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Mitigating Ergonomic Risk Factors in Labour-intensive Construction.

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Research report submitted in fulfilment of the BUQS7027 course and part fulfilment of the degree Master of Science in building at the School of Construction Economics and Management at Wits University

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Declaration

I, Marius Meintjes hereby declare, that this research and report is entirely my own work, under the supervision of Prof. David Root. The research was done during the BUQS 7027 module and it was submitted in completion of the Master of Science in Building degree at the University of Witwatersrand, Johannesburg.

_____ _____

Signed Dated

Abstract

South Africa has introduced a programme to help aid job creation and skills transfer. This programme is called the Extended Public Works Programme (EPWP), which requires a projected utilisation of labour-intensive construction for certain aspects of the projects. This programme can typically be seen implemented on road construction projects, particularly in rural areas. Although the programme has many positive attributes, labour-intensive construction increases the risk of workers developing muscoskeletal disorders (MSD) if ergonomic risk factors (ERFs) are not mitigated at the design stage.

Current legislation broadly addresses Ergonomics and states that the Designer has a responsibility of designing a project that does not place the health and safety (H&S) of workers at risk. However, a new Ergonomic regulation (awaiting promulgation) will place the onus on Designers to ensure that their projects are ergonomically sound. The issue being that most Designers have a lack of knowledge in terms of what Ergonomics entails, as this was not covered in detail during tertiary education and with no continuous professional development (CPD) courses available on this topic.

The research conducted aimed to explore to what extent Designers are currently implementing Ergonomic principles in their designs, and where they acquired the knowledge, if not at tertiary institutions, perhaps through continuous professional development courses, minimally addressing Ergonomics as part of H&S due diligence. The research had a single method approach that collected qualitative data by means of semi-structured interviews. The sample group consisted of Civil Engineers with road construction experience around the Gauteng Province.

Whilst only 9 participants were interviewed, a clear trend emerged that Ergonomics was not applied to designs of labour-intensive projects for the construction phase of the projects undertaken. Where Ergonomics was applied, it was consequence of direct experience. For Designers to comply with current and future Ergonomic legislation, as well as protect the workforce's H&S, they should undergo rigorous training in Ergonomic principles and how to incorporate it into their designs.

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I would like to thank Professor David Root for his insightful guidance and direction during this course. My mother, Anneli, who has imbedded in my character the concept of always reaching for the stars, and her devoted support throughout all my endeavours. Karien Coetzee for helping me find participants to interview, and Lawrence Tearle for his support and advice throughout this course. To my wife, Berenice Meintjes, thank you for keeping me motivated and on track. Thank you for your sacrifice of time without me, commitment to, and acceptance of me doing my Masters. Lastly, but most importantly, I would like to thank God for the opportunity to be able to do my second Master's degree, and that His grace shines down upon me. Without God and His unconditional love, none of this would be possible.

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Acronyms and Abbreviations

CIDB	Construction Industry Development Board
CPD	Continuous Professional Development
EPWP	Extended Public Works Programme
ERF	Ergonomic Risk Factor(s)
HAV	Hand Arm Vibration
H&S	Health and Safety
LIC	Labour-intensive Construction
MSD	Musculoskeletal Disorder(s)
OHSAct	Occupational Health and Safety Act, 85 of 1993.
WBV	Whole Body Vibration

1. Introduction

Health and Safety (H&S) plays an increasingly important role in the construction phase of projects. H&S is governed by laws and regulations stipulated in the OHSAct (Occupational Health and Safety Act 85 of 1993) and the Construction Regulations 2014. The OHSAct and Regulations set out roles and responsibilities of parties involved, and what actions are required or condemned. H&S is a discipline with many aspects to ensure the safety and wellbeing of employees performing their tasks. One of the important aspects to ensure H&S is to provide a working environment that suits the employee, known as Ergonomics.

Studies by Smallwood (2017) and Haupt and Pillay (2016) have found that Designers currently underestimate the importance of Ergonomics during the construction phase of projects. Smallwood (2017) suggested that Designers perceive traditional project parameters (such as time, cost and quality) more important than project H&S (particularly construction Ergonomics). Haupt and Pillay (2016) agreed and added that Designers would be more interested to focus on construction H&S in their designs if they can comprehend the cost saving ability of reducing H&S hazards and risks during the construction phase. How Designers perceive Ergonomics may be directly related to the lack of ergonomic knowledge and designing projects with the end user at mind rather than the employees responsible for the construction activities (Smallwood, 2015).

The lack of Ergonomic knowledge originates at tertiary education level where students are not adequately educated on Ergonomic principles (Ek et al., 2015; Naeinia and Mosaddad, 2013). The study by Smallwood (2017) concluded that the source of Ergonomic knowledge was more informal (such as experience) than formal. Although this may not be true in the case of every tertiary education institution or every civil engineer, an evaluation of the civil engineering curricula at four (4) major South African universities revealed that current courses do not include a module on Ergonomics.

Therefore, it is important to establish to what extent Designers implement Ergonomics in their designs, particularly in a labour-intensive setting.

1.1 Problem Statement

Currently Designers underestimate the importance of Ergonomics (Smallwood, 2017; Haupt and Pillay, 2016). Studies by Ek et al. (2015) and Naeinia and Mosaddad (2013) found that Designers have a lack in knowledge with regards to Ergonomic principles and, as evident from civil engineering courses at various universities, limited means to acquire the much-needed knowledge. However, Designers are still legally obligated to mitigate Ergonomic risk factors in terms of the Occupational Health and Safety Act 85 of 1993 and Construction Regulations 2014, of South Africa.

1.2 Primary Research Questions

The research was primarily undertaken to answer the following specific question:

To what extent do Civil Engineers address Ergonomics during labour-intensive construction projects in South Africa?

1.3 Secondary Research Questions

From the problem statement, the following secondary questions were identified:

1. What depth of knowledge do civil engineers have on Ergonomics?

2. How was ergonomic knowledge acquired amongst civil engineers?

3. Were civil engineers familiar with all applicable health and safety legislation?

1.4 Research Aims and Objectives

1.4.1 Research Aims

To determine the extent Civil Engineers address Ergonomics of labour-intensive construction projects in South Africa.

1.4.2 Research Objectives

From the aim, the following research objectives are identified:

- To ascertain the extent which Ergonomics is covered in Civil Engineering curricula and where Civil Engineers gained Ergonomic knowledge, if not at tertiary level.
- To establish common Ergonomic problems encountered on road construction projects and identify what was done about it.

- To determine whether Civils Engineers are competent to perform their duties as Designers, as set out in the OHSAct and Construction Regulations with regards to Ergonomics.

1.5 Research Design and Methodology

A literature review was conducted on Ergonomical designs in a labour-intensive setting, as well as the effects and consequences of not applying Ergonomical principles to designs.

A limited amount of literature was available on Ergonomical designs in labour-intensive road construction (LIC). Therefore, the review was extended to include studies about Designers' education in terms of Ergonomics, how they perceive Ergonomics, benefits of designing with H&S in mind, and general Ergonomic principles. The aim was to understand the knowledge available, and subsequently provide a starting point for the exploratory semi-structured interviews.

The research followed a phenomenological approach, which is a strand of interpretivism, in order to illustrate the participants' experiences and opinions with regards to Ergonomics in a labour-intensive setting. The research made use of a mono-method design (qualitative research), where data was collected using exploratory semi-structured interviews. Questions where based on topics found in the literature review with regards to Ergonomical design. The data was then coded according to common elements in the participants' answers. The detailed justification for the chosen method is provided under Chapter 3 of this Report.

1.6 Ethical Considerations

The nature of this research required data to be collected from individuals, who form part of organisations. This requires a certain degree of ethical consideration when approaching these organisations and the respective individuals. The University issued an ethics clearance certificate that was presented to the participants. This assured participants that the research was authentic and that the data collected was to be used for academic purposes.

In addition, consent forms were issued to willing participants to provide details on the research subject as well to get their consent to participate on the research.

1.7 Limitations and Constraints

As stated, the research is for academic purposes, and was carried out within a South African context. This therefore means that it was limited to the concept of LIC within a South African

environment, whilst the literature reviewed was global. This report was compiled for academic purposes only, to help define Ergonomics and how it can benefit project design at the onset. How well Ergonomics is understood and applied within the various Countries for which literature was reviewed, was not taken into consideration or viewed as a factor for the purposes of this study.

Time was a limiting factor in conducting the research, due to it being for academic purposes, the data used for the study is based on the amount of data that was collected in the limited period prescribed for the study. The research was also limited by the budget available in carrying out the interviews across the country, hence only the Gauteng Province was targeted for the interviews. The limitations and constraints are further detailed in Chapter 3 of this report.

1.8 Assumptions

The following assumptions were made for the purpose of the research:

- The underlying assumption is that H&S (particularly Ergonomics) in the construction industry will continue to play a critical role in projects.
- It will remain the Designer's lawful obligation to mitigate ERFs.
- The absence of Ergonomic design results in MSDs.
- Projects in rural areas must adhere to the EPWP to include LIC

1.9 Structure of the Research Report

Chapter 1 - Introduction: This chapter introduces the problem statement, the aim and objectives of the research, the research question, research design and method, ethical considerations, limitations, assumptions as well as the summary of the Report structure.

Chapter 2 – Literature Review: This chapter discusses the current knowledge in literature regarding prevention of ergonomic risk factors through design in the construction industry. The researcher used the key body of knowledged in order to support why the proposed research was undertaken, as well as to support the research problem/question stated in Chapter 1.

Chapter 3 – Research: This chapter discusses how the research was undertaken with regards to the research philosophy, research design, the research methods used in data collection, the ethical considerations, limitations and conclusions.

Chapter 4 – Interview Results: This chapter reflects the information gathered during the interviewing process to the data analysis to establish whether it answers the research question. It should be noted that this chapter simply deals with how questions associated with the research were answered and not who answered in line with the ethical considerations.

Chapter 5 – Data Analysis: This chapter gives a summary of the findings based on the analysis done on information presented in Chapter 4.

Chapter 6 - Conclusion and recommendations: This chapter provides an indication of whether the research question was answered, as well as what lessons or recommendations the researcher placed on the table in relation to the research problem.

2. Literature Review

The literature review aims to establish the context of occupational injuries in South Africa. Then it contextualises what labour-intensive construction (LIC) is, as a general philosophy, before investigating its use in South Africa through the expanded public works programme (EPWP). Lastly it looks at the legislative requirements with regards to designing labour-intensive projects, before investigating Ergonomic principles and evaluating if Designers are equipped with the necessary knowledge and experience to face these challenges and requirements.

2.1 Context of Occupation Injuries

The construction industry is known for the significant number of fatalities, injuries and / or diseases caused during the execution of construction activities (Smallwood, 2015). Technology and mechanisation have significantly reduced the risk of accidents and injuries in the construction industry, e.g. implementation of pedestrian detection systems and reducing the physical load among roadworkers by means of machinery (Burdorf et al., 2007; Teizer et al., 2010). Additionally, the Occupational Health and Safety Act 85 of 1993 (OHSAct), together with the Construction Regulations 2014, was promulgated as a mitigation instrument by government to prevent and avoid occupational injuries and illness. This creates an environment where employers, engineers, designers and even employees can be held accountable for their decisions and actions with regards to the H&S of workers. According to the Department of Labour's annual reports form 2003 until 2017:

- There was a significant overall downward trend in the number of incidents only requiring medical attention for the prescribed period.
- There was a significant overall downward trend in the number of temporary total disablement until 2011. Since 2011 the trend of temporary total disablement incidents levelled out.
- There was no significant change in permanent disablement and fatal incidents numbers for the prescribed period.

Baxendale and Jones (2000) explain that a company which operates a comprehensive H&S management system that enforces duties under the OHSAct and Regulations should be able to comply with any future safety directives that are required. The downward trend in incident

rates validate that H&S management, technology, mechanisation and legislation all contribute to the reduction of occupational related injuries.

2.2 Labour-intensive Construction

Essentially labour-intensive activities refer to workplace activities that require human force to execute (such a lifting, lowering, pushing or pulling). Therefore, labour-intensive construction refers to construction activities conducted primarily with manpower and supported by plant and equipment only where labour cannot feasibly conduct the activity (McCutcheon, 2017; Twala, 2007; Department of Public Works, 2015). However, there is an economical aspect to LIC as well. Economically the term is used to describe an operation that employs as great a proportion of labour as is technically feasible in order to construction within the boundaries of the specifications and the funding available (McCutcheon, 2008a).

McCutcheon (2017) goes further to state that modern labour-intensive construction has two main objectives:

- Good quality, economically efficient product: equivalent to conventional construction without compromising on economic cost, time and quality; and
- An increase in the use of labour per unit of expenditure.

Many governments of upper middle-income countries are facing extremely high level of unemployment which accompanies poverty, refer to Table 1 (Worldbank, 2020). In light of the high unemployment rate, a strong economic case exists for the generation of employment opportunities (Nattrass and Seekings, 2015; McCutcheon, 2008). Nattrass and Seekings (2015) explained that a country with a low employment rate (or alternatively a high unemployment rate) is not fully utilising its available human resources.

Therefore, the construction industry and the maintenance thereof, as well as public works sector, are particularly under pressure to create employment opportunities in both urban (water supply, sewerage reticulation and treatment, stormwater drainage, streets, electrical supply and waste disposal) and rural (dams, irrigation canals and roads) areas (McCutcheon, 2008a).

