:

- Reduction of time;
- Quality improvements;
- Reduction of cost;
- Health and safety performance improvements;
- Increased durability of prefabricated components relative to in situ methods;
- Reduction of rework;
- Reduction of labour;
- Ease of installation;
- Reduction of scaffolding;
- Manufacturing processes that are more efficient than traditional onsite construction processes;
- Reduction of trades which are in short supply in favour of new skills which easily learnt in a short time span;
- Reduction of formwork; and
- Reduction of delays.

Given these benefits and reasons for adopting prefabrication as an alternative construction method, it could be argued that clients and designers recognized its contribution to overall project performance. The study suggests that clients (42%) and designers (30%) did not totally resist the use of prefabrication. However, there were many reasons for resisting prefabrication, such as quality and cost of prefabrication, lack of experience with the product particularly by designers and client requirements. Further reasons for resistance were associated with perceptions that prefabrication was not good for external use and different detailing seemed to have confused inexperienced designers. It was noted that clients (74%) and designers (76%) had utilized prefabrication on less than 30% of their projects. Given these few projects involving prefabrication, it can be argued that clients and designers resisted the use of prefabrication as an alternative construction method.

Government as the main client for products of construction plays a vital role in the development of the construction industry. Despite the study finding that public sector contracts encouraged the use of prefabrication, most respondents, however, indicated that designers (70%) and clients (80%) preferred traditional construction methods to prefabrication. Their preference for the traditional construction method was reinforced by Rowlinson (1999) reported that the government initiatives on any government-funded project enforced contractors to employ as many local labourers or workers as possible, regardless of their status of experience within the construction industry. Regrettably, construction sites involve changing environment and different working conditions which places a major concern on issues such as health and safety of worker on site.

The findings suggest that the use of prefabrication would potentially improve the overall performance of construction time, cost and health and safety. Unfortunately, clients (93%) suggest that lack of knowledge by the designer led to their resistance to consider prefabrication as an alternative method. They therefore preferred using the traditional method which they knew well. The literature suggested that designers had technical difficulties distinguishing between designing for prefabrication and on site construction (Pasquire and Connolly, 2002).

The study found that designers rarely proposed prefabrication as an alternative method to their clients in their design. These findings suggest that designers did not encourage the use of prefabrication despite few being somewhat aware of its potential benefits. Arguably, both construction clients and designers undervalue the use of prefabrication as an alternative construction method although they perceived potential benefits associated its use.

6.3 Extent of health and safety benefits of prefabrication

The findings suggest that traditional construction method activities are more hazardous compared to prefabrication and preassembly processes on site. This notion was advanced by Gibb and Neale (1997) and Rwamamara (2007). Respondents identified various health and safety benefits from the use of prefabrication and preassembly when compared to onsite construction, namely

- Reduction of environmental hazards;
- Reduction of material handling hazards;
- Reduction of mechanical noise;
- Reduction of chemical hazards;

- Safe working conditions; and
- Reduction of risks on site.

Similar health and safety benefits were identified by McKay *et al.*, (2005) in their study. Although Haupt (2001) reported that the construction industry earned the reputation of being a dangerous or highly hazardous industry, the literature and findings suggest that the use of prefabrication is packaged with health and safety benefits on site. Arguably, this would change the image of construction industry with respect to health and safety.

The perceived poor health and safety performance within the construction industry has been attributed to major negative outcomes on the health and safety of workers. However, the literature suggested that the utilization of offsite production would lead to improvements on overall health and safety performance in the construction project (Hass *et al.,* 2000 and Court *et al.,* 2006). The findings supported this notion by acknowledging that the use of prefabrication would potentially reduce the exposure of workers to chemical hazards and steel reinforcement hazards and major falls hazards associated with height related activities. Impliedly, the use of prefabrication would reduce fall hazards by significantly reducing climbing and descending activities, reduce repetitive body movements during the onsite preparation of steel for reinforcement and reduce silica dust, welding fumes and organic solvents.

Despite prefabrication and preassembly being undervalued or ignored in developing countries like South Africa, the literature reported that offsite production improves the construction project performance, quality, productivity, profit and the time frame for completion of the contract (Pasquire and Connolly, 2002). Arguably, this ignorance is characterized with the government strategic plan to create employment opportunities through labour intensive methods. Unfortunately, the findings suggest that increasing the number of workers on a project site potentially leads to difficulties of managing construction worker health and safety. Consequently, the study also reports that labour intensive methods expose workers to physical demanding activities that pose risks to their health and safety. Baradan *et al.*, (2006) reported that construction activities and labour intensive methods were fraught with various hazards and risks to workers. However, findings suggest that offsite construction process would reduce risks associated with environmental hazards and onsite construction methods. This indicates that the difficulties of managing construction health and safety risks on site would be alleviated by doing more construction work offsite.

Despite the construction work on site involving physical demanding work activities and hazardous working conditions which have resulted in sicknesses to workers, the literature suggested that the use of prefabrication would improve construction site working conditions by reducing significantly work to be done on site (Lou *et al.*, (2008). The study further suggested that the utilization of prefabrication and preassembly would lead to improvements of health and safety performance.

