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The effectiveness of efficiently managing the process lifecycle of medium and low voltage equipment in building services

A Mini dissertation

By

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Abstract

The construction industry is one of the core businesses in any emerging economy such as South Africa's. It employs millions of un-skilled, semi-skilled and skilled labour which ultimately contributes hugely to the country's GDP. Over and above, this industry is one of the pillars of job creation, it provides shelter and safety to most of the inhabitants of the country. This entails that the processes and procedures that govern this industry should take into consideration the safety and satisfaction of the end users.

This dissertation will focus on electrical distribution systems as an entity of building services within the construction industry, and the efficient management thereof. It will concentrate on medium voltage (MV) and low voltage (LV) distribution equipment within the building services fraternity. It will explore the management skills that should be employed in efficiently delivering and installing these systems on site in order to ensure a safe, robust and efficient installation. This study will explore aspects that ensure that a satisfactory and reliable product is delivered site, and the current drawbacks that exist that hinder this achievement.

The core focus of this study is to investigate the effects that managing the life cycle of a project efficiently has on the final product itself. In the case the final product would be fully installed, tested, commissioned, fully functional and safe MV and LV equipment on site. The study will delve into obstacles that are experienced by project engineers during the process lifecycle that hinder his function in overseeing the lifecycle. The mini-dissertation will also investigate which processes and procedures should be followed in order to achieve the best results and product at the end of the project. Lastly this investigation will touch on the kind of skills and competencies that an EE requires in order to best fulfil their role in overseeing the process lifecycle.

In order to better comprehend the current state of affairs in the construction industry when it comes to management (or lack thereof), empirical studies will be conducted. These will include reviewing and analysing existing literature and historical data in the form of journals, books, reports, minutes as well as contract documentation in order to get a better understanding of the problem. In additional, key stakeholders in the industry will be interviewed in order to get greater insight on some of the issues identified above. Lastly, surveys and questionnaires will be issued to groups of individual within different disciplines in order to get a more holistic view of the problem and solutions.

The aim of conducting the above research is ultimately to outline the reasons why some installations are not done correctly in construction projects. Thereafter the research will outline methods and tools that can be used in order to eliminate the obstacles that prevent safe and reliable installations. The research will also focus on the functions of the Electrical Engineer (EE) within the project lifecycle and the crucial role that he plays in ensuring a safe and reliable installation. Lastly the research is intended to outline the skills and competencies that the EE is required to have in order to successfully fulfil his role. This includes the path the EE should follow from the time they graduate to the point they reach Professional Engineer status. This

information will assist professionals who get into the building services industry to better perform their tasks throughout the project lifecycle in order to ensure that the equipment that is installed is not only safe and reliable, but also that the client/end user is satisfied. This will ensure that the health and safety of the end user is maintained and that the EE does not face any civil or criminal action due to loss of property or life. This will also ensure future work for the EE's organisation and ensure growth and increased market share, thus ensuring the organisation's prolonged sustainability.

I believe this is the best approach to getting a balanced and holistic picture of the power distribution discipline and the construction industry as a whole. This will then highlight key areas of focus and attention and also produce possible solutions that can be applied not only to the electrical discipline but also the construction industry as a whole.

1 Contents

Table of Abbreviations

HV	High Voltage
MV	Medium Voltage
LV	Low Voltage
Pr. Eng	Professional Engineer
H&S	Health and Safety
CIBD	Construction Industry Development Board
FEMA	Federated Employers Mutual Assurance
SANS	South African National Standards
QS	Quantity Surveyor
LSS	Lean Six Sigma
RFP	Request For Proposal
RFQ	Request for Quotation
BMK	Bulk Metering Kiosk
Mini-sub	Miniature substation
DB	Distribution Board
PE	Project Engineer
BOQ	Bill of Quantity
EC	Electrical Contractor
COC	Certificate of Compliance
SS	Six Sigma
CPM	Critical Path Method
PERT	Project Evaluation and Review Technique
DCE	Design Consulting Engineer
ECSA	Engineering Council of South Africa
EE	Electrical Engineer
ADMD	After Diversity Maximum Demand
CIDB	Construction Industry Development Board
PROCSA	Professional Consultants Services Agreement
VO	Variation Order
HVAC	Heating, Ventilation and Air Conditioning
CB	Circuit Breaker
MCCB	Moulded Case Circuit Breaker
JBCC	Joint Building Contracts Committee
PBA	Principle Building Agreement
RMU	Ring Main Unit
RQ	Research Question