Table 1. Unemployment Percentages (%) of Upper Middle-income Countries

Country Name	2015	2016	2017	2018	2019
Albania	17.08	15.22	13.75	13.90	13.96
Algeria	11.21	10.20	12.00	12.15	12.35
Argentina	7.64	8.02	8.35	9.48	9.98
Armenia	18.26	17.62	17.83	17.71	17.71
Azerbaijan	4.96	5.00	5.00	5.22	5.40
Belarus	5.91	5.84	5.65	5.71	5.80
Belize	9.97	7.91	9.00	9.37	9.50
Bosnia and Herzegovina	27.65	25.41	20.47	20.84	21.22
Botswana	17.96	17.95	17.63	17.94	18.19
Brazil	8.44	11.61	12.83	12.54	12.22
Bulgaria	9.14	7.57	6.16	5.26	4.82
China	4.60	4.50	4.40	4.42	4.42
Colombia	8.30	8.69	8.87	9.09	9.19
Costa Rica	9.00	8.60	8.14	8.13	8.19
Cuba	2.40	2.36	2.28	2.26	2.25
Ecuador	3.62	4.60	3.84	3.91	3.98
Equatorial Guinea	8.91	9.28	9.15	9.16	9.21
Fiji	4.55	4.32	4.14	4.15	4.15
Gabon	19.99	19.63	19.37	19.49	19.61
Georgia	14.08	13.97	13.93	14.11	14.25
Guatemala	2.51	2.83	2.68	2.73	2.75
Guyana	12.55	12.34	12.11	12.15	12.22
Iran, Islamic Rep.	11.06	12.43	12.10	11.99	11.99
Iraq	8.08	8.09	7.89	7.93	7.91
Jamaica	13.51	13.19	11.66	9.44	9.52
Jordan	13.07	15.27	14.88	15.02	14.94
Kazakhstan	4.93	4.96	4.90	4.89	5.43
Lebanon	6.23	6.26	6.11	6.17	6.20
Libya	16.09	16.24	17.12	17.29	17.30
Malaysia	3.10	3.44	3.41	3.36	3.40
Maldives	5.68	6.12	5.83	6.07	6.40
Mauritius	7.41	6.81	6.75	6.87	6.87
Mexico	4.31	3.86	3.42	3.32	3.38
Montenegro	17.54	17.72	16.07	15.46	15.78
Namibia	20.83	23.35	23.09	23.09	23.19
North Macedonia	26.07	23.72	22.38	21.55	21.58
Paraguay	4.56	5.26	4.61	4.71	4.68

Peru	3.00	3.54	3.46	2.84	2.90
Romania	6.81	5.90	4.93	4.30	4.16
Russian Federation	5.57	5.56	5.21	4.74	4.55
Samoa	8.62	8.61	8.32	8.32	8.46
Serbia	17.92	15.26	13.48	13.51	13.51
South Africa	25.16	26.55	27.33	26.96	27.32
Sri Lanka	4.67	4.37	4.18	4.40	4.32
St. Lucia	24.09	21.26	20.79	20.87	20.47
St. Vincent and the Grenadines	20.20	20.07	19.73	19.76	19.71
Suriname	7.22	7.29	7.60	7.63	7.41
Thailand	0.60	0.69	0.63	0.67	0.69
Tonga	1.08	1.05	1.00	1.03	1.02
Turkey	10.24	10.84	10.82	10.90	11.90
Turkmenistan	3.84	3.80	3.69	3.78	3.85
Venezuela, RB	6.82	7.46	7.42	8.36	9.08
Dominican Republic	7.61	7.28	5.83	5.83	5.83

Information sourced from Worldbank (2020).

Construction, as a rule of thumb, is a labour-intensive industry. It is only the degree thereof that varies from sector to sector, project to project and country to country. The guide to best practice of the CIDB (2005) agreed that construction is inherently labour-intensive (referred to as "employment-intensive"), but highlights that LIC had been highly utilised in the civil engineering sector. In spite of the fact that the civil engineering sector is pressured to make use of more labour-intensive methods, conventionally it is significantly more plant-intensive when compared to the building sector. The CIDB (2005) based the previous statement on the fraction of employment opportunities per unit of expenditure within each sector. In other words, the building sector generally assigns more of a project's finances to labour when compared to the civil engineering sector. However, the inverse is true when labour is substituted for machines in the civil engineering sector (CIDB, 2005; McCutcheon, 2008a).

Since 1974, several sub-Saharan Africa countries have addressed factors contributing to the high unemployment rate by means of large-scale, long-term programmes of labour-intensive rural road construction (McCutcheon, 2008a). During this time the World Bank and the International Labour Organisation provided an intellectual framework for the implementation of these programmes, which resulted in the generation of productive employment throughout the decades and thousands of kilometres of rural road construction and maintenance (McCutcheon, 2008a).

The guide to best practice of the CIDB (2005) acknowledges that, within South African context, the construction of roads is particularly prone to LIC, which includes rural gravel roads, low level bridges and residential township roads. LIC can also be implemented during road maintenance activities, which may include regravelling and routine maintenance. The guide to best practice of the CIDB (2005) encourages the use of LIC as research has shown that labour-intensive practices are not significantly more expensive when compared to capital-intensive methods. It is easy to see why developing countries, as a matter of policy, encourage LIC, particularly when the overall increase in employment opportunities for a given project (compared to conventional plant-based practices) may increase twofold in urban infrastructure and may be three times higher in rural road construction (CIDB, 2005; McCutcheon, 2008b). Not only does LIC create employment opportunities, but offers the potential for skills development (McCutcheon, 2017).

Importantly, McCutcheon (2008b) mentions that there are basic principles to follow to ensure successful implementation of LIC programmes. In essence the project or programme must be implemented as a long-term process and not as short-term emergency relief. Proper engineering around LIC, such as appropriate choice of product and associated contract documents, is required. The programme's work must be done under the supervision of competent site supervisors. The research suggests that greater use of productive labour must be the "design driver" to ensure success of a LIC project. If the projects are well designed and implemented, labour-intensive construction methods do not compromise time, cost or quality (McCutcheon, 2008b).

However, when designing for labour-intensive construction projects, it is important that the H&S of employees are not compromised (Twala, 2007). It is important to keep in mind that LIC requires construction workers to often exceed their natural physical capability in order to meet the increasing demand and challenges of construction work (Nath et al., 2017*).*

2.3 The Expanded Public Works Programme

As a result of the socio-economic status of South Africa, where the unemployment rate was estimated at 27.1% (Statistics South Africa, 2018) and the majority of the unemployed are unskilled, the South African construction industry is encouraged to use labour-intensive construction techniques which is planned to increase economic growth, skills transfer and training (Department of Public Works, 2015; Musekene, 2013). Therefore, in an attempt to alleviate unemployment, the South African government has implemented a programme known

as the Expanded Public Works Programme (EPWP) and is defined by the Department of Public Works (2015) as follows:

"*EPWP is one of government's medium-to-long term programmes aimed at alleviating poverty and reducing unemployment. The EPWP will achieve this aim through the provision of work opportunities coupled with project-based training. It is a national programme covering all spheres of government and state-owned enterprises. The programme spans four Sectors comprising Infrastructure, Social, Non-State and Environment and Culture."*

The EPWP Infrastructure Guidelines require the public body to implement EPWP projects in the following types of infrastructure (Department of Public Works, 2015):

- Roads;
- Sidewalks and non-motorised transport infrastructure;
- Storm water drainage;
- Water and sanitation;
- Buildings;
- Landscaping; and
- Electricity.

With regards to road construction, the following activities should be conducted by means of labour-intensive methods (Department of Public Works, 2015):

- Site clearance.
- Layer work construction/maintenance including loading, hauling and spreading of material.

The Department of Public Works (2015) added that any compaction work should be done by conventional equipment and heavy machinery may be used to loosen material for excavation by hand.

2.4 Design Requirements

According to Section 10 of the OHSAct and Regulation 6 of the Construction Regulations, Designers are liable for the impact of their design on construction H&S (Republic of South Africa, 2017; Republic of South Africa, 1993).

Current regulations in terms of injury and disease prevention caused by exposure to ergonomic stressors are ill-defined. Therefore, Government decided to develop the Ergonomics Regulations under the OHSAct. The draft Ergonomic Regulations are more explicit on the matter, stating that Designers and Manufacturers have the duty and responsibility to:

"*Eliminate ergonomic risk factors at the design stage or, where this is not reasonably practicable, minimise ergonomic risk factors that workers may be exposed to during performance of their tasks*" (Republic of South Africa, 2017).

This expectation is supported by literature which provides substantial evidence that up to 50% of incidents/accidents can be avoided through hazards and risks mitigation by means of design (Goldwain and Smallwood, 2015).

Many non-fatal injuries are related to labour-intensive construction due to factors collectively called ERFs such as lifting, bending and twisting, repetitive motions, and heavy material handling. Continuous exposure to these factors may result in Ergonomic injuries. The most common Ergonomic injury is musculoskeletal disorders (MSDs), which adversely affects the health of employees as a result of continuous/repetitive exposure (Ahankoob and Charehzehi, 2013).

Although little research has been done on the presence of ERFs during Civil Engineering projects in the setting of LIC, it is a key problem in construction. When not designed with Ergonomic principles at mind, LIC is likely to increase the rate and severity of Ergonomic injuries on construction sites. This is due to the increased workload on construction workers and the absences of risk mitigating technology installed in machinery. For Laryea (2011) the quality of tender information provided by design teams is poor, and they identified 'completeness of tender documents' as a significant factor affecting mark-up in a questionnaire study of 29 US contractors.

2.5 Ergonomics

The term Ergonomics was derived from two Greek words, namely "ergon" which translates to work and "nomos" which translates to laws (Scott, Kogi and McPhee, 2010). The science of Ergonomics is defined as adapting the physical working environment to the physiological and psychological needs, capabilities and limitations of a worker, by considering different disciplines that may have an influence on the worker / working environment interaction (such as anatomy, engineering, physiology and psychology) (Ahankoob and Charehzehi, 2013).

Simply put, Ergonomics is applied to engineer a working environment that is appropriate to the worker instead of forcing the worker into an inappropriate working environment (Naeinia and Mosaddad, 2013). By applying Ergonomics to the working environment, obstacles will be eliminated to improve quality, productivity and worker performance (Ahankoob and Charehzehi, 2013). Naeinia and Mosaddad (2013) added that Ergonomics and economics are connected in a sense that lower human error and a safer working environment allows for better working conditions.

Ergonomics can be divided into three primary domains, namely: 1. Physical Ergonomics; 2. Cognitive Ergonomics; and 3. Organisational Ergonomics. However, all these disciplines are connected and influence each other (Pazell et al., 2015). Scott, Kogi and McPhee (2010) aided in distinguishing these domains from each other and are identified as follows:

- ***Physical Ergonomics:*** Physical Ergonomics is concerned with characteristics that relate to physical activities, such as anatomical, physiological, anthropometric and biomechanical activity. Some topics include vibration, heavy work, working postures and repetitive movements.
- ***Cognitive Ergonomics:*** Cognitive Ergonomics is concerned with processes that require mental input, such as memory, perception, reasoning and motor response to interact with the environment or amongst humans. Some topics include human error, mental workload, training and decision making.
- ***Organisational Ergonomics:*** Organisational Ergonomics is concerned with socio-technical systems and how to optimise them, such as organisational structures, processes and policies. Some topics include human resource management, design of work schedule, communication, teamwork and quality management.

Pazell et al. (2015) explained that Ergonomics is in its essence a Design profession. They added that the involvement of workers, operators and maintainers are crucial to proper Ergonomic design. This collaboration is known as participatory Ergonomics.

Participatory Ergonomics ensure that everyone who is affected by the design is involved in the process of analysing the work and work demand, identification of hazards, evaluating the risks, identifying intervention priorities, development of controls and monitoring the effectiveness of the implemented controls (Pazell et al., 2015). It is important for the Designer to be competent in ergonomic design. Goldswain and Smallwood (2015) agreed with the statement and added

that a crucial element of designing for construction H&S (which includes Ergonomics) is the ability of Designers to be able to undertake hazard identification and risk assessments (HIRAs) during the design process. These skills will enable Designers to apply risk control mechanisms to mitigate such hazards and ERFs.

2.6 Ergonomic Risk Factors (ERFs)

There are various ERFs that are common to construction sites, each different to the specific task, equipment or tools used in construction activities (Ahankoob and Charehzehi, 2013). Ergonomic risk factor may cause injuries immediately or have a long latent period before affecting a person's health. Combining Ahankoob and Charehzehi (2013); Choi, Yuan and Borchardt (2016); Wang et al. (2015); Jaffar et al. (2011) and the Department of Employment and Industrial Relations (2007), ERFs consist of the following:

- Awkward posture
- Static posture
- Repetition
- Vibration
- Force / forceful exertions
- Contact stress
- Extreme temperature
- Duration

2.6.1 Awkward Posture

Awkward postures refer to an unnatural position of the body which results in the shorting or stretching of the connective or nervous tissues when raising the arms above the head or bending the back and wrists. These activities cause a reduction in muscle function capacity which increases the risk of injury. It is important to note that awkward postures are not intrinsically harmful, it is however harmful when conducted repetitively or over a long period of time (Ahankoob and Charehzehi, 2013; Jaffar et al., 2011; Department of Employment and Industrial Relations, 2007).

2.6.2 Static Posture

Static posture refers to a body (part or whole body) in one position over a long period of time. Blood flow to muscles are reduced when there is a lack of movement which causes the muscle

to fatigue and in turn increases the risk of injury (Department of Employment and Industrial Relations, 2007).

2.6.3 Repetition

Repetition is continuously using the same muscles to produce the same movement. Risk of injury is increased during short work cycles (the time it takes to complete the task without interruption) that are performed for longer than an hour. Injury occurs because of muscle overuse (Wang et al., 2016; Jaffar et al., 2011; Department of Employment and Industrial Relations, 2007).

2.6.4 Vibration

Vibration is defined as any movement the body makes around a fixed point (Jaffar et al., 2011). Exposure to vibration increases the risk of developing MSDs. Vibration can be divided into two main categories, namely: Whole body vibration and Hand/arm vibration (Department of Employment and Industrial Relations, 2007).

- Whole body vibration (WBV) refers to exposure to vibration over the entire surface of the body. A good example of WBV is when an operator is operating a machine, the vibrations of the machine is conducted through the seat he/she is sitting in into the body. WBV increases the risk of lower back injuries.
- Hand/arm vibration (HAV) refers to exposure to vibration localised in the arm or hand of the worker. HAV damages vascular and nerve tissue in the hand and fingers which typically causes White Finger Syndrome (or Raynaud's Syndrome) when exposed to over long periods of time.

2.6.5 Force / Forceful Exertions

Force is defined as the amount of physical effort required to do a task (Ahankoob and Charehzehi, 2013). In a construction sense it will equate to the amount of effort required to control and maintain the equipment and tools used in construction activities (Jaffar et al. 2011). Forceful exertions (strenuous activities) place a larger load on the muscles, tendons, ligaments, joints or discs (Department of Employment and Industrial Relations, 2007). Muscle fatigue is directly proportionate to exertion and increases the risk of injury when muscle tissue does not have enough time to recover (Department of Employment and Industrial Relations, 2007). It is important not to apply force above the capability of the tissue.