For example, the findings suggest that the use of prefabrication and preassembly would reduce ergonomic problems associated with manual handling of heavy material. The literature reported that it was the responsibility of the construction planner or designer to determine materials and equipments handling methods. In this regard designer would select light weight material which would not pose any difficulties for workers to handle. Unfortunately, the findings suggest that designers ignore health and safety of workers in their designs. Further, despite the study having reported that private sector clients acknowledged the health and safety improvements associated with the utilization of prefabrication and preassembly, both private sector and public sector clients, however, tended to be neutral relative to major improvements of health and safety attributed to utilization of prefabrication. It was also found that clients selected prefabrication and preassembly for other reasons which were not associated with particular improvements of health and safety on construction projects. These findings suggest that clients and designers undervalue the potential improvements of health and safety associated with the utilization of prefabrication and preassembly.

6.4 Impact of traditional construction method activities on health and safety of workers

The literature confirmed that construction site activities were major causes of health problems to workers. Consequently, it was imperative to investigate the impact of traditional construction method activities and offsite construction methods on health and safety of workers on site. A comparison of ergonomic problems encountered by workers while involved in onsite construction process and the erection of prefabricated components on site revealed that most workers experienced pains in their waist areas, shoulders, backs and wrists under both construction methods. However, less workers experienced these ergonomic problems while involved in the erection of prefabrication when compared with traditional construction method processes. These results suggest that prefabrication significantly reduces the ergonomic hazards to workers as compared to traditional construction methods. McKay *et al.*, (2005) supported these findings by reporting that allowing more work to take place offsite would diminish hazardous construction activities and also ease risks on site.

While the literature had reported that manually lifting, pulling, pushing and carrying large and heavy material were the most common activities to be performed by workers on site (Lipcomb *et al.*, 2005), 78% of workers felt like changing jobs due to their physical workload while they were involved in traditional construction methods. Carpenters were found to be often exposed to activities which involved manual handling of heavy material while general worker, plasterers, painters and shutter fixer were sometimes involved on such activities. Furthermore, the findings suggest that carpenters, bricklayer, plasterers, painters and shutter fixer were sometimes involved in height related activities and almost all of them sometimes experienced noise caused by large construction equipment. However, 85% of workers reported that prefabrication, preassembly or precasting would reduce hazards associated with material handling on site and reduce falls by eliminating the need for scaffolding and noise caused by large construction equipments on site. These findings suggest that the utilization of prefabrication and preassembly would lead to potential improvements of health and safety on site. Workers were aware of these health and safety benefits. Consequently 69% workers reported that the use of prefabrication would reduce many health and safety risks on site.

6.5 Comparison of ergonomic challenges exposure between construction methods on site

The issues of ergonomic problems within the construction industry had been previously explored and possible factors which led to these problems had been reported. The findings of this study suggest that workers sometimes had to experience noise caused by heavy construction equipments near their working area, working at heights and handle heavy material manually. The literature reported that workers had to experience the same ergonomic challenges with additional exposure to activities that demand repetitive bending and twisting the body, working above shoulder height and working below knee level (Smallwood, 2004; 2006; Rwamamara, 2007; Samuels, 2005; Ajayi and Smallwood, 2008). Consequently, the study reported findings emanating from body movements of workers while they were involved in traditional method and prefabricated wall construction.

The literature reported that bending and twisting the body were highest ergonomic challenges to workers (Samuels, 2005). The comparative study revealed that bending and twisting the body and working below the knee level were common and highly performed body movements by bricklayers, bricklayer assistants (manual supply of bricks activities and manual mixing and supply of mortar activities), plasterer assistants, steel fixers, plasterers and prefabricated insulation wall fixers per hour.

Bricklayer assistants (manual supply of bricks activities) also experienced more reaching away from the body and working above shoulder height when working per hour. Steel fixers suffered more wrists twisting and working below the knee level while plasterers also experienced more working below the knee level and kneeling per hour. Among these activities, manual supply of bricks experienced the highest bending (429 times) and twisting (373 times) the body and prefabricated insulation wall fixers experience the least bending (67 times) and twisting (58 times) the body per hour.

These findings suggest that the utilization of prefabrication on site would reduce repetitive bending and twisting the body and activities that involve working below knee level which were more likely to arise from the traditional construction processes. The comparison of bricklaying activities and prefabricated wall fixing suggests that prefabricated wall fixing processes potentially reduced manual handing of heavy material associated with manual supply of bricks activities and bricklaying process. It can be argued that the utilization of prefabrication reduced health and safety threats associated with traditional construction method on site.

6.6 Chapter Summary

In this chapter findings were discussed emanating from a survey of contractors, clients and designers. The Cronbach's alpha coefficient for scaled responses was 0.7 for a survey of client, 0.8 for a survey of designers and contractor and they were all confirmed to be reliable. Relative to clients perceptions of prefabrication and preassembly, respondents had adopted prefabrication on their projects to a greater or lesser degree despite their recognition of its benefits. However, only one client reported that they had previously adopted the prefabrication, preassembly and precast on most of their construction projects. The findings and literature confirmed that designers and clients resisted the use of prefabrication. As a result it was found that construction clients preferred traditional construction methods than utilizing prefabrication. It was also found that designers did not consider prefabrication as an alternative construction method because they were unfamiliar with this approach. Health and safety benefits associated with prefabrication and preassembly were reported on both literature and findings. However, it was reported that designers tend to ignore health and safety of workers in their design. Despite private sector clients perceiving the utilization of prefabrication to eliminate few health and safety risks on site, both private sector and public sector clients, however, tend to be neutral relative to major improvements of health and safety attributed to the utilization of prefabrication. It was also found that clients selected prefabrication and preassembly for other reasons which were not associated with particular improvements of health and safety in construction project. It can be argued that both clients and designers undervalue the potential improvements of health and safety associated with the utilization of prefabrication and preassembly.