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1 CHAPTER 1

OVERALL INTRODUCTION

1.1 Introduction

This main purpose of this chapter is to introduce the overall crux of the investigation to the reader. The reader will gradually unveil the industry that this topic is based on, how this investigation came about, why there is a need for such an investigation, the type of problems experienced in the industry and what the possible solutions are. This chapter will also outline the process that will be followed in the attempt to prove the hypothesis. It will outline the research questions and more importantly what objectives this investigation seeks to achieve. This chapter also includes key literature reviews that will give the reader a better understanding of the bigger picture.

1.2 Background

The construction industry, and in particular the electrical MV and LV distribution industry is based on the principle of designing and eventually delivering a safe and reliable product to the end user. The most important aspect in this industry is safety; therefore careful consideration has to be taken for the health and safety of the end user. Overall H&S in the industry has been an issue of contention to industry stakeholders, and has been on the decline for numerous years. (Levitt, 2008)

Another aspect that hinders H&S in the construction industry is the lack of compliance to regulations during the design and installation of electrical equipment. This comes about when the professionals who design the system and the electrical contractors who install the equipment take short cuts either to save money or time. (Pillay & Haupt, 2008) The CIBD is mandated to ensure that professionals and contractors apply and promote best practice standards in their work in order to ensure safety. This entails that individuals designing the electrical distribution systems should be Professional Engineers and those installing it should possess wireman's licenses. These qualifications entail that the respective individuals involved are sufficiently competent to ensure H&S. (CIDB, 2009)

Many risks are associated with electrical distribution systems that are not designed or installed correctly. Numerous accidents and deaths occur in the industry due to noncompliance. Unfortunately many of the incidents are not recorded and published in order to compile statistical data. Electrical accidents can be attributed to technical issues, either from a design or installation perspective (Bouakouir, 1987).

The most essential part of distribution system is the design. Herein the Electrical Engineer (Project Engineer) is tasked with applying in depth technical knowledge from SANS to design the distribution system. SANS 10142 is specifically concerned with ensuring compliance and safety in electrical distribution systems. This publication of standards focuses on the following key elements of safety, namely shock current, fault current, over current, over voltage, under voltage, electrical arcs and excessive temperature. In all of the above elements the bottom line is for the Electrical Engineer to design systems and subsystems that automatically isolates themselves from the source in cases of emergency in order to preserve life and minimize injury (SABS, 2017).

From the commencement of the project to the point when the product is handed over to the client, the engineer has to take on the role of a project manager throughout this process. This entails overseeing the entire process of delivering the electrical distribution system to the end user/client (Barrie & Paulson, 1992). Once the design is done and signed off it then becomes the responsibility of the qualified electrical contractor to install the electrical services in accordance to the engineer's design. However the engineer's work does not stop with the design. The engineer has to monitor and control the electrician during the installation. This entails ensuring that the installation is done to the best practice, quality and standards to ensure a safe and durable product. Also during the process lifecycle any quality issues that are discovered have to be communicated to the electrician for rectification (Sawant, 2013).

1.3 Aim of Study

This study is intended to highlight the importance of efficiently managing the process life cycle of delivering MV and LV equipment to the end user. It is intended to outline the role of the Project Engineer (Electrical Engineer) in the entire process and the sort of skills and competencies that are required in order to execute his duties. The intention is also to investigate the kind of setbacks and mishaps that could be experienced if certain processes are not followed by the Project Engineer/EE.

1.4 Problem Statement

Project management has been neglected as a profession historically. However in recent the last 3 decades it has become recognised as a necessary tool in order to achieve the required results within the specified time, budget and scope (Iron Triangle). The Project Manager does not have to perform the key technical functions with the project lifecycle himself. He just has to be able to guide the respective professionals to achieving the required goals within the specified constraints. (PMI, 2013). The Project Engineer in this study has a similar role in terms of delivering the electrical MV and LV product to the end user within the above mentioned constraints (Iron Triangle). Over and above this the Project Engineer has perform technical electrical design functions in accordance to the specifications and ensure that it is done efficiently (Sawant, 2013).