2.6.6 Contact Stress

Contact stress is caused by continuous localised pressure on a body part when exposed to any sharp or hard objects. The result is acute pain in the tissue where pressure is applied and interrupted blood circulation or nerve function (Ahankoob and Charehzehi, 2013; Jaffar et al. 2011).

2.6.7 Extreme Temperature

Extreme temperature can be divided into extreme heat and extreme cold. Extreme heat may lead to heat stress and heat related disorders which reinforced fatigue. Extreme cold will cause the blood vessels to narrow which results in decreased sensitivity and range of motion of the body part (Ahankoob and Charehzehi, 2013; Jaffar et al. 2011).

2.6.8 Duration

Duration is the time it takes a worker to complete a task or repeat a task without rest or interruption. Duration is directly proportionate to muscle fatigue, the longer the duration of the task, the greater the load on the muscle tissue. There is an increased risk of injury when muscles are worked for long durations without adequate rest (Department of Employment and Industrial Relations, 2007).

Workers that are continuously exposed to poor Ergonomic conditions, commonly found on construction sites, may develop MSDs (Nath et al., 2017*;* Ahankoob and Charehzehi, 2013). In many cases, risk factors function together (are present at the same time) to expose the worker to a risk of contracting work-related MSDs. Consequently, exposure to MSDs may result in significant amount of financial and human resource losses which negatively impacted productivity (Nath et al., 2017*).*

2.7 Musculoskeletal Disorders

Musculoskeletal Disorders (MSDs) is a direct result of continuous exposure to ERFs (Abrey and Smallwood, 2014). MSDs (also known as cumulative trauma disorders, repetitive strain injuries, repetitive motion disorders, and overuse syndrome) is a range of conditions that can be defined as Ergonomic injuries to the musculoskeletal structure of the body caused over time by the working conditions or environment (Wang et al., 2015; Scott, Kogi and McPhee, 2010).

MSDs are a primary cause of non-fatal injuries and known as one of the most common ergonomic injuries in the construction industry (Wang et al., 2015; Ahankoob and Charehzehi, 2013). According to the Department of Employment and Industrial Relations (2007), 39 percent of non-fatal workers' compensation claims in the construction industry were related to manual tasks during the 2000/2001 to 2005/2006 financial years.

Symptoms of these disorders include pain, aching, discomfort, numbness, tingling, and swelling that normally occur in the back, shoulders, neck, legs, wrists, fingers, elbows, and arms (Wang et al., 2015; Scott, Kogi and McPhee, 2010; Department of Employment and Industrial Relations, 2007). These disorders are not age specific as a study by Eaves, Gyi and Gibb (2016) found that workers of all ages reported a high occurrence of symptoms in the entire body, although workers aged 50 and higher particularly complained about symptoms in the knees, lower back and wrists/hands. Scott, Kogi and McPhee (2010) stated that back pain associated with manual handling, awkward postures or vibration is the commonest symptom of MSD Disorders.

According to the Department of Employment and Industrial Relations (2007), MSDs may result in permanent damage which has a significant impact on a person's working ability and quality of life. This in turn impacts the productivity and economic performance of the company.

2.8 Mitigation of Ergonomic Risk Factors

The Department of Employment and Industrial Relations (2007) attributes risk factors to design. It is further suggested that risk factors are caused by the following:

- Work area design: includes the entire working environment where the job is located. Poor design of work area may lead to forceful exertions, awkward and static postures.
- Tool design: includes the design of any tools used to perform a work-related task in the work area. Poor tool design may lead to vibration, forceful exertions, awkward and static postures.
- Load handling design: includes the characteristics of the load and the method of how the load is handled. Poor design of load handling may lead to forceful exertions and awkward and static postures.
- Work organisation design: which includes issues such as the length of the shift, how often the task is performed, and the number of workers assigned to the task and the pace of work. Poor design may cause repetition and duration.

To successfully eliminate or mitigate ERFs, it is important to determine the root cause of the problem. Once the cause is identified, control measures should be implemented and aimed at modifying the work area, tool, load, method of handling and/or the way the work is organised (Department of Employment and Industrial Relations, 2007).

2.8.1 Hierarchy of Controls

Control options are ranked according to the hierarchy of controls (this ranks the efficiency of controls from most effective to least effective). Engineers should take this hierarchy into account when designing and implementing controls. Controls are divided into design/engineering controls and administrative controls.

Design/engineering controls require redesigning elements or the entire task, workplace, tools or equipment. Design/engineering controls can be subdivided into: elimination, substitution and engineering controls.

Elimination requires the problem task to be eliminated completely (e.g. automation). This is the most effective control measures as the problem task is no longer applicable in the workplace (Choi, Yuan and Borchardt, 2016; Ahankoob and Charehzehi, 2013; Scott, Kogi and McPhee, 2010; Department of Employment and Industrial Relations, 2007).

Substitution involves alternative ways to complete the problem task (replacing the practice with a less hazardous practice) (Choi, Yuan and Borchardt, 2016; Ahankoob and Charehzehi, 2013; Scott, Kogi and McPhee, 2010). This requires substituting heavy items with lighter and easier to handle items or replacing tools with Ergonomically designed tools (Department of Employment and Industrial Relations, 2007).

Engineering controls are implemented when elimination or substitution is not reasonably practicable (Ahankoob and Charehzehi, 2013). Engineering controls involve finding the best or most efficient way to perform a task. Some examples include providing work benches, storing items between knee and shoulder height to reduce awkward postures and the amount of force needed to move the items, slip resistant surfaces, machine guards, using mechanical aids to move items instead of carrying them or dampening materials to reduce vibration exposure (tool handles, floors or workbenches) (Ahankoob and Charehzehi, 2013; Scott, Kogi and McPhee, 2010; Department of Employment and Industrial Relations, 2007).

Administrative controls involve changing labour practices and are the least effective form of design control and should only be considered after the above controls are proven not to be reasonably practicable (Ahankoob and Charehzehi, 2013). Administrative controls require continuous supervision as they are forgotten/ignored under stressful conditions (approaching deadlines, limited staff or increased production targets).

Although it is stated as control, it is rather a method to manage the risk by reducing the duration and frequency that workers are exposed to the risk (Ahankoob and Charehzehi, 2013; Wang et al. 2015; Scott, Kogi and McPhee, 2010; Department of Employment and Industrial Relations, 2007). According to the Department of Employment and Industrial Relations (2007), controls require a comprehensive control strategy and focusses on implementing policies and procedures. These typically include:

- Regular maintenance programs to ensure plant, tools and equipment are in good working condition,
- Job rotation or reduced shift length,
- Job specific training,
- Personal Protective Equipment (PPE), and
- Fitness for work programmes.

Training, as stated above, is a significant administrative control measure to reduce the risk workers are exposed to. They should be trained in safe operating procedures and use of relevant mechanical aids. However, it must be stressed that manual tasks training is not, on its own, an effective risk control strategy and cannot be relied on to change long-term behaviour of workers.

2.9 Benefits Ergonomic Risk Factor Mitigation

Goldwain and Smallwood (2015) suggested that up to 50% of incidents/accidents can be avoided through hazards and risks mitigation by means of design. Thus, if Designers truly apply Ergonomic principles to their designs during the construction phase of the project, many incidents or accidents can be avoided. A reduction in the number of incidents or accidents is not the only benefit of implementing Ergonomics principles in a project's design.

Implemented Ergonomic programmes improve worker moral (increasing productivity) and reduces compensation costs, which in turn improves increasing profitability (Choi, Yuan and Borchardt, 2016). Abrey and Smallwood (2014) agreed with the previous statement, but added

that company reputation can be affected by the H&S status of the company. Ahankoob and Charehzehi (2013) added improved quality to the benefits of ergonomic risk factor mitigation.

As stated, cost is one of the main benefits of implementing ergonomic programmes. This is illustrated by Haupt and Pillay (2016), as their investigation into 100 construction accidents found that the approximate cost of construction accidents totalled to Thirty-three million Rands. They when further by identifying the four main components of expenditure with regards to construction accidents, namely: 1. Sick pay; 2. Administrative costs; 3. Recruitment costs; and 4. Insurance costs.

According to Haupt and Pillay (2016), construction accidents present a significant cost to employers and society. It is in the employer's and society's best interest to identify and improve the management of construction H&S. Health and safety should not be regarded a financial burden, but rather a means of improving productivity (Abrey and Smallwood, 2014). If quality and cost-effectiveness are not compromised, labour-intensive approaches to infrastructure development can also be an important instrument for economic growth (Twala, 2007)

2.10 How Engineers' Perceive Ergonomics

Designers are required to apply Ergonomic design principals to the construction phase of the project to reduce the risk of occupational fatalities or injuries, which they are lawfully obligated to do by section 10 of the OHSAct and Construction Regulations (Smallwood, 2015). Considering this, how important is Ergonomics to Designers?

A study done by Smallwood (2017), suggested that Architectural Technologists (in their capacity as Designers) perceive traditional project parameters (such as time, cost and quality) more important than project H&S, particularly construction Ergonomics. Although Architectural Technologists see construction Ergonomics as an important parameter, they do not fully comprehend the importance of Ergonomics during the maintenance and commissioning phases. Haupt and Pillay (2016) agreed and added that Architectural Designers would be more interested to focus on construction H&S in their designs if they can comprehend the cost saving ability of reducing H&S hazards and risks during the construction phase.

Smallwood (2015) stated that Designers have limited ergonomic knowledge and with this limited knowledge (mostly gained by experience) they design buildings with the end user in mind rather than the employees constructing the building.

2.11 Ergonomic Knowledge

The lack of Ergonomic knowledge originates at tertiary education level where students (future engineers, designers, and managers of socio-technical systems) are not adequately educated on Ergonomic principles (Ek et al., 2015; Naeinia and Mosaddad, 2013). A study by Smallwood (2017) concluded that the source of Ergonomic knowledge was more informal (such as experience) than formal (tertiary education) and found that Architectural Technologists rate their knowledge of Ergonomics and designing for Ergonomics skills 'below average'.

The previous statement was reinforced by Smallwood and Wium (2015) stating that students lack knowledge and awareness relative to the mass and density of materials, a variable which plays a significant role in ergonomic design. As a result, students in the study failed to conduct optimal hazard identification and risk assessments with regards to design. Universities have a responsibility to educate engineering students about human-work area interaction related to H&S problems (Naeinia and Mosaddad, 2013).

Ek et al. (2015) emphasised that Students need to gain an understanding of how Ergonomics can be integrated in the design of workplaces, organisations, products, and services. From the position of Naeinia and Mosaddad (2013), Ek et al. (2015) and Smallwood (2015) it can be concluded that there is a need for accredited ergonomic courses at tertiary level.

However, given the below average rating of Ergonomic knowledge and Ergonomic designing skills amongst Designers, as well as the lack of awareness with regards to certain provisions of the OHSAct and the Construction Regulations, Smallwood (2017) concluded that the design profession is not addressing construction Ergonomics to the extent that they should.

2.12 Technological Applications

Currently, it is not feasible to implement automation and robotics across all South African road construction projects due to the high unemployment rate and EPWP requirements for LIC (refer to section 2.2 and 2.3 where this is discussed in detail). However, other technological applications exist apart from automation and robotics that may improve project efficiency, quality and construction safety. Bock (2015) stated that there are various indicators that suggest conventional construction methodology has reached its peak in terms of efficiency. Momin, Patil and Nale (2015) agreed with Bock (2015) and added that construction productivity on large projects, including road construction, has reached a platue or has been declining since the

1970’s due to significant increases in construction labour cost and scarcity of funding for new road construction and maintenance projects.

Taking into account that the construction industry is currently in the development phase of automation and other technological applications (Bock, 2015), the means of how to apply advanced technology in order to improve construction safety management is still being inevtigated. Zhou, Irizarry and Li (2013) found that most of the technological applications researched were limited to academic study and predominately not yet implemented to improve construction safety management.

According to Zhou, Irizarry and Li (2013) there are two approaches to study construction safety. One being reactive safety management which includes, but is not limited to, hazard identification, risk assessments and accident cause analysis. The second is categorized as proactive safety management such as safety through design, safety monitoring and safety information. The latter utilizes technology to a great extent to achieve the zero-harm goal by providing users with real-time information or minimizing the human error element in the process. Zhou, Irizarry and Li (2013) categorised the technology under: automation and robotics; information and communication; sensor-based; virtual reality and wireless and visualization technology. According to Zhou, Irizarry and Li (2013) the following topics were researched to improve construction safety management in order of prevalence:

1. Virtual reality,
2. Sensor-based technology,
3. 4D visualization technology,
4. 3D visualization technology and robotics.

Although the above-mentioned technological application may be implemented to improve construction safety, there remains limited approaches for effectively identifying the potential ergonomic risks of a proposed design (Golabchi, Han and AbouRizk, 2018). For an approach to be effective it must be able to address designers' lack of familiarity with ergonomic paired with an understanding of how to mitigate these risks through design and implementation (Golabchi, Han and AbouRizk, 2018).

To solve this problem Golabchi, Han and AbouRizk (2018) proposed integration of available ergonomic assessment tools into event simulation modeling. The developed framework intends to provide feedback on the level of ergonomic risks associated with the design and

automatically links the ergonomic evaluation with a productivity analysis without requiring the designer to have high levels of knowledge in production planning or ergonomics (Golabchi, Han and AbouRizk, 2018). This will facilitate implementation of prevention through design in the construction industry and enable designers to assess performance and safety concurrently.

It is noteworthy that while some ergonomic risks associated with the design of a workplace and operations can be prevented through design via frameworks such as the one proposed by Golabchi, Han and AbouRizk (2018), a prevention through design approach will not consider every ergonomic risk factor as it will be too difficult to fully model and analyse. For example, A study done by Li et al. (2019) found that the lack of cognitive ergonomics risk factors influences operators' ability to detect hazardous situations that require their visual attention. As a result, the likelihood of construction equipment related accidents such as collisions between equipment and pedestrian workers increase due to mental fatigue induced by prolonged and monotonous operating tasks. According to Li et al. (2019) the participants' hazard detection rate decreased to 70% of their initial performance after only 36 min of operating and down to 60% after 60 min of operaing. Additionally, their reaction speed decreased as the task progressed (Li et al., 2019). One can imagine that an ergonomic risk factor such as monotonous work will be challenging to accurately model and analyse. Such a framework would rather be suited for physical risk factors.