Findings from the interviews and observations of construction workers on site were also discussed. A comparison of the impact of traditional construction methods and prefabrication methods on the health and safety of workers was done. It was found that workers experienced pains on their bodies when involved in both construction methods. However, less workers felt such pains when involved in the erection of prefabrication on site as compared to traditional construction methods. Although workers had to experience repetitive body bending and twisting while handling heavy material manually when involved with the traditional construction process activities, the findings suggested that prefabrication reduces these challenges. Consequently, 85% of workers reported that prefabrication/preassembly or precast would reduce hazards associated with material handling on site and reduce falls by eliminating the need for scaffolding on site. It can be concluded that prefabrication reduces ergonomic challenges and other health and safety risks associated with traditional construction method and workers are aware of these health and safety benefits.

CHAPTER 7
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 Summary

The study sought to determine whether the utilization of prefabrication and preassembly leads to potential improvements of health and safety of workers on construction projects. The objectives of this study were:

- To examine the health and safety hazards associated with traditional construction methods in South Africa;
- To investigate the merits of prefabrication and pre-assembly in terms of their impact on overall health and safety improvements when compared with traditional construction methods; and
- To investigate to which extent to which construction clients perceive the use of prefabrication and pre-assembly as alternative construction methods that positively impact overall health and safety of construction workers on site.

The hypotheses to be tested for this study were:

- H1:Traditional methods of construction threaten the health and safety of workers on site;
- H2: Prefabrication and preassembly reduce threats to the health and safety of workers when compared with traditional methods of construction; and that
- H3: Clients undervalue the impact of pre-assembly and pre-fabrication as alternative construction methods that will improve overall health and safety performance.

This chapter will test these hypotheses, draw conclusions and discuss the limitation and recommendations.

7.2 Hypotheses testing

The following hypotheses were tested, namely

- H1: Traditional methods of construction threaten the health and safety of workers on site

  The study found that labour intensive methods also known as traditional construction methods exposed workers to physical demanding activities that posed health and safety risks to their health and safety. As a result, 76% of workers experienced pains in their waist areas, 70% pains in their shoulders and 66% backaches problems while they were involved in the traditional construction. It was found that workers sometimes had to handle heavy material manually, be involved in working at heights and experienced noise caused by heavy construction equipment.

  The hypotheses that traditional methods of construction threaten the health and safety of workers on site cannot be rejected.

- H2: Prefabrication and preassembly reduces threats to the health and safety of workers when compared with traditional methods of construction

  The study found that bending and twisting the body were the most frequent body movements performed by workers both in traditional construction and prefabrication construction methods. A comparison of ergonomic problems associated with construction methods revealed that most workers when involved in traditional method experience pains in their different body parts. However, observation of bricklaying activities and prefabrication insulation wall fixing relative to ergonomic challenges and ergonomic problems revealed that prefabrication reduced the exposures of workers to both ergonomic challenges and ergonomic problems. 85% of workers acknowledged that prefabrication, pre-assembly or precasting reduced hazards related to material handling activities on site. The findings also suggest that traditional construction methods were more hazardous than prefabrication.

The hypotheses that prefabrication and preassembly reduces threats to the health and safety of workers when compared with traditional methods of construction on site cannot be rejected.

- H3: Clients undervalue the impact of pre-assembly and pre-fabrication as alternative construction methods that will improve overall health and safety performance

While the findings portrayed that clients did not totally resist the use of prefabrication, the literature, however, suggested that construction clients resisted the use of prefabrication on their projects. The study revealed that 80% of clients preferred traditional construction methods instead of prefabrication. Despite their neutral tendency regarding the major potential improvements of health and safety associated with prefabrication and preassembly, it was also found that clients selected prefabrication and preassembly for other reasons which were not associated with particular improvements of health and safety in construction project.

The hypotheses that clients undervalue the impact of pre-assembly and pre-fabrication as alternative construction methods that will improve overall health and safety performance cannot be rejected.

7.3 Conclusions

7.3.1 Traditional methods of construction threaten the health and safety of workers on site

The study found that traditional construction methods exposed workers to frequent body movements and energy demanding activities which led to body pains. Workers were more likely to experience ergonomic problems with major negative outcomes on their health and safety due to their involvement on activities that involved manual handling of heavy material; recurring noise caused by construction equipments and height related activities which involve repetitive ascending and descending. A comparative study also confirmed that workers sometimes had to work in awkward posture and handle heavy material manually while they were involved in traditional construction methods. The survey revealed that 96% of workers had experienced pain in their waist area and 88% experienced backache pains while involved in the traditional construction method. It can be concluded that traditional construction methods threatened the health and safety of workers.