Many issues are experienced in construction electrical projects that are caused by the lack of efficient and effective management. This means that not enough effort is put into managing the process lifecycle of the project which leads not only to the triple constraints not being satisfied, but also unsafe and unreliable products being delivered to site. This problem compounds when alterations and rectifications have to be done on site in order to achieve the desired standard of product. This in turn puts the lives and wellbeing of the end users at risk because the incorrect procedures are followed could create a H&S hazard (Smallwood, 1995). The main cause of projects failing is the lack of management thereof from the very onset. This means that these projects lack the authoritative overarching figure who will be tasked with making all necessary vital decisions, resolving conflict when necessary, delegating resources where required, and promoting the project to the necessary stakeholders if necessary. It is also necessary for this individual to set out clear objectives, expectations and timelines at the beginning of the project and to delegate the functions to the responsible parties throughout the project in order to achieve success at the end (Schwalbe, 2012).

This study is aimed at investigating ways to improve the management of the process lifecycle of MV and LV equipment that will be delivered to site in construction projects. This entails finding the best and most efficient manner of achieve these goals by managing the process from the conceptual stage, to the design, planning, execution, monitoring and controlling, commissioning and testing and finally the handover of then equipment on site. This will be achieved by researching the type of challenges that are experienced that lead to the correct processes and procedures not being followed. The study will also aim to prove through investigation that following the correct procedures throughout the process lifecycle will result in a safer product being delivered to site the first time round, avoid delays that could have financial and reputational implications and maintain a satisfied client. The intention is also to develop the necessary processes and procedures that can be followed to ensure efficient management of the process lifecycle.

1.5 Research Questions

a) What are the skills and attributes that an a Project Engineer/EE should possess in order to oversee the process lifecycle of a project
b) What are the risks involved if the process lifecycle is not managed efficiently
c) What are the challenges experienced by all the key stakeholders throughout the process lifecycle
d) What are the technical and managerial processes and procedures that the Project Engineer should follow in order to efficiently manage the process lifecycle
e) How essential is reliability and when should it be factored into the process lifecycle
f) How important is quality control and should the Project Engineer undertake quality control measures
g) Who are the key stakeholders that need to be managed throughout the process lifecycle in order to achieve project success

1.6 Research Objectives

a. To highlight the risks involved if a project is not managed efficiently and effectively by the EE/Project Engineer
b. To prove that if the EE/Project engineer follows certain processes and procedures the he will be more effective in delivering the final product (MV and LV equipment) to the client/end user
c. To outline the complete role of the Project Engineer in delivering safe and reliable MV and LV equipment to the end user
d. To outline the ideal characteristics of a EE/Project Engineer in order to efficiently and effectively conduct a project that entails delivering MV and LV equipment to the end user

1.7 Motivation for the study

The drive behind this study is to find efficient ways of improving the safety and reliability of MV and LV equipment that is delivered to site without having to cut corners. It is aimed at outlining some of the risks and shortcomings that are experienced during the process lifecycle, therefore exploring and documenting the mitigating strategies that can be employed to allow for a more efficient and smoother journey to project success. It is based on an industry that the author (Morena Don Makhateng) is personally involved in. Therefore in conducting this research the author also aims to improve his project engineering skills throughout his career and to eventually share this information with other aspiring professional engineers who may be interested in pursuing this industry.

1.8 Significance of the study

If this study is conducted successfully, it will assist all entry level and intermediate engineers to better structure their management of projects. The research will also red flag some of the more pertinent issues that require the engineer’s attention throughout the process lifecycle of the project. In so doing the engineer will hopefully experience a smoother transition from junior to professional engineer. As a result of the risky nature of the consulting business, this research will also assist the professional engineer to avoid civil and criminal action against himself by minimizing the risk of delivering and unsafe or unreliable product to the end user.

1.9 Research Methodology

This entails the method that will be used to answer the RQ’s. In this study this will be achieved by using qualitative and quantitative methods in order to gather vital research information. The data collection will be done by means of empirical studies. This model works well for this type of research and will ensure that a holistic set of data is obtained in our journey to prove the hypothesis. This will be broken down into 3 main methods of answering the RQ’s. The first will entail analysing existing historical data in order to get a feel of the kind of direction the research will take. It will also assist in determining if the research problem exists and whether or not it can be solved.