2.13 Key findings

From the literature reviewed, the following was identified:

- Designers have a below average rating of Ergonomic knowledge and Ergonomic designing skills.
- Designers lack awareness with regards to certain provisions of the Occupational Health and Safety Act 85 of 1993 and the Construction Regulations 2014.
- The design profession is not addressing construction Ergonomics to the extent that they should.
- There is an absence of Ergonomic courses in tertiary engineering education and a lack of available accredited courses to fill this gap.
- Technology applications exist that can assist designers in preventing ergonomic risk factors without requiring the designer to have high levels of knowledge in production planning or ergonomics.

3. Research Design and Methodology

3.1 Introduction

This section aims to clarify how the various research techniques and tools were utilised to address the primary research question. The suitability of each technique and tool is substantiated in relation to the topic and research question. Additionally, ethical issues during the undertaking of the research are addressed.

3.2 Research Philosophy

Research philosophy is a system of how knowledge is developed. The system applies beliefs and assumptions to develop knowledge in a particular field (Saunders, Lewis and Thornhill, 2016).

Research philosophies are categorised in three categories, namely ontology, epistemology and axiology. Ontology is concerned with nature of reality whilst epistemology concerns what constitutes acceptable knowledge in a field of study. Axiology is concerned with values and ethics within the research process (Saunders, Lewis and Thornhill, 2016). The five major philosophies within the stated categories are positivism, critical realism, interpretivism, postmodernism and pragmatism.

This research follows a phenomenological based philosophy. Phenomenology is defined as a philosophy that primarily focuses on several participants' interpretation of lived / everyday experiences and what insight or meanings those phenomena can generate (Saunders, Lewis and Thornhill, 2016; Converse, 2012; Creswell, 2007). The research participants' information and perceptions are gathered through inductive qualitative research methods such as interviews and observation (Lesser, 1999). From the definition of phenomenology one can concur with Saunders, Lewis and Thornhill (2016) that it is a strand developed from interpretivism. Interpretivism is concerned with studying the meaning that humans have created around a phenomenon (Saunders, Lewis and Thornhill, 2016). Different people from different backgrounds and experiences are bound to make different meanings that results in different realities.

Data received from the interviews were based on the perceptions and interpretation of civil engineers with regards to Ergonomics. The phenomenological based philosophy is used to

create a new understanding of what civil engineers perceive and how they interpret Ergonomics.

3.3 Research Approach

The research approach is important to define when undertaking research, as it explains how the researcher developed and / or tested the theory. The approach can be either deductive, inductive or abductive. The three approaches are defined as follows:

- ***Deductive approach:*** starts with the development of a theory that is in turn a research strategy is designed to test the theory (Saunders, Lewis and Thornhill, 2016; Sekaran, 2003).
- ***Inductive approach***: initially data is collected to explore a phenomenon which is then used to generate theory (Saunders, Lewis and Thornhill, 2016; Sekaran, 2003).
- ***Abductive approach:*** data is collected to explore a phenomenon, identify themes and explain patterns, to create a new or modify an existing theory which is in turn subsequently tested by means of additional data collection (Saunders, Lewis and Thornhill, 2016).

This research adopted an inductive approach. The purpose of the inductive research is to get a feel of how Civil Engineers perceive Ergonomics and how they implement the principles in their designs, so as to understand better, the nature of the problem. From the interview data collected and analysis of the data a theory may be formulated.

3.4 Research Design

Research design is defined as a general plan of what the researcher will do to answer the research question or how data can be gathered and analysed to arrive at a solution (Saunders, Lewis and Thornhill, 2016; Sekaran, 2003). In order to successfully answer the research question, the design requires clear objectives, sources for the data collection, method of the data collection and analysis, ethical considerations, as well as any constraints that will be encountered during the research process.

3.4.1 Research Methodology

According to Saunders, Lewis and Thornhill (2016) research methodology can essentially be categorised under two methods namely, mono method or multiple method. Mono method refers to utilising a method that is either qualitative or quantitative. Multiple method refers to utilising

a method that incorporates both qualitative and quantitative research. MacDonald and Headlam (2015) stated that quantitative research is concerned with concerned quantifying data and to generalise results from a sample of the population of interest by asking questions such as ‘how long’, ‘how many’ or ‘to what degree’. Qualitative research attempts to gain an understanding of reasoning and motivations for actions and establish how people interpret their experiences and the world around them (MacDonald and Headlam, 2015).

This research study is qualitative in nature as the stated research questions aimed to explore to what extent Designers apply Ergonomics during the construction phase of labour-intensive projects, within the South African context. The research only used qualitative data collection and analysis, making it a mono method research design.

3.4.2 Data Collection Instrument

Due to there being limited studies and knowledge directly relating to the Ergonomics with regards to road construction and how it is applied during the design stage of the project, interviews were conducted to explore what knowledge Designers have in terms of Ergonomics and to what extent it is applied to their designs.

The questions for the semi-structured interviews were formulated to elicit information from the participants without them feeling a sense of unease.

Questions 1 to 4 were broad based questions in respect of H&S on a road construction project. Broad based questions were asked, to put the participant at ease, as these were questions formulated around topics participants would be familiar with and would not have any trouble answering as they encounter it daily.

The remainder comprised of focused questions. These focused questions were formulated to evaluate participants’ knowledge or understanding with regards to Ergonomics and the legislative requirements, duties and responsibilities placed on Designers in terms of Ergonomics.

Table 2. Semi-structured Interview Questions

No	Questions	Purpose of the Question	Literature Source
Broad Introductory Questions			
1.	Why is health and safety important on a construction site?	Broad introductory questions are not essentially literature-based questions, but rather questions asked for the purpose of putting the participant at ease.	
2.	What type of injuries have you encountered or heard of?		
3.	What are the positive and negative impacts when designing with Health and Safety in mind?		
Focused Questions			
4.	How do you define Ergonomics?	Questions 4 and 5 addresses whether Designers are able to identify some of the ERFs found in literature.	Ahankoob and Charehzehi (2013), Choi, Yuan and Borchardt (2016), Wang et al. (2015), Jaffar et al. (2011), and the Department of Employment and Industrial Relations (2007),
5.	What are common ergonomic problems you have encounter or identified during a project?		
6.	In your opinion, who should be responsible for mitigating ergonomic risk factors?	Questions 6 and 7 attempts to evaluate whether Designers are aware of their current legal obligations and to convey the participants opinion about future ergonomic legislation.	Republic of South Africa, (2017); Republic of South Africa (1993) and (Republic of South Africa (2017).
7.	Please elaborate on how you feel about new legislation which might hold you accountable for the ergonomic wellbeing of construction workers on site?		
8.	How do you feel about the EPWP's requirements of using labour-intensive construction?	This question addresses whether Designers are of the opinion that labour-intensive construction is truly beneficial and whether designer are reluctant to design for such projects.	McCutheon (2017) and McCutcheon, (2008b) and Twala (2007).
9.	Have you implemented ergonomic principles in your designs? If yes, what were major challenges?	This question addresses whether Designers have applied their ergonomic knowledge in practice, whether the knowledge was obtained formally (tertiary education) or informally (experience).	Smallwood and Wium (2015).
10.	What courses have you attended with regards to Ergonomics?	Question 10 and 11 addresses lack of means whereby Designers can obtain ergonomic knowledge and portrays their interest in such education or training if it becomes available.	Naeinia and Mosaddad (2013); Ek et al. (2015); Smallwood (2017) and Smallwood (2015).
11.	Do you feel formal training on ergonomic principles is important?		

The expectation of achieving 1 [one] interview per week was often achievable, but occasionally there were no interviewees available for several weeks, and then occasionally a few interviewees scheduled their interviews in the same week.

Interviews were recorded by means of an audio recording device (Dictaphone). Recordings were saved on a secure password protected storage device and deleted from the recording device. Recordings of the interviews were transcribed and summarised into a table for data coding purposes.

3.5 Collection of Data

3.5.1 Sourcing of Participants

Six emails were sent to organisations that are well-known for conducting civil engineering projects, as well as a total of twenty-one emails and private messages to practicing civil engineers found on LinkedIn. However, these efforts were mostly unsuccessful.

The only successful method of sourcing participants was the so called “snow ball” method. This method relies upon a willing participant to introduce you to the next potential participant and so forth. Due to the time constraint of this study, only 9 participants were interviewed.

3.5.2 Semi-structured Interviews

After agreeing to the interview, the informative introductory letter was emailed with a copy of the ethics clearance. A mutual location, being proposed by the participant, was agreed upon beforehand, generally at the participant’s offices. Interviews always began with an introduction to the study as described in the introductory email. The informed consent form was discussed and signed, and participants were assured that information shared would be anonymous. Each question was read out and the participant’s answer was recorded. Additionally, the researcher took notes as the interviewees stated their opinions and descriptions. Whenever an interviewee ran short of specific responses, the researcher would rephrase the question to elicit an answer. Participants were reminded that positive responses were also welcome. After all the questions were covered the interview was then closed out. The recording was saved and the notes filed together with the informed consent form.

3.6 Validity and Reliability

3.6.1 Validity

Validity is defined as the extent to which data collection method(s) accurately measure what they were intended to measure (Saunders, Lewis and Thornhill, 2016). In other words, was the tools and processes used for collecting data appropriate in order to reach the desired outcome.

Leung (2015) explained that qualitative research validity is concerned with the validity of the research question in order to have the desired outcome; whether the methodology is suitable to answer the research question; if the design is appropriate for the methodology, whether appropriate sampling and data analysis is conducted; and finally whether the sample and context is validated by the results and conclusions.

The data collection method (semi-structured interviews) was considered appropriate to answer the research questions. By interviewing participants, the researcher could obtain how Designers perceive Ergonomics and how they implement the principles in their designs as to better understand the nature of the problem

3.6.2 Reliability

Saunders, Lewis and Thornhill (2016) stated that in order for research to be reliable the data collection methods must be able to generate consistent findings; there must be a high degree of transparency in how raw data was analysed; and other researchers must be able to make similar observations and therefore come to the same conclusions. However, in a qualitative research setting with diverse perspectives and opinions, the definition of reliability is challenging and may be seen as counter-intuitive (Leung, 2015).

Therefore, the reliability of qualitative research may be questioned. All efforts were made to ensure a degree of reliability; however, the semi-structured interview method will not produce consistent finding as opinions, experience and knowledge varies between individuals.

3.7 Generalisability

Generalisability (or external validity) refers to the extent that findings of the research study can be applied to other settings other than the setting it was originally tested (Saunders, Lewis and Thornhill, 2016). In other words, can the findings of the study be generalised. Leung (2015) addresses the issue of generalisability in qualitative research as qualitative research studies aim

to study a specific issue or phenomenon in a population within a specific context. Therefore, qualitative research is generally not attributed with external validity.

This research aimed to study the extent to which civil engineers address Ergonomics in a labour-intensive construction setting. As a result, the findings are not appliable to any other setting as it may not be true reflection of the state of affairs outside its own setting.

3.8 Bias

MacDonald and Headlam (2015) defined bias as a loss of balance and accuracy in the use of research methods. Simply put Saunders, Lewis and Thornhill (2016) explained that researcher bias is any factor that may influence the researcher and how the researcher records the findings. For example, biasness may occur in the way participants are selected or who is selected, what findings to include and exclude to alter the outcome, or in the way the data is analysed which will result in inaccurate findings (Saunders, Lewis and Thornhill, 2016). It must be noted that the researcher is an occupational health and safety practitioner and this may have inadvertently caused some degree of biasness.

3.9 Data Analysis

Data collected during the interviews were analysed by coding the responses of participants. Each question's responses were carefully analysed for answers similar in nature. Corresponding answers were consolidated, and where the participants disagreed from each other, the different answers were noted.

By doing so, it was possible to establish the similarities and differences between the participants' views and opinions. Participants' views and opinions were then compared to what was found in literature during the literature review.

3.10 Ethics

No ethical problems were encountered during the study. Questions were comfortably answered without partiality and all the participants were found to be very honest, direct and often critical of the profession with regards to Ergonomics.

Access to the interviewees was as difficult as can be expected. Some difficulties experienced was around the willingness to participate, and the ones that were willing to participate found it difficult to accommodate a corresponding timeslot in both the interviewer and interviewee's diary. However, once the interviews started, participants were keen to share their experiences,

thoughts and opinions in terms of the topic. Designers were apprehensive to participate possibly due to them not fully understanding the topic.

A short introductory note was emailed to all possible participants. The email was composed to highlight who the researcher was, a brief explanatory description of the research, outlining what was expected of them if they were to participate. Once the person was committed to participate, engagement to participate revolved around scheduling a formal meeting to discuss their views and concerns on the topic.

The information under research was not sensitive nor controversial and therefore did not raise any red flags. The research did not create any negative connotations around the people involved, as participants were assured that interviews would remain anonymous.

Finally, the results were analysed in an extremely objective state of mind. The research was not done for any organisation that stands to ultimately benefit from the outcome.

4. Data Presentation

Transcribed interview data was summarised and tabulated. The questions will be addressed in chronological order (from one to eleven) in which they were asked.

4.1 Guided interview Results

Nine civil engineers with road construction experience were interviewed to ascertain to what extent they address Ergonomics during their design of labour-intensive construction projects. Questions 1 to 3 were broad-based question with regards to H&S. These questions were asked to put the interviewee at ease, knowingly that they should not have had any difficulty answering these common questions. Questions 4 to 11 were focused on Ergonomic knowledge and understanding, and to what extent Ergonomics was applied in their designs.

Question 1: Why is health and safety important on a construction site?

Participant 1	Construction regulation dictates adherence to the Occupational Health and Safety Act as a legal requirement. Imperative to adhere to the OHSAct, because when injured on duty, man hours are lost. Project programme is jeopardised. At worst, a fatality will see a stoppage of all works for the duration of a full investigation. It is a legal requirement to adhere to the OHSAct and Construction Regulations. Companies will be penalised with a severe monetary penalty should an injury occur, and they are found to be non-compliant.