7.3.2 Prefabrication and preassembly reduces threats to the health and safety of workers when compared with traditional methods of construction

The study found that traditional construction methods were more hazardous when compared with prefabrication and preassembly construction methods. A comparative survey found that prefabrication reduced activities associated with repetitive body movements, ergonomic challenges and ergonomic problems. The survey found that 92% workers reported that the use of prefabrication/ preassembly and precast would reduce hazards related to material handling on site and that the reduction of scaffolding through the use of prefabricated /pre-assembly or precast components would lead to less falls on sites. The survey found that 85% of workers acknowledged that prefabrication / pre-assembly or precastig reduced hazards related to material handling activities on site. The survey further found that the use of prefabrication and/or pre-assembly would reduce the exposure of workers to steel reinforcement hazards and health and safety risks, and consequently lead to improvements of health and safety performance on site. It can therefore be concluded that prefabrication and preassembly reduced threats to the health and safety of workers when compared with traditional methods of construction.

7.3.3 Clients undervalue the impact of pre-assembly and pre-fabrication as alternative construction methods that will improve overall health and safety performance

Despite several respondents having reported that public sector contracts supported prefabrication and less than a half of respondents acknowledging that clients did not resist prefabrication, 80% of clients reported that they preferred traditional construction methods instead of prefabrication. Evidently, the findings suggested that only one respondent reported to have utilized prefabrication on most of his projects. The study found that 93.3% of respondents reported that their resistance to the use of prefabrication and/or pre-assembly as an alternative construction method was due to the lack of knowledge by designers. While the study indicated that offsite reduces environmental hazards, ergonomic hazards on site and the risks associated with on-site construction methods, clients tended to be neutral regarding the major potential improvements of health and safety by prefabrication and preassembly. It was also found that clients selected prefabrication and preassembly for other reasons which were not associated with particular improvements of health and safety in construction project. It can be concluded that construction clients and designers does not only resist prefabrication as an alternative method, but they also undervalue its potential improvements of health and safety in the construction project.

7.4 Limitations

There was limited literature relative to the impact of prefabrication and preassembly on construction health and safety. Previous studies had focused on measuring cost benefits associated with prefabrication and preassembly.

It was difficult to get respondents to fill in the questionnaires. While the targeted sample frame was 20 clients, 20 designers, 20 contractors and 60 construction workers, some respondents returned unanswered or blank questionnaires. Some were not interested in completing the questionnaire given that they had no experience with the use of prefabrication and preassembly. Although the findings may not be broadly generalizable they are indicative of the impact of prefabrication and preassembly on the health and safety of workers on site given that most of the key findings confirmed the findings of the literature review.

It was difficult to get construction sites which were utilizing prefabrication and preassembly within the Western Cape region. Consequently, an exploratory study was necessary which focused on measuring particular construction site activity in traditional construction method and prefabrication on site. The study focused on construction processes which took place on site instead of factory working environment.

7.5 Further Research

The empirical study was conducted to investigate the impact of construction methods on health and safety of workers. This study focused on measuring ergonomic hazards associated with bricklaying activities and prefabricated wall fixing activities due to the scarcity of construction sites that were using other forms of prefabricated elements. It was found that bricklaying activities were more ergonomically hazardous when compared to prefabricated wall fixing on site. Further research is necessary to determine whether other forms of prefabricated and preassembled components would reduce ergonomic hazards and health and safety hazards associated with traditional construction methods.

The study investigated the impact of prefabrication and preassembly on health and safety of workers on site. It was revealed that prefabrication and preassembly improved health and safety performance on site. The study found that the traditional construction processes were more hazardous and exposed workers to activities which involved various risks on site. Further investigation is needed on the impact of prefabrication and preassembly on the health and safety of worker within the factory working environment in order to determine the health and safety performance in the area were off site prefabrication, preassembly and precasting occurs. Such a study could be used as a basis to determine how conducive the factory working environment is to workers when compared to the construction site working environment.

APPENDICES

APPENDIX A: REQUEST FOR ACCESS ON SITE

Cape Peninsula
University of Technology

To whom it may concern
29 April 2010

Dear Sir / Madam

Masters Student: Luviwe Bikitsha (203170539)

The student is currently doing his Masters in Construction Management at CPUT in the Department of The Built Environment. He needs to conduct a series of surveys on construction sites where he will observe workers performing certain functions. This observation will in no way interrupt or hamper the workers performance. The study will be done totally anonymously which means at no point will your companies name be mentioned in the research.

His area of research is investigating the impact of prefabrication and pre-assembly on construction health and safety.

We appreciate the assistance you can provide to the student in completing his research.

The study will be conducted over a period of 3 weeks (not necessarily daily) but he will make prior arrangement with Site staff for the days he will be on site. He will be assisted by 5 other students, but he is the lead researcher.

Please feel free to contact me if you have any further queries.

Yours Sincerely

Zainu Khan
Departmental Research Coordinator
Lecturer: Department of Built Environment
+27219596631 (phone)
+27219596656 (fax)
khanz@cput.ac.za

APPENDIX B: CONTRACTOR QUESTIONNAIRE

This research study seeks to investigate the impact of prefabrication and pre-assembly on construction health and safety in South Africa.