The second part will involve collecting data from experienced professionals who would normally form part of the key stakeholders in a project situation. This is known as empirical data which is vital in proving the hypothesis. This is because individuals who deal with similar kinds of projects on a daily basis are best suited to provide valuable insight on the ups and downs of the project lifecycle. This will be done by interviews. Key stakeholders involved that work in the industry and have day to day experience of project and the process lifecycle thereof will be interviewed. Key questions will be posed to them and valuable data will be collected. The remainder of the data will be collected by issuing questionnaires to other key stakeholders in order to collect the required data. The sample area will consist of 50 individuals who can be considered key stakeholders within the process lifecycle. These will included but not be limited to electrical contractors, project managers, quantity surveyors, project managers and manufacturers and suppliers of MV and LV distribution equipment. The third tier of the research will involve analysing the data collected using the necessary tools

1.10 Research Approach and Design

This section is intended to outline the overall strategy that will be employed with the intention to integrate the respective components of the research. This is to ensure that the research problem is addressed in a coherent, logical and effective manner. The strategy from this research is to explore existing literature on the necessary skills required for efficiently managing the process lifecycle. It will also explore existing literature on failed projects as a result of Project Engineers not doing their jobs optimally. The author also intends exploring the technical procedures and processes of the project lifecycle that should be followed to install MV and LV distribution equipment. Lastly the researcher intends to interview experienced professionals to determine when reliability should be factored into the process lifecycle.

1.11 Research Area and Targeted Respondents

The most reliable information will be obtained from those individuals that are involved in construction projects as a profession on a daily basis. This means interviews will be conducted with and questionnaires handed out to professional engineers, QS’s, electrical contractors, project managers, manufacturers and suppliers, etc. This study will be concentrated in the province of Gauteng as this is where most of the construction projects in South Africa take place. Also it is the birth and residing province of the researcher.

1.12 Scope of the Study (Delimitation)

Although the industry that this study highlights is the construction industry in general, the stature of limitation for this particular study will be electrical distribution systems. These also form an integral part of the construction umbrella, however the construction industry and all its sub-systems is too broad and will not be included in this scope. It should be noted that although this research covers only MV and LV equipment, the principles derived here can be applied effectively in all the disciplines that fall under the construction industry.

1.13 Sampling and Data Collection

This study employs a random sampling space. In this manner all the individuals giving feedback will have an equal chance of responding. The method of collecting data will be through questionnaires and interviews. The questionnaires will either be distributed via email to individuals or completed online. The interviews will be done either face to face or telephonically. The total intended sample space will be 50 appropriate individuals.

1.14 Overview of Chapters

CHAPTER ONE – INTRODUCTION

This chapter introduces the reader to the reason for the research and the intended outcome. It also delves into the background of the topic and how the study is intended to assist professionals in their day to day work. It describes the kind of problems that are experienced in the industry that led to the need for this study. It also outlines the chronological process that will be followed throughout the research.

CHAPTER TWO – SIX SIGMA PROJECT MANAGEMENT

This chapter summarises and highlights an approach to projects that aims to ensure that all the stages of a project lifecycle are carefully undertaken. It aims to guide the EE/PE by outlining the important aspects of a project that require careful attention. This style of project management aims to assist the PE in delivering a safe and reliable product to the client/end user.

CHAPTER THREE – DESIGN CONSULTANT GUIDE

This chapter takes a detailed delve into the technical and procedural processes of getting MV and LV services to a building. It is intended to educate the prospective professional engineer on how to efficiently, reliably and effectively conduct a typical project in a manner that will ensure that the client or end user is satisfied. It also gives an idea of the kind of issues and stumbling blocks that may be encountered during the process lifecycle.

CHAPTER FOUR – RESEARCH METHODLOGY

This chapter will describe in detail how the research will be carried out. It will outline who will be targeted as respondents and the reasons for that. It will also describe in detail what method of research will be used and how long it will take to conduct it. Also the method of collection of the information will be described. Lastly the chapter will describe how the interviews will be conducted and the type of information that will be extracted during these interviews. All the questionnaires and interviews will be based on the research questions as this forms the core of the research.

CHAPTER FIVE – QUESTIONAIRE RESULTS AND ANALYSIS OF DATA

In this chapter all the results from the research methods will be recorded. These results will then be broken down and analysed in the hope of proving the hypothesis/RQ. The results will either be assessed analytically or a pattern will be investigated that will either support or reject the hypothesis.

CHAPTER SIX – DISCUSSION OF RESULTS

The findings of the analysed results will be tabled and elaborated. This will either lead to a consensus that will support or reject the hypothesis. The discussion of the results will be closely related to the RQ's. The chapter will then correlate the results to the RQ's and discuss the findings.