Participant 2	A fatality causes stoppage of works. Department of Labour investigates, lengthy safety reports must be concluded indicating root cause analysis, extensive documentary evidence all to be drafted by the Engineers involved. Two days up to a week will be lost on programme, dependent on the root cause analysis. Financial implication of the production loss in most cases will be astronomical.
Participant 3	It is very important. Employees should be trained in the proper use of their tools for the trade. In most cases the safety part is being ignored in favour of production. For instance, one would use a spade instead of a hammer to hit something and then the injury resultant could be a bone fracture.
Participant 4	It is first of all a legal requirement. But if you ask me why it is important, it is because you've got a life ahead of you, it is important to keep people safe for their families, as they normally rely on the person working on the project as the breadwinner. It is also important that people can do their day job and return tomorrow, because we invest a lot of time and money in people. When they sustain injuries or be off sick, or even killed, it is economically bad. To me that is always secondary, most importantly it is about the human aspect. Life is important, life is not to be wasted by indiscriminate conduct.
Participant 5	Firstly, it is important because construction is inherently dangerous. You have heavy equipment and machinery. There is a lot of risk factors. Dealing with big loads of material and lots of moving parts. Compared to your normal environment, for instance office work, health and safety is not as intense, in construction you have to ensure that people get home safely from the working environment. A lot of people rely on their jobs to provide for their families. When someone gets injured or hurt, and they can't work, then they can't provide for their families.
Participant 6	H&S has gained momentum lately, first the mining industry was more focussed, however lately the private sector also practises it, because all people's health and safety are important. Everyone has a right to work in a safe environment, so that they can produce optimally.
Participant 7	Safety is paramount. You must ensure that your design does not negatively influence the community by having an unsafe end-user result. The correct standards must be applied. In terms of health and safety, the design must also be practically suited for the built environment. You must incorporate health and safety for the construction phase.
Participant 8	For the safe being of employees, which is not always regarded, because on certain road projects, even structural projects, you have deep excavations such as trenches for stormwater, sewer and water lines that can easily collapse. If there is no health and safety measures in place, soil collapse can occur very easily as well as during construction, you work with heavy 20 ton or 50 ton rollers and if one is not observant of your environment, and rules are not in place, and operator can easily drive over a person and not even notice it.
Participant 9	It is the professional duty of the engineer to look after the public which includes labour. It is the Law and everyone needs to comply. Having good H&S on site

	make working conditions better, which results in a motivated workforce which is more productive. Goodwill is gained with the workforce and community by showing the project team cares and takes H&S seriously, and this has lots of positive spinoffs.

Question 2: What type of injuries have you encountered or heard of?

Participant 1	Mostly the injuries consist of vehicular hits, where the workers are not visible enough or the use of cell phones defer their attention. Accidents also occur when crossing roads as workers miscalculates the speed of oncoming vehicles. Workers might also walk behind a reversing truck, expecting to be seen.
Participant 2	None on the road works I had been involved with. In my opinion working at heights has proven to be more of a safety hazard to workers than roadworks.
Participant 3	None encountered on the road works projects I have been involved with. Being a consultant, I am not exposed to the "hands-on" physical labour. But I have witnessed an accident involving a bakkie, which overturned, due to the driver exceeding the speed limit of 60 km/h. In the mornings water is sprayed on the road surface so that the dust settles. The driver lost control of the bakkie as the road surface was slippery.
Participant 4	I have personally witnessed death, lacerations and amputations. I have seen the worst there is.
Participant 5	Let's say, starting with the simplest ones, the types of injuries that you usually get to see is stressed injuries, people using shovels or incorrectly picking up material results in them hurting their backs is a very common one. Straining of backs is relatively common injury. Hand injuries, splinters, cuts or abrasions, blisters. Impact injury with a pick or shovel to the foot. Tripping over things, hurting themselves that way.
Participant 6	On one of our sites we had a fatality. The guy was working on scaffolding with shutters and fell with the shutter board which landed on him and cut the arterial vein in his leg. He bled out. Fingers are a common injury. I have seen a person's fingers trapped in cables. Also, fingers got caught in a chain, which saw the person losing his fingers. I witnessed a guy cutting into an electric cable with bolt cutters.
Participant 7	I was involved in the upgrade of Fourways mall and on that project, I have heard of scaffolding accidents where workers were not adhering to the correct harness method to secure themselves. There was a fatality, where a person fell to his death. Road injury health and safety transgressions, I have not experienced or heard of.
Participant 8	On one of my sites, a trench collapsed on a worker, luckily it was not a fatality. The team was quick to react and get him out of the trench, but he broke 5 ribs in the process.

	On a site of one of my colleagues, an impact roller operator drove over a person. The guy crossed the line of impact rolling with headphones in his ears and he did not hear the impact roller coming. This was a fatality.
Participant 9	Small day to day injuries working with steel, back pain from picking up cement etc. Also motor accidents.

Question 3: What are the positive and negative impacts when designing with Health and Safety in mind?

Participant 1	**Positive**: Production flow, full labour force, Department of Labour buy in. **Negative**: Safety files takes time & effort to prepare. For most smaller work packages, safety files are non-existent. Time is wasted getting these compliant. Induction of the work force takes time.
Participant 2	**Positive**: during design, an engineer who is experienced in the worker health & safety regulations, is an asset to the project. I worked with very experienced design engineers, and the leadership they provide and close out reports they present, formed the basis of my knowledge, rather than what was taught in the tertiary environment. **Negative**: Focus was more on the use of the road, after handover, completion than on the Ergonomics during the construction of the road. Designers automatically assumed the contractor will put the measures in place to ensure health and safety of workers. During the appointment process of a main contractor, it is stated as a requirement that they should take this role on board, which absolves the designer in an extent of the involvement.
Participant 3	In my current experience, I would say that focussing on the end user safety, and not the worker safety, during the construction of the road, is pertinent. During the design stage the only focus is that the road is fit and safe for vehicular traffic upon completion.
Participant 4	**Positive**: Allows you to work in a structured way. It is actually the fastest way of working but then you need a working culture of the first order. We battle in South Africa with that. **Negative**: Negative impact on productivity. That is not first and foremost. The other negative thing is that it causes delays, purely because of human nature, not because of the institution itself. Health and Safety should not cost you more, in fact it should save you time, but it is the human approach / culture that affects it negatively.
Participant 5	**Positive**: It makes it much easier for you to draft a health and safety plan if you have already incorporated / allowed for it in your design. If you have allowed for phase and for access and so on, it makes your health and safety implementation during construction much easier. It sensitises the entire project team, for example, when you have a kick off meeting and design health and safety into it, it becomes much easier for you to communicate what the health and safety requirements are on a project. If you have not even thought about health and safety in the design

	phase, then when you get to a kick-off meeting, and you have to now brief the contractor about the health and safety parameters of a project, it is harder to bring it home to them. Compliance is much easier down the line, if you introduce health and safety at the onset and you reduce the likelihood of somebody getting injured or having an incident on the project. Which will save you time in the long run. If your project is safe, you won't have lost time injuries and investigations. Once you have the discipline to think health and safety first, then the benefit is it becomes easier on the next project. Benefits outweighs the negatives. **Negative**: The extra time spent and some extra effort and thoughtfulness to plan around health and safety.
Participant 6	**Positive**: Taking people's safety into consideration. It is to the benefit of the person working on the project. **Negative**: It cannot always be implemented successfully, for instance in deep trenches, there are fixed constraints, and then you cannot excavate the batters with full safety. Designers are sometimes hindered from designing to the full safety specification due to the site constraints. It makes it more difficult to adhere to the regulations, and then alternative methods are looked at to find a solution.
Participant 7	**Positive**: You feel at peace that you don't put a person's life and health in danger. **Negative**: it makes the design more costly.
Participant 8	I have never designed entirely with health and safety in mind, only when detailing trenching, where anything above 1,5m creates additional step out for excavations for safety purposes. When we do our batters, cut & fill, we always maintain a minimum of 45 degrees. Small things, like working space around the edges are detailed as well.
Participant 9	Smooth construction with no interruptions caused by injuries.

Question 4: How do you define Ergonomics?

Participant 1	Not quite clear on the interpretation of the terminology.
Participant 2	Working within the boundaries of physical human attributes and abilities.
Participant 3	Will someone be able to produce as much production as is required. The production that I can push might not be able to give that much.
Participant 4	Ergonomics to me is the shaping of things to be better adapted to the use of things. For instance, a telephone, needs to be picked up easily and needs to fit your mouth, ear, facial profile easily. So that is basically it.
Participant 5	Ergonomics is the way that people interact with things. It could be for example the way a person will interact with a chair, or interacts with a piece of plant or a piece of equipment or a site. For me, it is the interaction between human beings, who are the ones instrumental in doing the work, and the physical environment that they occupy and how well that is designed and structured. Good Ergonomics

	would mean that the person who is interacting is well thought out in the design of the thing and bad Ergonomics is when the person is not well thought out in the planning process.
Participant 6	Ergonomics is the adjustment of a person's physical mobility in their environment. It is basically how he conducts movement for the work at hand. How he uses his body to complete the task assigned to him.
Participant 7	I would say it is basically what your job specification entails and how you can physically enact the task at hand, without compromising your abilities to live an unencumbered life. For instance, when employed at a mine, taking care of mitigating pollution to lungs.
Participant 8	The impact that your work load has on your body and what are you physically capable of, especially in the era we are entering into now, of women becoming more integrated in the harsh engineering fields. It was hugely manly dominated, and we have to make space for women, and how to ergonomically integrate them. Heavy lifting for instance, like carrying cement weighing 50kg.
Participant 9	Your working environment.

Question 5: What are common ergonomic problems you have encountered or identified during a project?

Participant 1	Sub-contractor non-compliance. Unskilled labourers not utilising equipment correctly Stormwater piping stacked on top of another exasperate the risk of collapse, when a labourer carrying out the stacking stands on top of the pile. Improper walkways, taking shortcuts and not adhering to the safe ways to transverse a site. Duration, sun exposure, hot work temperature and dehydration.
Participant 2	Noise pollution, which causing hearing loss, as well as heat stroke, is the main contributors to workers adverse health problems in road works.
Participant 3	So, what was done, was all labour-intensive works, from loading of the tipper trucks. The guys at the bottom would use their pick and shovels to load the trucks. A person, per day, was required to dig a cube, there was a guy who would measure a cube, and then after a cube, he would get paid.
Participant 4	It is, many times, getting the purpose of the project overshadowed by money. Things getting too snug. People adapt getting more square meters out of piece of land, turning circles is getting too tight, accesses aren't always optimally easy. People start improvising in a stupid way. So, money actually dictates. It is understandable, but money is first, not people.
Participant 5	A big ergonomic issue is people who operate plants, so you might have somebody who operates a crane, basically climb up the ladder to the top of the crane and then they site there the entire day, regardless of whether it is hot or cold. There are no ablution facilities. They just sit there the entire day and at the end of the

	day they come done at dusk. That is a unique ergonomic problem, over and above the common ones mentioned before. Persons who drives a dump truck, TLB, graders and the like, very often they don't have easy access to ablution facilities. It is very normal for persons to just pee next to the plant they operate. A big thing, I experienced when I worked in the Northern Cape, is it gets very, very hot, and people work in extreme hot temperatures, and they don't have access to water and things like that. Also, in roads, surfacing, particularly in rural areas, it gets very hot outside, asphalt becomes very hot, the conditions are not very conducive to peoples' well-being.
Participant 6	I have not encountered it myself, but would think it can be related to persons who cannot execute or complete the task for which he was assigned to. For example, heavy material lifting and straining his body beyond its capability. Building of roads has particular reference, as materials to build roads are generally heavy. To move this material around, you need heavy duty machinery, but for labour-intensive projects, it is people driven, causing strain on muscles, backs etc.
Participant 7	I deem the long duration working in the sun a huge problem, often sunburnt skin, eventually causing skin cancer. Contractors are susceptible to skin conditions caused by over exposure to the damaging rays of the sun.
Participant 8	When stabilising layers, in most operations, where we are bound to employing 30% local labourers, you get these workers to pack out cement, 50 kg a bag, and you pack about 4 per 2 sqm. If you do a 20 km road, you pack a lot of cement bags, with the unfortunate strain to the persons, arms, legs, back & neck.
Participant 9	Small injuries not seen as major risk but are not good for people such as back problems.

Question 6: In your opinion, who should be responsible for mitigating ergonomic risk factors?

Participant 1	In my opinion, the mitigation of problems is already mainly allocated to the main contractor's priority and responsibility. Hence, main contractors engage task planners, who determines targeted outcome for the day, machinery required, labour force physical strength & agility. Risk factors are attached to the task plan. When an injury occurs, the client's health and safety officer will demand an incident report, which must be compiled by the main contractor.
Participant 2	Primary the responsible party to mitigate and take responsibility with regards designing to ergonomic standards should be a specifically focussed task team. The team should consist of design engineer, contractor, client and worker union representative. Design engineers lack the focus on Ergonomics, it is still not part of the tertiary education agenda, therefore in my opinion, the sole responsibility, currently, vests with the main contractor, in the appointment process of direct, nominated, domestic sub-contractors.