You are invited to participate in this study by completing this questionnaire as fully and as accurately as possible.

Please Luviwe Bikitsha, return via:
Fax: +27 21 959 6870
E-mail: luviwe.b23@gmail.com
Mobile: +27 73 742 8210, +27 21 959 6317

SECTION A: Client perceptions about prefabrication and preassembly in construction industry

1. Which of the following best describes your occupation?

No	Occupation	Tick only one box
1.1	Site agent	
1.2	Site manager	
1.3	Health and safety representatives	
1.4	Site foreman	
1.5	Site Engineer	
1.6	Others	

2. How long have you worked in the construction industry? ......years

3. What percentage in value (Rands) of your projects included prefabricated/ preassembled or precast components?

0 %	10 %	20%	30%	40%	50%	60%	70%	80%	90%	100%

4. What were the benefits?

Cost reduction	
Increased productivity	
Improved H&S	
Other, specify below	

5. In your own opinion, to what extent do construction clients and designers recognize the benefits associated with the use of prefabricated/ preassembled or precast construction?

0 %	10 %	20%	30%	40%	50%	60%	70%	80%	90%	100%

6. The following statements refer to the use of prefabrication / or precast pre-assembly. Please indicate your level of agreement with these statements on a 5-point scale where **1= strongly disagree (SD), 2= Disagree (D), 3=Neutral (N), 4=Agree (A) and 5=Strongly agree (SA)**

		SD	D	N	A	SA
	Statement	1	2	3	4	5
6.1	Prefabrication / pre-assembly or precast reduce material wastage on site					

6.2	Designers are aware of the potential benefits of prefabrication and/or pre-assembly relative to worker health and safety					
6.3	Prefabrication and/or pre-assembly leads to a reduction of labor on site					
6.4	Public sector contracts encourages the use of prefabrication within the construction industry in South Africa					
6.5	The use of prefabricated /pre-assembled or precast will change the structure of the industry					
6.6	The use of prefabricated and/or pre-assembled or precast construction will improve the overall performance of the construction in terms of cost, time and health and safety					
6.7	Clients tend to focus mostly on time, quality and cost instead of worker health and safety					
6.8	Designers do not consider worker health and safety in their designs					
6.9	The use of prefabrication and/or pre-assembly will reduce the skills shortage in construction					
6.10	Designers do not consider prefabrication and/or pre-assembly because they are unfamiliar with this method of construction					
6.11	Designers do not have enough knowledge about prefabrication to propose it to clients as an alternative					
6.12	Construction clients prefer traditional construction methods instead of prefabrication and preassembly					
6.13	Lack of knowledge by designers leads to resistance to the use of alternative construction methods such as prefabrication and/or pre-assembly					
6.14	Designers rarely propose the use of prefabrication and/or pre-assembly to clients in their design					
6.15	Construction clients are not informed about the benefits of prefabricated/ preassembled or precast					
6.16	The use of prefabricated /pre-assembled or precast will create employment opportunities					

SECTION B: Measurements of health and safety improvements by prefabrication and preassembly

7. When comparing the traditional/in-situ construction process to the prefabricated process to what extent does each expose workers to hazards?

Traditional	0 %	10 %	20%	30%	40%	50%	60%	70%	80%	90%	100%
Prefabricated	0 %	10 %	20%	30%	40%	50%	60%	70%	80%	90%	100%

8. What health and safety benefits would you ascribe to prefabrication compared to on-site construction methods?

....
....
....
....
....
....
....
....

9. To what extent do you agree with the following statements where **1= strongly disagree (SD), 2= Disagree (D), 3=Neutral (N), 4=Agree (A) and 5=Strongly agree (SA).**

		SD	D	N	A	SA
	Statement	1	2	3	4	5
9.1	*Prefabrication and/or pre-assembly reduces the exposure of workers to* chemical hazards on site					
9.2	The use of prefabrication and/or pre-assembly will reduce the prospect of contract demartitis					
9.3	The use of prefabrication and/or pre-assembly will reduce construction falls by reducing working at height related activities					
9.4	Reduction of construction activities through prefabrication will reduce health and safety threats associated with confined spaces on site					
9.5	The use of prefabrication and/or pre-assembly will reduce the need for formwork					
9.6	The use of prefabrication and/or pre-assembly will reduce the exposure of workers to steel reinforcement hazards					
9.7	The use of prefabrication and/or pre-assembly will reduce the need for scaffolding					

10. The following statements require your opinion relative to the impact of prefabrication and/or pre-assembly on health and safety. Please indicate your level of agreement with the statements on a 5-point scale where **1= strongly disagree (SD), 2= Disagree (D), 3=Neutral (N), 4=Agree (A) and 5=Strongly agree (SA).**

		SD	D	N	A	SA
	Statement	1	2	3	4	5
10.1	Labour intensive projects expose construction workers to physically demanding activities that pose risks to their health and safety					
10.2	Reduction of labour through prefabrication will lead to improvement of health and safety on site					
10.3	Quality is improved through the use of prefabrication and/or preassembly					
10.4	*Prefabrication and/or pre-assembly reduces the exposure of workers to* health and safety risks					
10.5	The use of prefabrication and/or pre-assembly will lead to improvement of construction health and safety performance					
10.6	The use of prefabrication and/or pre-assembly will reduce ergonomic hazards on site					
10.7	Off-site construction processes reduce environmental hazards					
10.8	*Prefabrication and/or pre-assembly reduces hazards related to material* handling activities on site					
10.9	Off-site construction processes reduce the risks associated with on-site construction methods					
10.10	Increasing the number of workers on a project site potentially leads to difficulties in managing construction worker health and safety					

APPENDIX C: CONSTRUCTION DESIGNER QUESTIONNAIRE

This research study seeks to investigate the impact of prefabrication and pre-assembly on construction health and safety in South Africa.