	Designers are tasked with the design life expectancy of the road, not the Ergonomics of the work environment. For future expansion, the road must be wide enough. It is very difficult to design the upgrade of the road, when the future expansion was not planned for in the onset design. Drainage and kerbs will further complicate the future design. Therefore, future design engineer will be faced with the strain the labour force will undergo in widening the existing road to for instance become a highway. This physically challenging to workers. I am of the opinion that design engineers can be held responsible in the capacity of dictating the specification of the different road types in RSA.
Participant 3	I think it is everyone and should not be narrowed down to one discipline. If I see that this is going to harm someone, I have the right to say "No, I won't do that". No one can fire your for saying No.
Participant 4	I think the project team. The project team leader. Remember we have value engineering, risk assessments, so the project team leader should be responsible to make sure. Let's just think about this again, many cases like when we building projects or commercial projects, it is the architect. When you look at a warehouse for instance, what truck is going to park there. Is it an interlink or a double interlink, is the person sitting in the driver seat able to reverse with ease? That is the type of thing, and in many of the projects that I have been involved in, it is the architect who determines the design. In many cases it is overruled by the Client, trying to squeeze out the maximum square meters out of something, but there is a need for a conscious look at Ergonomics, which we currently ignore. It is an important field now that you bring it up.
Participant 5	I think it is a combination, because ultimately, especially now in the construction sector, things are hyper competitive, and it is very much driven by price. A lot of construction companies have cut their costs to bare bones to be able to complete a project. I would say that the first thing is that we have a lot of legislation which government imposes. The Designers firstly must be cognisant of the legislation in their design, and make sure that they plan ergonomic factors in their design. You must think about, when you are building 10 km of road, where are you going to provide ablutions, shade, water points, pause areas. Designers sometimes takes this for granted. Designers must undertake to sensitise Clients to budget for Ergonomics, such that the contractor can price for something and not have to take it out of his normal Preliminaries & General (P&G's). The Client needs to make money available to comply with all the Ergonomic requirements imposed by legislation. The contractor as well, has to think about the well-being of his people. But ultimately the contractor is responsible for the well-being of his work force, so he needs to consider the well-being of his people as well and make sure he plans accordingly and even if, maybe not the full allowances has been approved by the Client, that he still ensures the well-being of his people through correctly resourcing tasks. Ergonomics in my opinion is everybody's responsibility, and on top of that, even the people, must look after themselves. For example, they will always show you

	there is a right way to pick things up and there is the correct way to dig, but people must practise what they are taught. They need to think about these things and look after their well-being as well. Some of these ergonomic factors comes down to a person protecting his health through taking personal responsibility. Training is key in empowering people to look after themselves during the lifespan of the project.
Participant 6	Firstly, the designer must be informed that it will be a labour-intensive project. He may then be able to make an adjustment to his design. For instance, to not design too many layers, the alignment of the road can be engineered to suit labour-intensive construction. The contractor or site manager who is tasked with supervision, must ensure that persons who are executing their duties, are not strained unduly.
Participant 7	First and foremost, you must be responsible for your own personal safety. Then the company you work for must take up their responsibility in equipping their work force with proper methods and equipment to safely conduct their tasks. Most workers cannot afford to equip themselves with safety gear.
Participant 8	I think it is a collaboration between your Community Liaison Officer [CLO] and your site agents, or contracts manager of the construction company. The CLO will want as many of the community workers to be employed, but the site agent must then be realistic in evaluating the skill set of the workers and informing the CLO of the decision not to employ physical unsuitable labourers for tasks where only physically fit workers can successfully complete the tasks at hand.
Participant 9	The occupational health and safety agent on site.

Question 7: Please elaborate on how you feel about new legislation which might hold you accountable for the ergonomic wellbeing of construction workers on site?

Participant 1	This poses a difficult dilemma, should an injury occur, then the main contractor becomes the responsible party, the designing engineer will retract. It will prove to be very difficult in apportioning blame to the designing engineer, as the designing engineer does not have a close relationship with the implementation of labour force. In the General Conditions of Contract (GCC), Joint Building Contracts Committee (JBCC) and South African National Roads Agency SOC Ltd (SANRAL) contractual documentation, it is specifically outlined that the contractor is responsible and remains responsible until the site is handed over. Therefore, the entire project scope of works, inclusive of environmental and safety falls under the contractor.
Participant 2	There is a National Codes of Practise, which is being adhered to, this being best practise and safe. Any designing engineer that carries out his design within this Code is practising good principles, as well as protecting the public which is the correct mandate. South African National Standard [SANS], encapsulates

	structural design in respect of loading specification, in relation to layers required, ensuring safe road boundaries.
Participant 3	I think it is fair, there is not anything wrong with that law. Like I said it is the responsibility of everyone to ensure work safety. The designer might go according to the law and design correctly, so that no one gets harmed, but if the labourer decides to come to work drunk, whose fault is it then when he gets injured. Is this still the designer's fault?
Participant 4	I totally agree with it. I said the project leader, but remember he needs to make sure that his design is safe, does not matter which designer. The onus is on the designer himself; somebody needs to be accountable to ensure this has been done.
Participant 5	I think this is a very complex question, because I do think that Ergonomics is the responsibility of all parties involved in the project. Also, in terms of health and safety, there is certain responsibilities which is already part of the designer's scope, which is fine, we all accept that we must design things safely and so on. I think that if there is a requirement that a designer takes responsibility for Ergonomics, I think there is a couple of things that you need to do before you do that. Firstly, how many Designers think about Ergonomics in their design process? How many people currently understand what the legislation requires, especially if it is new legislation, that requires certain things to be inputted into a design. And then, also, ultimately who pays for that additional effort that goes into incorporating all those ergonomic aspects required, per project, into the design. I think that what we generally say as consultants, because sometimes we also act like mercenaries, we can take responsibility for anything as long as we are compensated in accordance. So I think it is important for Designers to be cognisant of the facts, if there is new legislation that requires new steps to be taken, it might mean that new clauses have to be written into a contract document, new items to be put into a bill of quantities and new design elements to be introduced into drawings. If there is a legal ramification in the case where you don't incorporate ergonomic aspects, actually you face a certain level of legal liability at the end. I think every consultant would then say, that if that is the case, we need to be compensated accordingly.
Participant 6	Depending on the type of project, some for which you won't necessarily find it practical to take this new legislation into consideration, especially for projects where enormous amount of material in volume must be moved, and big distances covered in the build. Again, it boils down to whether it was a stipulation or specification at the onset, then Designers will find ways to accommodate and adhere to the new legislation. But I am of the opinion that it will have a major influence on the economic model of the project. Projects will most likely become more expensive at the design stage and that may negatively affect the Clients green light to commence with the project. It will have a detrimental economic impact. I am not entirely comfortable that the risk must vest with the Designer, as Designers are not necessarily on site every day. You can take as much care to

	design for the optimum ergonomic benefit at the onset, but if they don't practise it on site in the correct manner, then the risk can't vest with the designer.
Participant 7	I don't deem it fair that this legislation is imposed on Designers alone. In terms of knowledgeable decisions at design phase, I do agree that due care must be exercised in ensuring a safe design. Implementation of the design, however, must be the major driving factor and there the designer has a limited role.
Participant 8	I deem it a bit unfair, because it depends on your appointment. If you are not a full-time site agent, and you have only done a design intent to the best of your capable knowledge and as per the Engineering Council of South Africa (ECSA's) requirements, I fail to see how I, as a designer, can be held liable. How can I be held liable if a site agent is not applying the health and safety act properly, or not looking after the well-being of his work force, getting them to dig trenches by hand for kilometres, just to make his 30% mark.
Participant 9	I feel the responsibility should be shared and H&S prioritized. Legislation is good as it defines who takes responsibility and creates a standard for H&S and compliance.

Question 8: How do you feel about the EPWP's requirements of using labour-intensive construction?

Participant 1	All the construction firms enact this now, at the onset, clarity is sought regards the type of contract and labour is sourced in accordance. I am of the opinion that the EPWP contract is hampering the economic benefit to the labourer, as the renumeration rates within the contract is lower than the legislative construction charter. With the EPWP more labourers are to be employed, hence more job opportunities are created, which is positive, however the project takes longer to complete. Daily rates are being adhered to, normally from 07h00 to 17h00 with 30min lunch break. EPWP requires 8 hours a day with an hour lunch break. Production time is lost. Targets are seldomly achieved. Tenders are generally won on costings and duration, EPWP labour force missing target, will incur penalties. The requirements, standardly requires overalls, courses etc to be issued and implemented, which the design engineer is absolved from as the Client pays for this as an item in the bills of quantity. The only way for labour-intensive construction to be more viable, is for it, at the onset to be subjected to the EPWP contract, the duration expectation to be lengthened to accommodate, and the technological specification relaxation to be granted. Typical labour-intensive activities are laying of piping, head walls, v-drains, kerbs and paving. Earthworks is machine driven.
Participant 2	I think that the quality of labour-intensive construction can match that of conventional methods. However, time is the largest factor when considering labour-intensive construction. Unfortunately, you don't have the time to waste on

	projects and if you state to the client that the project will take that much longer, you will surely not win the tender.
Participant 3	I think it can work. I have seen it work before. Obviously, it won't be as productive and as cost effective as conventional methods, but in terms of financial gain, the community will grow and it will benefit the entire community's living standards. The only problem becomes the quality of the end product, as sometimes this is not 100% up to standard. Quality is compromised in most cases. In labour-intensive projects they use small rollers, instead of the big ones. With the big ones, compaction is more likely to achieve the density required by the set specification, but with the small rollers, you have to do lots of passes to attain the specification, as opposed to the big rollers.
Participant 4	Look, it is a more hazardous thing, but I really like it. I tell you why, it creates a sense of hope for the people. It is however more expensive but it has got other spin offs. The problem with this is, in South Africa, that once you employ them, they start becoming a pressure group trying to force their way into permanent appointments and stuff like that. I really like it but it has got a bad side to it as well, where it is more expensive and it is obviously destitute people who benefit from it, and then when they get onto their feet, they get laid off after the project is completed. I have had this in many cases. Some people would say that it is as productive and as cost effective as conventional methods. However, I would marginally disagree. You may be able to build it "good enough", but you cannot grade a road with people, it will be bumpy. So no, I don't think you will get the same quality. But you can do certain things in the project, but not the whole project.
Participant 5	In my experience there was a fundamental flaw in the way these projects were structured. On one of my projects we used unskilled labour for things like digging trenches, and casting concrete side drains. Therefore, the workers required training. The client (being the municipality) needed the project to get started, so they put the responsibility on the contractor to train the work force, and then because they get budget allocated from department of labour for training, they said they would do the training later, when the funds came through. The task to train the work force fell on the contractor. I believe this was not fair practise as the contractor has a programme and milestone dates to meet with an unskilled work force to complete the tasks. This exposed the contractor to rework, injuries and undue risk. The training, which took place at the end of the project, was way too late. The planning should have included 2 weeks prior to commencement training. What was very positive though, was that you had many poor and underprivileged people who, even if it was for a short period of time (6 to 8 months,) at least could earn a living and could upskill their lives and knowledge of trade. They had been given a certificate at the end, so they added a life skill and some technical experience. Some of the guys that were really good, ended up with permanent employment with the contractor. The contractor could more readily and easily identify talented, hardworking and ethical workers.

Participant 6	I feel it is warranted in some cases as it creates jobs. Which is the main goal. It is multi-faceted, as it uplifts the local communities. Even though it is "give a little, take a little". If you don't have to conform, projects will be cheaper and faster to execute, at a higher quality. But everyone acknowledges that there is a need for creating jobs and hence it is warranted. In terms of comparing it with conventional methods, I don't think that you can fairly compare the two. Conventional methods make use of machinery and you can tackle the project and get it over and done with in the shortest space of time. Compaction for instance, utilising a person with a small roller as opposed to a big roller. But because you want to create jobs for 5 people, the smaller rollers are the more cumbersome approach. Quality is not the same and it is indeed cost intensive.
Participant 7	I am not as experienced in EPWP projects, I am aware of the concept though. I believe there is a place for it, especially in projects where it has the benefit of uplifting and educating the community, but there are certain projects where tasks demands conventional methods. You can't rebuild the N1, for instance, as an EPWP driven project. It must make sense realistically and economically. I have first-hand knowledge of a design project where the quality was outstanding, for the type of traffic this rural road would experience. In the bigger projects there is a component of EPWP that can be worked into it, like walkways for instance, where good quality is achievable.
Participant 8	I am not completely in line with it. I know it is job creation, but it is a temporary job creation. If the project is done the worker did not learn any new skills, which he is going to use in the near future. Rather make them operators, or give them better skills in conventional methods, not only using them as local hand labourers.
Participant 9	Good initiative to create jobs, let people work for their grant money. Employs rural populations.

Question 9: Have you implemented ergonomic principles in your designs? If yes, what were major challenges?

Participant 1	Yes, I have. Toolbox talks is held every morning. Daily Safety Task Instruction (DSTI's) is important. Safety, barricading, reporting of minor injuries to re-assign the person in accordance. Walkways to site, clearance is not dictated by the consulting engineer, rather the work force finding their way. Only for long distance, will labourers be transported by vehicular methods. Health and safety dictates that labourers can no longer be carried from point to point on the back of a truck. It must be a CAB fitted out with safety belts. Very few contactors can implement, or have this in their fleet. Transport of labourers is becoming a major challenge. Working at heights is a challenge. Lifting heavy pipe work is a challenge.

	A designer, who is designing for a labour-intensive project, must look into various other products that can fulfil the same quality requirements as concrete piping. Armco corrugated steel pipes, can be carried or pushed in a wheelbarrow and assembled in the trench. Designers must be more open minded when designing for a labour-intensive project. Hence, practical designing is a huge challenge. Most Designers do not have labour-intensive experience, nor contractual experience, and have not completed labour-intensive courses to understand the Ergonomics behind it.
Participant 2	Yes, we reduce the number of layers when designing roads in rural areas because layer work is very labour-intensive. The major challenge is to ensure the road is fit for purpose with regards to lifespan and to ensure that the road is the correct width from the onset. It is very difficult to broaden a road after completion due to existing infrastructure such as drainage or pedestrian walkways.
Participant 3	Not me personally, but the engineer I worked under during an EPWP project made it a matter of principal. For example, workers were required to use their pick and shovels to load the trucks with material. Each person was required to dig a cube of material per day and load it onto the truck. Firstly, through trial and tested methods, a cube per day was deemed a reasonable load on a person's body to perform this task day in and day out for the duration of the project. Secondly trucks were parked on a lower level to ease the loading process. The major challenge that everyone does not have the trial and tested experience required to effectively mitigate these risk factors.
Participant 4	Yes, I have done that, and it is in actual fact a must. I have done it many times. Bus lay-byes, docking manoeuvres at warehouses with articulated delivery trucks, making sure the turning circles work and people being able to see where you are parking. If you can't see where you are parking, there will be an accident. And we designed the nudge bars to catch the wheels. Ergonomics in delivery heights is a problem, you should design so that people aren't working in a crouched position all the time. It is important that your designs allow people to work in a relaxed manner. Are designs were predominantly implemented on projects like large ports and mines. A challenge is when you have fixed conditions, like existing infrastructure. What that means, you have to put a bridge under something where people walk, but the existing embankment has got certain restrictions and services to relocate. Especially on brownfield projects where you have to adapt the new with the old and there you need to be very creative.
Participant 5	I would say, informally yes. An example, I stress this to all, also my juniors that I work with, is whenever they give me a detail, or a section or something, I put a person there, a scale model, so that they understand how a person interacts with that piece of infrastructure that they have designed. For example, with things like chambers, valve chambers, manholes and things like that, you need to design access into a manhole, how do you make space available for someone to climb down a very narrow shaft and ensure that there is ventilation. So, some of these ergonomic principles I have written into the design guidelines.

	However, this is not governed by a formal process of ergonomic design. But ultimately it is a thought process with the end-user in mind and not the work force during the construction of it. We do consider things like where the site camp is going to be located and what facilities need to be made provision for because we have to price this into the project and put it in a bill of quantities. Foremost we think about the health and safety legislation. To summarise, we don't have a formalised process in respect of ergonomic design. Biggest challenge is always time and budget. When under pressure to get something out, something that complies only with the minimum design standards, goes out a lot quicker. In general, in the construction industry, we are under much more pressure in terms of budgets. We work for a lot less now than what we billed 5-10 years ago. Time is money. Commercial clients sometimes have unrealistic expectations regards timelines. Government clients' frequently delays projects and then at the last minute there is a mad rush to put the designs out. That ends in the biggest risk items for ourselves, as we don't have the benefit of time to think about Ergonomics during the built phase, but rather simplistically address the end-user Ergonomics. Perhaps most don't fully understand the ergonomic requirements. Sometimes we don't work with the contractors closely enough, so we don't put ourselves in their shoes, and then we don't know how our design will impact the person who is implementing it.
Participant 6	I want to respond in the affirmative. Specifically, in using paving instead of asphalt. Paving is a lot more labour-intensive than asphalt, more commonly machinery is utilised for asphalt. You must adhere to standards when you design. For example, when you design layer works and the persons that will execute the work, you must still have some depth control over roads. But when you have to practise Ergonomics, you will opt for a sacrificial layer, meaning that you will have less layers, to accommodate the work force. The design therefore is not an optimum design, and that is challenging.
Participant 7	A road construction is actually very straight forward, I could not highlight a specific element of the design as a challenge. It does have a slight financial implication. I won't say that there is a major challenge to Designers in the holistic sense of the word pertaining to civil engineering.
Participant 8	No, I have not. However, challenges with regards to health and safety design is mostly cost, and client related cost for redesign.
Participant 9	Yes. I'm in road projects mostly where traffic accommodation and keeping traffic away from the work front is very important and is looked at carefully in design stages. Designing occupational health and safety friendly works that is general enough to be implemented by any contractor is a challenge.

Question 10: What courses have you attended with regards to Ergonomics?

Participant 1	None. However, I have completed CBD & NQF5 courses.
Participant 2	None, but I have some road construction courses under my belt. These focussed on construction, the utilisation and work methodology of plant, the operation thereof, in short good practise in designing, but not at all focussed on Ergonomics.
Participant 3	None. I have not seen or heard of any Ergonomic courses.
Participant 4	I have not done any courses related to Ergonomics, neither have I seen or heard of any courses for Ergonomics. But that would be excellent if it was introduced. Any designer design things because the client wants it. You need to think for the user. That came with experience, as you have to go back and fix problems as they occur. You need to know that when walking on the sidewalk, you need 1.5m as two people need to be able to pass one another safely, otherwise one will step into the road and get run over, possibly knocked down or killed.
Participant 5	The closest thing that covers Ergonomic design is that when I studied, this is 15 years ago, we had a course on environmental management and in the environmental management course, because it is quite human centred, it would talk a lot about, what is the impact of construction on people. That really is the extent of it. I have not done any CPD courses related to Ergonomics. I have not heard of any Ergonomic courses for Designers.
Participant 6	No formal module existed when I was busy studying, it was mentioned though. I have not done any CPD courses related to Ergonomics. I have not heard of or seen any Ergonomic courses.
Participant 7	None. I have not seen or heard of any Ergonomic courses.
Participant 8	None. I have not seen or heard of any Ergonomic courses.
Participant 9	None.

Question 11: Do you feel formal training on ergonomic principles is important?

Participant 1	Yes, this is very important. This will close the large gap between design and site experience. Most Designers have no site experience and only design what was taught as basic design principals. They don't understand the working conditions of construction workers and therefore cannot effectively mitigate these problems.
Participant 2	I am 100% for this being a tertiary requirement for a degree.
Participant 3	In general, you just have to be smart for you to avoid people sustaining injuries on site. I don't think anyone received specific training on it. So, lets rather excavate, the tipper truck would go deeper and then you load it from top to

	bottom. Trial and tested rather than study material. If you are lazy to think, no added module or course can teach you how to think in a problem-solving manner. I have met many brilliant engineers who solve the problem on site. They see something wrong and they address it there and then and propose an alternative method to do it, rather than designing it.
Participant 4	Yes, I think so. I will tell you why, we were very structured when I was young and we had exceptionally good mentors. There is a huge gap nowadays. So that middle tier people are gone. So yes, we need it now.
Participant 5	I absolutely think that a course matter on Ergonomics as a module in the secondary and tertiary phase of learning will be a benefit.
Participant 6	I think if the legislation is passed, and the Designers must take the responsibility, then it is instrumental that the thought processes in design be changed to accommodate. Therefore, Designers must be educated in the ergonomic mitigation of risks.
Participant 7	Yes, I think it would be very interesting to have a subject dealing with this included in the study material. Only health and safety regulations were addressed in course material when I studied. Ergonomics is a new thing. I do feel that if Designers are going to be kept legally responsible for Ergonomics, then there must be official guidelines issued for the industry. At the moment the mentor's pathways formed by experience, are being followed by most. Designers think technically and are not used to considering ergonomic issues that might come up.
Participant 8	Yes, because at the moment only a relative background of it is available.
Participant 9	Yes.

5. Data Analysis

This chapter presents the data analysis of the interviews. The participants responses were coded to highlight common answers and differences to each question. The results have been summarised to provide easily interpreted and understandable information.

5.1 Interview Data Analysis

Participants were asked a series of questions and asked to elaborate during a semi-structured interview. Below are the coded responses to the focused questions and how their answers compared with what was found in literature.

Question 4

Although participants could not define Ergonomics in its totality, most were familiar with the term and could mention some aspects of Ergonomics. This supports a study done by Smallwood (2017) that found that Designers rated their knowledge of Ergonomics as 'below average'.

Question 5

Majority of the participants mentioned some form of physical Ergonomics as common problems. Heat stress was the most prevalent amongst the problems mentioned. Repetitive stress and forceful exertions where mentioned to a lesser extent. Some added that organisational Ergonomics were common during a project. Particularly where health and safety were overshadowed by money and where a health and safety culture problem existed amongst contractors leading to a disregard of health and safety measures.

The above mentioned are common ERFs encountered on construction projects as supported by literature (Ahankoob and Charehzehi, 2013; Choi, Yuan and Borchardt, 2016; Wang et al., 2015, Jaffar et al., 2011 and the Department of Employment and Industrial Relations, 2007). However, many ERFs were left unmentioned which indicated that Designers did not fully comprehend how to identify ERFs.

Question 6

The majority of the participants were of the opinion that responsibility should be shared between members of the project team (contractor, site agent, health and safety agent etc.). This is supported by the common knowledge that health and safety is the responsibility of all stakeholders involved. However, literature suggests that up to 50% of incidents / accidents can

be avoided through hazards and risks mitigation by means of design (Goldwain and Smallwood, 2015). Therefore, Designers should not take the responsibility lightly and not shift the responsibility to other stakeholders without applying due diligence.

The remaining participants felt that the site agent and / or health and safety site agent, together with the appointed contractor, should be responsible for mitigating ERFs. Although the site agent, H&S agent and contractor may be better suited to mitigate ERFs on site, the Designer has an important role to play by degining ergonomical sound projects that can be implemented by the H&S agent and contractor.

The Designers' resistance to take responsibility for ERF mitigation may be attributed to the lack of Ergonomic knowledge amongst Designers (Smallwood, 2017 and Smallwood and Wium, 2015).

Question 7

The prevailing theme amongst the participants was that such legislation (Republic of South Africa, (2017); Republic of South Africa (1993) and Republic of South Africa (2014)) would not be fair due to the fact that Designers are not on site every day to ensure compliance. Therefore, the implementation of their designs is out of the designer's control.

A valuable concern was raised whereby the participant explained that contractually the contractor is responsible and remains responsible for health and safety matters until the site is handed over. Therefore, the entire project scope of works, inclusive of environmental and safety falls under the contractor's responsibility. The researcher is unsure whether contractual law supersedes legislation set out in the OSHAct and Construction Regulations.

Question 8

Participants agreed with literature that EPWP's requirements of using LIC is a good initiative for addressing the unemployment rate in rural areas as well as providing workers with skills that they can utilise when the project is completed (McCutcheon, 2017).

However, contradictory to McCutcheon (2008b), participants were of the opinion that mostly time, but in some cases quality, will be sacrificed to accommodate labour-intensive construction. McCutcheon (2008b) stated that if the projects are well designed and implemented, LIC methods do not compromise time, cost or quality. The participants opinion

may likely have been influenced by personal experiences where the basic principles to ensure successful implementation of LIC programmes were not applied.

Although it is crucial that the H&S of employees are not compromised it is when designing for labour-intensive construction projects (Twala, 2007), only one participant acknowledged the fact that with labour-intensive construction comes higher risk of workers sustaining injuries or even fatalities.

Question 9

Whilst participants were able to mention some ERFs (refer to Question 5), the majority acknowledged that they have not implemented Ergonomic principles into their designs. A participant added when Ergonomics was integrated into his designs, it was ultimately with the end-user in mind and not the work force during the construction of the project. This statement corresponds with the findings of Smallwood (2015).

Again, participants mentioned that time and money were the biggest constraints for implementing Ergonomic principles into their designs. As seen in Question 8, this contradicts the findings of McCutcheon (2008b). Choi, Yuan and Borchardt (2016) disagree with the participants as their study found that implemented Ergonomic programmes improve worker moral (increasing productivity) and reduces compensation costs, which in turn improves increasing profitability.

Question 10

According to the majority of participants, their tertiary studies did not include a module on Ergonomics. A participant mentioned that the only module that came close to Ergonomic design during his tertiary studies was Environmental Management. The module was essentially human centred and focussed on what impact construction has on people. The absence of Ergonomics in civil engineering curricula is supported by the civil engineering curricula review of four (4) major South African universities, together with studies conducted by Ek et al. (2015) and Naeinia and Mosaddad (2013).

Interestingly, all participants stated that they have not attended any CPD course or workshop with regards to Ergonomics, neither have they heard of any such course or workshop. Therefore, participants relied primarily on mentorship and / or professional experience, by means of trial and error, to attain Ergonomic knowledge. This is supported by Smallwood

(2017) which stated that the source of Ergonomic knowledge is more informal (such as experience) than formal (tertiary education).

Question 11

The general opinion amongst participants was that Ergonomic principals should be included as a module and made a prerequisite for a degree at tertiary institutions. This is supported by literature as Ek et al. (2015) emphasises that Students need to gain an understanding of how Ergonomics can be integrated in the design of workplaces, organisations, products, and services. Without a solid theoretical foundation, Designers will not be able to conduct optimal hazard identification and risk assessments with regards to Ergonomics in their designs. Universities have a responsibility to educate engineering students about human-work area interaction related to H&S problems (Naeinia and Mosaddad, 2013).

5.2 Summary of Results

Below is the summary of responses during the interviews.

Question 1: Why is health and safety important on a construction site?

- There was a general consensus amongst participants that health and safety is an essential part of any successful project.
- Some participants acknowledged the legislative nature of health and safety in the construction industry.
- Participant 1 and 2 mentioned the ‘lost time’ as a result of severe injuries and fatalities being a cost and programme burden.
- Participant 4, 5 and 6 described the social impact which health and safety has on a person, his dependants and the community.
- Participant 7 was the only one that placed emphasis on the construction phase of projects.
- Participant 9 mentioned some of the benefits of good health and safety practices, such as a motivated workforce, which in turn is more productive.

Question 2: What type of injuries have you encountered or heard of?

- Participant 1, 3, 8 and 9 mentioned that incidents / accidents involving traffic and machinery were common.
- Working at heights was a common cause of injuries / fatalities according to participant 2, 6 and 7.
- Participant 5 and 6 explained that hand injuries (such as lacerations, splinters, cuts, abrasions or blisters) were common amongst construction workers.

Participant 5 and 9 were the only interviewees that expressed musculoskeletal injuries, such as back strains, as a common cause of injury due to repetitive stress. Participant 5 added trips and slips to the list of common injuries.

Question 3: What are the positive or negative impacts when designing with health and safety at mind?

Positive Impacts:

- Participant 1, 4, 5 and 9 all mentioned an aspect of structured and smooth process flow which allows for easier implementation of health and safety measures according to the health and safety plan. This in turn reduces injuries and construction can proceed without delays due to severe injuries.
- Participant 1, 2, 6 and 7 acknowledged the legislative requirements and governance with regards to health and safety. Designing within the framework of the regulations aids in reducing injuries and keeping people safe.
- Participant 8 has never entirely designed with health and safety at mind.

Negative Impacts:

- Participant 2 and 3 acknowledge that their designs are focussed on end-user health and safety rather than worker health and safety during the construction phase of projects.
- Participant 1, 4 and 5 mentioned that health and safety designs and plans took extra time and effort to implement, which reduces productivity. It is worth noting that Participant 4 explained that health and safety only causes delays because of human

nature, not because of the institution itself. The Participant added that Health and Safety should not cost you more timewise, it should save you time, but it is the human approach / culture that affects it negatively.

- Participant 7 stated that costs were higher due to health and safety implementation.
- Participant 6 expressed that Designers are sometimes hindered from designing to the full safety specification due to the site constraints.

Question 4: How do you define Ergonomics?

- Participant 1 was not familiar with the terminology.
- Participant 2, 3, 6, 7 and 8 defined Ergonomics in the line of being physically able to adapt to working conditions.
- Participant 4 and 5 defined Ergonomics as a science of how people interact with things.
- Participant 9 defined Ergonomics as the employees working environment.

Question 5: What are common ergonomic problems you have encountered or identified during a project?

- Participant 1, 3 and 4 stated that organisational Ergonomics were common during a project. Particularly where health and safety were overshadowed by money and where a health and safety culture problem existed amongst contractors leading to a disregard of health and safety measures.
- All participants, except 2 and 3, mentioned some form of physical Ergonomics as common problems. Heat stress was the most prevalent problem mentioned. Repetitive stress and forceful exertions where mentioned to a lesser extent.