You are invited to participate in this study by completing this questionnaire as fully and as accurately as possible.

Please Luviwe Bikitsha, return via:
Fax: +27 21 959 6870
E-mail: luviwe.b23@gmail.com
Mobile: +27 73 742 8210, +27 21 959 6317

SECTION A: Client perceptions about prefabrication and preassembly in construction industry

1. Which of the following best describes your occupation?

No	Company description	
2.1	Structural Designer	
2.2	Architectural Designer	

2. How long have you worked in the construction industry? ......years

3. Which party should be responsible for selecting the construction method on projects?
Please tick ONLY one box below.

No	Company description	
2.1	Designers	
2.2	Clients	
2.3	Contractors	

4. How many of your projects have involved prefabricated/ preassembled or precast components?

0 %	10 %	20%	30%	40%	50%	60%	70%	80%	90%	100%

5. What were the benefits?

Cost reduction	
Increased productivity	
Improved H&S	
Other, specify below	

____

____

6. In cases where you considered the use of prefabrication / pre-assembly or precast what were the factors that influenced that consideration?

____

____

7. In cases where you resisted the use of prefabrication / pre-assembly or precast construction what were the reasons for this resistance?

8. In your own opinion, to what extent do construction clients and designers recognize the benefits associated with the use of prefabricated/ preassembled or precast construction?

0 %	10 %	20%	30%	40%	50%	60%	70%	80%	90%	100%

9. The following statements refer to the use of prefabrication / or precast pre-assembly. Please indicate your level of agreement with these statements on a 5-point scale where **1= strongly disagree (SD), 2= Disagree (D), 3=Neutral (N), 4=Agree (A) and 5=Strongly agree (SA)**

		SD	D	N	A	SA
	Statement	1	2	3	4	5
9.1	The use of prefabricated and/or pre-assembed or precast construction will improve the overall performance of the construction in terms of cost, time and health and safety					
9.2	Prefabrication and/or pre-assembly leads to a reduction of labor on site					
9.3	The use of prefabrication and/or pre-assembly will reduce the skills shortage in construction					
6.4	Construction clients prefer traditional construction methods instead of prefabrication and preassembly					
9.5	Prefabrication / pre-assembly or precast reduce material wastage on site					
9.6	Construction clients are not informed about the benefits of prefabricated/ preassembled or precast					
97	Designers are aware of the potential benefits of prefabrication and/or pre-assembly relative to worker health and safety					
9.8	Clients tend to focus mostly on time, quality and cost instead of worker health and safety					
9.9	Lack of knowledge by designers leads to resistance to the use of alternative construction methods such as prefabrication and/or pre-assembly					
910	The use of prefabricated /pre-assembled or precast will create employment opportunities					
9.11	Public sector contracts encourages the use of prefabrication within the construction industry in South Africa					
9.12	Designers rarely propose the use of prefabrication and/or pre-assembly to clients in their design					
9.13	The use of prefabricated /pre-assembled or precast will change the structure of the industry					

SECTION B: Measurements of health and safety improvements by prefabrication and preassembly

10. When comparing the traditional/in-situ construction process to the prefabricated process to what extent does each expose workers to hazards?

Traditional	0 %	10 %	20%	30%	40%	50%	60%	70%	80%	90%	100%
Prefabricated	0 %	10 %	20%	30%	40%	50%	60%	70%	80%	90%	100%

11. To what extent do you agree with the following statements where **1= strongly disagree (SD), 2= Disagree (D), 3=Neutral (N), 4=Agree (A) and 5=Strongly agree (SA).**

		SD	D	N	A	SA
	Statement	1	2	3	4	5
11.1	The use of prefabrication and/or pre-assembly will reduce the exposure of workers to steel reinforcement hazards					
11.2	The use of prefabrication and/or pre-assembly will reduce the need for formwork					
11.3	Reduction of construction activities through prefabrication will reduce health and safety threats associated with confined spaces on site					
11.4	Prefabrication and/or pre-assembly reduces the exposure of workers to chemical hazards on site					
11.5	The use of prefabrication and/or pre-assembly will reduce construction falls by reducing working at height related activities					
11.6	The use of prefabrication and/or pre-assembly will reduce the need for scaffolding					
11.7	The use of prefabrication and/or pre-assembly will reduce the prospect of contract demartitis					

12. The following statements require your opinion relative to the impact of prefabrication and/or pre-assembly on health and safety. Please indicate your level of agreement with the statements on a 5-point scale where **1= strongly disagree (SD), 2= Disagree (D), 3=Neutral (N), 4=Agree (A) and 5=Strongly agree (SA).**

		SD	D	N	A	SA
	Statement	1	2	3	4	5
10.1	Increasing the number of workers on a project site potentially leads to difficulties in managing construction worker health and safety					
10.2	Off-site construction processes reduce the risks associated with on-site construction methods					
10.3	Prefabrication and/or pre-assembly reduces hazards related to material handling activities on site					
10.4	Quality is improved through the use of prefabrication and/or preassembly					
10.5	Prefabrication and/or pre-assembly reduces the exposure of workers to health and safety risks					
10.6	Reduction of labour through prefabrication will lead to improvement of health and safety on site					
10.7	The use of prefabrication and/or pre-assembly will lead to improvement of construction health and safety performance					
10.8	The use of prefabrication and/or pre-assembly will reduce ergonomic hazards on site					
10.9	Off-site construction processes reduce environmental hazards					
10.10	Labour intensive projects expose construction workers to physically demanding activities that pose risks to their health and safety					

APPENDIX D: CONSTRUCTION CLIENT QUESTIONNAIRE

This research study seeks to investigate the impact of prefabrication and pre-assembly on construction health and safety in South Africa.

You are invited to participate in this study by completing this questionnaire as fully and as accurately as possible.

Please Luviwe Bikitsha, return via:
Fax: +27 21 959 6870
E-mail: luviwe.b23@gmail.com
Mobile: +27 73 742 8210, +27 21 959 6317

SECTION A: Client perceptions about prefabrication and preassembly in construction industry

1. Which of the following best describes your organization?

No	*Company description*	*Tick only one box*
1.1	Public Sector Client	
1.2	Private Sector Client	

2. How long have you been active in the construction industry? ……years

3. Which party should be responsible for selecting the construction method on projects?
Please tick ONLY one box below.

No	**Company description**	
3.1	Designers	
3.2	Clients	
3.3	Contractors	

4. How many of your projects have involved prefabricated/ preassembled or precast components?

0 %	10 %	20%	30%	40%	50%	60%	70%	80%	90%	100%

5. What were the benefits?

Cost reduction	
Increased productivity	
Improved H&S	
Other, specify below	

____

____

6. In cases where you considered the use of prefabrication / pre-assembly or precast what were the factors that influenced that consideration?

____

____

7. In cases where you resisted the use of prefabrication / pre-assembly or precast construction what were the reasons for this resistance?

____

____

8. In your own opinion, to what extent do construction clients and designers recognize the benefits associated with the use of prefabricated/ preassembled or precast construction?

0 %	10 %	20%	30%	40%	50%	60%	70%	80%	90%	100%

9. The following statements refer to the use of prefabrication / or precast pre-assembly. Please indicate your level of agreement with these statements on a 5-point scale where **1= strongly disagree (SD), 2= Disagree (D), 3=Neutral (N), 4=Agree (A) and 5=Strongly agree (SA)**

		SD	D	N	A	SA
	Statement	1	2	3	4	5
9.1	Prefabrication and/or pre-assembly leads to a reduction of labor on site					
9.2	Lack of knowledge by designers leads to resistance to the use of alternative construction methods such as prefabrication and/or pre-assembly					
9.3	The use of prefabricated /pre-assembled or precast will change the structure of the industry					
6.4	Designers do not consider prefabrication and/or pre-assembly because they are unfamiliar with this method of construction					
9.5	Construction clients prefer traditional construction methods instead of prefabrication and preassembly					
9.6	Prefabrication / pre-assembly or precast reduce material wastage on site					
97	Public sector contracts encourages the use of prefabrication within the construction industry in South Africa					
9.8	Designers do not have enough knowledge about prefabrication to propose it to clients as an alternative					
9.9	Designers rarely propose the use of prefabrication and/or pre-assembly to clients in their design					
910	The use of prefabricated and/or pre-assembed or precast construction will improve the overall performance of the construction in terms of cost, time and health and safety					
9.11	The use of prefabrication and/or pre-assembly will reduce the skills shortage in construction					
9.12	Designers do not consider worker health and safety in their designs					
9.13	Designers are aware of the potential benefits of prefabrication and/or pre-assembly relative to worker health and safety					
914	Construction clients are not informed about the benefits of prefabricated/ preassembled or precast					
9.15	The use of prefabricated /pre-assembled or precast will create employment opportunities					

SECTION B: Measurements of health and safety improvements by prefabrication and preassembly

10. When comparing the traditional/in-situ construction process to the prefabricated process to what extent does each expose workers to hazards?

Traditional	0 %	10 %	20%	30%	40%	50%	60%	70%	80%	90%	100%
Prefabricated	0 %	10 %	20%	30%	40%	50%	60%	70%	80%	90%	100%

11. To what extent do you agree with the following statements where **1= strongly disagree (SD), 2= Disagree (D), 3=Neutral (N), 4=Agree (A) and 5=Strongly agree (SA).**

		SD	D	N	A	SA
	Statement	1	2	3	4	5
11.1	The use of prefabrication and/or pre-assembly will reduce the exposure of workers to steel reinforcement hazards					
11.2	The use of prefabrication and/or pre-assembly will reduce the need for formwork					
11.3	Reduction of construction activities through prefabrication will reduce health and safety threats associated with confined spaces on site					
11.4	Prefabrication and/or pre-assembly reduces the exposure of workers to chemical hazards on site					
11.5	The use of prefabrication and/or pre-assembly will reduce construction falls by reducing working at height related activities					
11.6	The use of prefabrication and/or pre-assembly will reduce the need for scaffolding					
11.7	The use of prefabrication and/or pre-assembly will reduce the prospect of contract demartitis					