Question 6: In your opinion, who should be responsible for mitigating ergonomic risk factors?

- Participant 3, 4, 5 and 7 stated that responsibility should be shared between members of the project team (contractor, site agent, health and safety agent etc.). This is supported by the common knowledge that health and safety is the responsibility of all stakeholders involved.

- Participant 8 and 9 are of the opinion that the site agent and / or health and safety site agent should be responsible for mitigating ergonomic risk factors. Participants 1 and 6 expressed their opinion that the contractor should take responsibility to mitigate ergonomic risk factors. Participant 6 does however state that Designers must be informed beforehand that the project will be labour-intensive in order for them to design accordingly.

Question 7: Please elaborate on how you feel about new legislation which might hold you accountable for the ergonomic wellbeing of construction workers on site?

- Participant 3 and 4 stated that the legislation is fair and just. However, Participant 3 added, although their designs are in accordance with health and safety regulations and standards, that the implementation of their designs is out of the Designer's control. Participant 2 and 6 shares the same concern of Participant 3 as Designers are not on site every day to ensure compliance.

- Participant 6 is of the opinion that it will have a major influence on the economic model of the project. The participant explained that projects will most likely become more expensive at the design stage and that may negatively affect the client's green light to commence with the project.

- Participant 7, 8 and 9 expressed that it is unfair to solely hold Designers accountable for ergonomic wellbeing of construction workers. They reiterated that health and safety should be a team effort and responsibility should be shared.

- Participant 1 was in two minds. Although the participant accepts the legislative nature of designing, the enforcement thereof was questioned. The participant explained that in the GCC, JBCC and SANRAL contractual documentation, it is specifically outlined that the contractor is responsible and remains responsible until the site is handed over. Therefore, the entire project scope of works, inclusive of environmental and safety falls under the contractor.

- Participant 5 highlighted the fact that it is acceptable for Designers to take responsible for safe designs and be held accountable. However, the participant posed the following concerns with regards to ergonomic legislation:

- How many Designers actually do think about Ergonomics in their design process?
- How many people currently understand what the legislation requires?
- Ultimately who pays for that additional effort that goes into incorporating all those Ergonomic aspects required?

Question 8: How do you feel about the EPWP's requirements of using labour-intensive construction?

- All participants, except for participant 8, stated that EPWP's requirements of using labour-intensive construction is a good initiative for addressing the unemployment rate in rural areas as well as providing workers with skills that they can utilise when the project is completed. These opinions are well supported by literature. Participants do acknowledge the fact that mostly time, but in some cases quality, will be sacrificed to accommodate labour-intensive construction.
- Only participant 4 acknowledge the fact that with labour-intensive construction comes higher risk of workers sustaining injuries or even fatalities.
- Participant 8 accepts that the EPWP's requirements is good for job creation, however, the participant is concerned about how temporary the situation is. Talking out of experience, labourers are not left with skills they can utilise in the near future. The participant suggested that the unskilled labour should be rather made operators, or provided with better skills in conventional methods, not only using them as local hand labourers where nothing is learned.

Question 9: Have you implemented ergonomic principles in your designs? If yes, what were major challenges?

- Participant 3, 7 and 8 have not implemented ergonomic principles in their designs.
- Participant 5 stated that Ergonomics was informally applied to the participant's designs. The participant explained that designs are modelled to demonstrate how a person will interact with the particular design to junior engineers. However, there is no formal process governing the designs. The participant added that it was ultimately a thought process with the end-user in mind and not the work force during the construction of it.

With that said, time and money were listed as the biggest constraints for implementing ergonomic principals into designs.

- Participant 6 stated that Ergonomics was applied in designs by limiting the number of layers for labour-intensive construction projects. The participant added that material selection also plays an important role, for example using paving instead of asphalt as paving is a lot more labour-intensive when compared to asphalt. The participant found quality to be a major challenge as quality of labour-intensive roads cannot be compared to that of conventional methods.

- Participant 9 stated that a common challenge was to design health and safety friendly works that is general enough to be implemented by any contractor.

Question 10: What courses have you attended with regards to Ergonomics?

- According to the majority of participants, their tertiary studies did not include a module on Ergonomics. One of the participants mentioned that the module that came the closest to ergonomic design during his tertiary studies (which was 15 years ago) was Environmental Management. The module was essentially human centred and focussed on what impact construction has on people.

- Participants have not attended any ergonomic CPD courses, neither have they heard of any courses on offer. However, all participants stated their interest of attending such a course if one becomes available.

Question 11: Do you feel formal training on ergonomic principles is important?

- All participants, except participant 3, said that they feel ergonomic principles should be included as a module and made a prerequisite for a degree at tertiary institutions. Participants said that their degrees, did not cover Ergonomic principles in detail, if it was mentioned at all.

- Participant 4 added they learnt by experience and guidance from exceptionally good mentors. The participant went further to state that there is a large gap nowadays as a result of middle tier professionals which are no longer in the industry.

- Participant 3 is of the opinion that experience and willingness to think is how Ergonomic risk factors should be solved. The participant explained that if you are lazy to think, no added module or course will or can teach you problem solving thinking abilities.

6. Conclusions and Recommendations

6.1 Introduction

Before the conclusions and recommendations are discussed, it is important to establish whether the research aim and objectives were achieved and if the research questions were answered.

6.2 Results Discussion

The results, as presented in the previous chapter, achieved the aim and objectives that the study set out to investigate. A discussion of how the aim and objectives were achieved is described below.

6.2.1 Research Aim and Objectives

The aim of the research was to determine the extent Civil Engineers address Ergonomics during labour-intensive construction projects in South Africa. This was achieved by conducting semi-structured interviews with civil engineers responsible for designing road construction projects, particularly projects that had an element of LIC.

The research set out to achieve the following objectives:

- To ascertain the extent which Ergonomics is covered in Civil Engineering curricula and where Civil Engineers gained Ergonomic knowledge, if not at tertiary level.

This objective was achieved by conducting a curricula review from various universities to establish whether Ergonomics formed part of their civil engineering programme, as well as asking participants where they obtained their knowledge of Ergonomics. The curricula review found that Ergonomics did not form part of any civil engineering programme investigated. This was supported by literature and confirmed by participants, whereby none of the participants stated that their course work included Ergonomics. Additionally, participants stated that they have not attended any CPD course or workshop with regards to Ergonomics, neither have they heard of any such course or workshop. Therefore, participants relied primarily on mentorship and / or professional experience, by means of trial and error, to attain Ergonomic knowledge.

- To establish common Ergonomic problems encountered on road construction projects and identify what was done about it.

This objective was partially achieved by means of the semi-structured interview process. The objective was partially achieved in the sense that a significant number of participants mentioned thermal stress (particularly heat stress) as a common Ergonomic problem, which is classified under physical Ergonomics. Not only does the exposure to UV-rays from the sun cause adverse health effects, but it increases the risk of fatigue related injuries. One participant mentioned the carrying of heavy material, such as 50 kg bags of cement, which increases the risk for back and lower limb injuries. These injuries are a direct result of improper lifting techniques, repetitive stress and forceful exertions.

However, the objective failed due to Remainder of the participants that could not mention any problems or did mention Ergonomic problems, but it was not applicable to road construction. Consequentially, the majority of participants did not have a clear and concise explanation on how they have mitigated ergonomic problems in a labour-intensive setting, nor how they would mitigate the risk factors if they should come across these problems during a project.

- To determine whether Civils Engineers are competent to perform their duties as Designers, as set out in the OHSAct and Construction Regulations with regards to Ergonomics.

This objective was achieved by evaluating the participants' answers together with the curricula review. As supported by literature, currently there is an Ergonomic knowledge shortfall amongst Designers. A Designer cannot solely rely on experience and mentorship to impart this knowledge on a person, as Designers will be exposing the workforce to ERFs during the "trial and error" phase of their career. In order to be found competent, a Designer should have a solid theoretical foundation and ample practical experience with regards to Ergonomics and the mitigation of ERFs.

6.2.2 Primary Research Question

The research set out to answer the following primary research question:

To what extent does Civil Engineers address Ergonomics during labour-intensive construction projects in South Africa?

The question was answered by evaluating the participants' answers. The study found that civil engineering designs did not implement or include Ergonomic principles. Where Ergonomics

was applied, it was not applicable to road construction projects and concerningly focused on end-user Ergonomics rather than worker Ergonomics during the construction phase of projects.

6.2.3 Secondary Research Questions

The research set out to answer the following secondary research questions:

1. What depth of knowledge do civil engineers have on Ergonomics?

Results of the interviews indicated that the majority of participants could not define Ergonomics without some explanation / assistance. After a short introduction, participants managed to derive that Ergonomics has to do with the physical ability of a human to perform a specific function, how things are designed to adapt to the user and the workers physical working environment. Although these elements mentioned do form part of Ergonomics, not one participant could comprehensively define Ergonomics in its totality.

2. How was Ergonomic knowledge acquired amongst civil engineers?

During the interview process, participants revealed that they relied primarily on mentorship and / or professional experience, by means of trial and error, to attain Ergonomic knowledge.

3. Were civil engineers familiar with all applicable health and safety legislation?

The legislative nature of Health and Safety, particularly Ergonomics, was discussed during the interviews. The results indicated that participants were aware of the Occupational Health and Safety Act and the Construction Regulations. However, participants were not aware of the draft Ergonomics Regulation (awaiting promulgation). Neither where they aware of the duties and responsibilities placed on them by these regulations.

6.3 Conclusion

Keeping the limited data set in mind, the study's findings formulated a proposition that labour-intensive construction projects are likely designed without taking ergonomic risk factors into account as civil engineers, in their capacity as Designers, lack ergonomic knowledge in South Africa.

This was made evident when the majority of participants could not define Ergonomics without some explanation / assistance. Consequentially, the majority of participants did not have a clear and concise explanation on how they have mitigated Ergonomic problems in a labour-intensive

setting, nor how they would mitigate the risk factors if they should come across these problems during a project. Where Ergonomics was applied, it was not applicable to road construction projects and concerningly focused on end-user Ergonomics rather than worker Ergonomics during the construction phase of projects.

Additionally, participants were not aware of the draft Ergonomics regulation (awaiting promulgation). Neither where they aware of the duties and responsibilities placed on them by these regulations. This is striking because of the fact that the draft regulations have been circulated for public comment in 2014. One will expect that Designers will at least be aware of the regulations, if not familiar with the content thereof. This speaks to literature that found that engineers do not acknowledge the importance of Ergonomics, even though it is legislated and might hold serious consequences.

Interestingly, all participants were concerned with the time and cost aspect should the Ergonomic regulation be promulgated. However, only one participant seems to be wary of the current competence amongst Designers with regards to Ergonomics. This is concerning as many of them do not fully comprehend what Ergonomics entail, nor how to mitigate these risk factors during the construction phase of a labour-intensive project.

Worthy to mention, one participant rightfully brought up an issue relevant to the change we see in the workforce these days, woman in construction. Designers should be mindful of who the workforce will consist of. Gender plays a significant role in the physical abilities of the workforce (along with age, regular exercise, diet and environment) and Designers should design accordingly and make provision for woman in construction.

6.4 Recommendations

Whether or not labour-intensive construction is the South African government's long-term solution to job creation and imbedding skill into the unemployed, Designers should be able to design projects that does not place the worker's H&S at risk. Not designing Ergonomically sound projects does the opposite of what is lawfully prescribed in the OHSAct, Construction Regulations and soon to be promulgated Ergonomics Regulation.

6.4.1 Theoretical Recommendations

The current Ergonomic knowledge shortfall amongst Designers should be addressed by formal education. As suggested by the majority of the participants, a module should be added which

will cover Ergonomics principles and should be a prerequisite for a degree at tertiary institutions. This will ensure that Designers obtain a solid Ergonomic foundation, in order not to place the workforce' H&S in danger, whilst continuously building on that foundation, by means of experience and mentorship.

6.4.2 Recommendations for Applying Ergonomics in Practice

As soon as the Ergonomics Regulation is promulgated, Ergonomics CPD courses should be promoted and commonly made available for enrolment therein. Designers who are currently practicing, without having covered Ergonomics in their tertiary degrees, should be strongly advised to attend such a course in order to apply theory to practice. In the case where CPD courses do not become available, I would strongly advise Designers to do self-studies on the topic.

Whether ergonomic knowledge is acquired by means of a tertiary module, CPD course, or self-study, it will benefit the workforce having to implement these designs and the Designer will be able to design projects that will be easier and faster to construct. The nett result will be a productive and happy workforce.

Lastly, the result indicate that Designers were unaware of the new Ergonomic Regulation. Therefore, it is recommended that Designers should be made fully conversant with all the Laws and Regulations that govern Ergonomics and what duties are placed on Designers in order for them to comply.

6.5 Suggestions for Future Research

Research with a larger sample size would give a better insight into the extent of the research problem. Further research could also include contractors in order to evaluate how they implement the health and safety measures that the Designer has incorporated into the designs.

The construction industry is a male-dominated environment. However, the construction industry is moving toward employing more females. Gender plays a significant role in the physical abilities of the workforce. Therefore, future research could investigate how Ergonomics principles are applied to make provisions for woman in construction.

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8. Appendix A

Ethical Clearance Certificate

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SCHOOL OF CONSTRUCTION ECONOMICS AND MANAGEMENT RESEARCH ETHICS COMMITTEE

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER CEM/19/02/MM**
PROJECT TITLE	Mitigating Ergonomic Risk Factors in Labour-intensive Construction
INVESTIGATORS	Marius Meintjes (690834)
SCHOOL/DEPARTMENT	**SCHOOL OF CONSTRUCTION ECONOMICS AND MANAGEMENT**
DATE CONSIDERED	13/02/2019
DECISION OF THE COMMITTEE	Approved conditionally with respect to the declaration
EXPIRY DATE	14th February 2020
DATE 13/02/2019	**CHAIRPERSON** Dr. Kola Ijasan

cc: Supervisor: Prof D. Root

DECLARATION OF INVESTIGATOR (S)

To be completed in duplicate and **ONE COPY** returned to the Secretary Mrs. M. Sithole at the CEM reception desk.

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

Signature _____ Date 14 / 02 / 2019