12. The following statements require your opinion relative to the impact of prefabrication and/or pre-assembly on health and safety. Please indicate your level of agreement with the statements on a 5-point scale where **1= strongly disagree (SD), 2= Disagree (D), 3=Neutral (N), 4=Agree (A) and 5=Strongly agree (SA).**

		SD	D	N	A	SA
	Statement	1	2	3	4	5
10.1	Increasing the number of workers on a project site potentially leads to difficulties in managing construction worker health and safety					
10.2	Off-site construction processes reduce the risks associated with on-site construction methods					
10.3	Prefabrication and/or pre-assembly reduces hazards related to material handling activities on site					
10.4	Quality is improved through the use of prefabrication and/or preassembly					
10.5	Prefabrication and/or pre-assembly reduces the exposure of workers to health and safety risks					
10.6	Reduction of labour through prefabrication will lead to improvement of health and safety on site					
10.7	The use of prefabrication and/or pre-assembly will lead to improvement of construction health and safety performance					
10.8	The use of prefabrication and/or pre-assembly will reduce ergonomic hazards on site					
10.9	Off-site construction processes reduce environmental hazards					
10.10	Labour intensive projects expose construction workers to physically demanding activities that pose risks to their health and safety					

APPENDIX E: WORKER INTERVIEW QUESTIONS

This research study seeks to investigate the impact of prefabrication and pre-assembly on construction health and safety in South Africa.

You are invited to participate in this study by completing this questionnaire as fully and as accurately as possible.

Please Luviwe Bikitsha, return via:
Fax: +27 21 959 6870
E-mail: luviwe.b23@gmail.com
Mobile: +27 73 742 8210, +27 21 959 6317

SECTION A: Impact of traditional construction method activities on health and safety of workers

1. Which of the following best describes your trade?

No	Trade	Tick only one box
1.1	General worker	
1.2	Carpenter	
1.3	Bricklayer	
1.4	Roofer	
1.5	Painter	
1.6	Plasterer	
1.7	Steel fixers	
1.8	Other, specify below	
1.9	Tiler	
1.10	Floor layer	
1.11	Operator/semi-skilled	

2. How long have you worked in the construction industry? ......years........months

3. Have you experienced any of physical health problems listed below while you were involved in construction site activities?

No	Health problems	Yes	No
3.1	Backache		
3.2	Wrist pains		
3.3	Shoulder pains		
3.4	Headaches		
3.5	Skin problems		
3.6	Muscle and joint pains		
3.7	Bones problems		
3.8	Lungs problems (Cough)		
3.9	Waist problems		
3.10	Other, specify below		

____

4. From your personal experience, how frequently are you involved on the following activities on site?

No	Instruction	Never	Seldom	Sometimes	Often	Always
4.1	Working in awkward posture					
4.2	Height related activities					
4.3	Manual handling of heavy material					
4.4	Noise caused by construction material					
4.5	Bending and twisting body while working					
4.6	Working in same place for a long time					
4.7	Vibrating equipments					
4.8	*Hazardous materials*					

5. Do you sometimes feel like changing jobs because of the physical workload you perform at work? Please tick yes or no.

Yes ☐ No ☐

SECTION B: Measurements of health and safety improvement by prefabrication

6. Have you been involved in any construction project where prefabricated/ preassembled or precast components were adopted?

Yes ☐ No ☐

7. Have you experienced any of physical health problems listed below while you were involved in the erection of prefabricated/ preassembled or precast components?

No	Health problems	Yes	No
3.1	Backache		
3.2	Wrist pains		
3.3	Shoulder pains		
3.4	Headaches		
3.5	Skin problems		
3.6	Muscle and joint pains		
3.7	Bones problems		
3.8	Lungs problems (Cough)		
3.9	Waist problems		
3.10	Other, specify below		

8. Based on your experience, indicate whether each of the following statements are true or not.

No	Statement	Yes	No	Unsure
11.1	Prefabrication / pre-assembly or precast reduces hazards related to material handling activities on site			
11.2	When work is done offsite large amount of noise is reduced on site			
11.3	Doing more work offsite would lead to reduction of many health and safety risks on site			
11.4	Prefabrication / pre-assembly or precast reduces heavy manual handling hazards			
11.5	Reducing a need for scaffolding by prefabricated /pre-assembly or precast components would lead to less falls on sites			

APPENDIX F: ACTIVITY OBSERVATIONS OF WORKERS IN THE CONSTRUCTION INDUSTRY

Activity: ____________________ **Date:** ____________________ **Observer:** ____________________

Site location: ____________________ **Start time:** ____________________ **Stop time:** ____________________

Level of Employment		
Artisan	Operator	General worker

(Circle the Level of Employment)

	Activity	Observations/5 minute intervals																								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1.																										
2.																										
3.																										
4.																										
5.																										
7.																										
8.																										
9.																										
10.																										

Sheet Number: ____________________

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