CHAPTER SEVEN – CONCLUSION

This chapter will close the research and discuss how the hypothesis has either been supported or rejected and the reasons for this. It will also delve into how further research can be done to improve the study of the hypothesis. It will also reflect on the research objectives and whether or not they have been achieved.

2 CHAPTER 2

LITERATURE REVIEW – SIX SIGMA PROJECT MANAGMEMENT

2.1 INTRODUCTION

This part of the research focuses on the function of the Project Engineer as project manager. This entails the Project Engineer overseeing the process lifecycle of delivering MV and LV equipment to the end user. Project managers are tasked with improving the efficiency and productivity of the tasks throughout the project lifecycle. They have to approach the tasks flexibly in order to achieve the desired results. Lean Six Sigma (LSS) is a tool that provides a holistic data driven process for detecting and enhancing system defects. This being said, project management also has the required tools to create and evaluate a defined project management plan. The point of this literature review is to test the functioning of LSS in conjunction with project management. The main components of LSS are to define, measure, analyse, improve, control and closure of all elements within the project lifecycle.

The main function of LSS is to minimize defects within the project lifecycle. Other aspects such as managing time, reducing cost and general planning must also be part of the holistic package. The main issue of contention has always been where project management can benefit LSS. This study proposes a more comprehensive and in depth approach to LSS. When starting a new project the project manager assembles a team, assigns roles to each member and guides each member to completing these tasks in accordance to the spec in order to achieve the objectives. Similarly the Project Engineer (Electrical Engineer) puts together his team that will be tasked in ensuring that the LV and MV equipment is delivered to site in accordance to the objectives. (Young, 2010)

2.2 PROJECT MANAGEMENT

A project can be defined as a temporary undertaking that aimed at achieving a set of objectives within a set time. A project normally involves more than one person, either a small or large group depending on the size thereof. Usually a project has a unique content that can never be repeated again. Project management can be defined as a dynamic process that makes use of appropriate resources of an organisation or organizations. These resources are used in a structured and controlled manner in order to achieve set outcomes that are defined at the beginning of the project. In order for a project to be deemed as successful it has to be done within set constraints, these being time, scope and cost. This is known as the Triple Constraint or

The Iron Triangle. A project has many processes throughout its lifecycle, each of which is a stepping stone to achieving a certain objective. (Young, 2010)

There are many different types of projects. These include but are not limited to:

a) Personal project – such as writing a thesis, books, dissertations, weddings, plays, etc.
b) Local projects – public programs, conference or seminar programs, volunteer projects, etc.
c) Organizational projects – these include delivering MV and LV equipment to an end user, constructing bridges and freeways, launching a new product, etc.
d) Project of National Importance – Launching a child abuse awareness drive, launching a rocket, the matric final exams, etc.
e) Projects of global importance – organizing a peace mission, a world war, the world cup, etc. (Snee & Rodebaugh Jr, 2002)

A project comes about when a need arises. Then a process of identifying the ideal project to be undertaken is embarked on. Depending on the type of project it is, a couple of methods may be undertaken to determine the ideal process. These including brainstorming, RFP's, etc. (Snee & Rodebaugh Jr, 2002).It should be noted that every project involves numerous processes which are characterised by the inputs and outputs. The outputs of the respective processes depend on planning, customer surveys in order to determine needs, competitive analysis and benchmarking of the various processes. Everyone involved in the project should ensure that they work to the same processes and procedures in order to achieve cohesion. Once cohesion is achieved then communication will be much easier and sharing thereof will be manageable (Snee & Rodebaugh Jr, 2002).

2.3 SWOT ANALYSIS

After the first phase of the project where all the objectives have been thoroughly established, the next step entails determining the strengths, weaknesses, opportunities and threats. This is known as the SWOT analysis. This is a way of determining the risks that could be involved in the project. The main objective of the SWOT analysis is determining the risks and outlining the mitigating strategies should the risks occur. A good tool for approaching this exercise is brainstorming so that everyone involved has a clear picture of the entire process. A few solutions can be established with the SWOT profile by exploring various ideas (Thomspon Jr & Strickland 3, 1998).

SWOT Analysis can be broken down into the following segments:

Strengths

- Expertise and Experience – Determining whether the organisation has the capacity to deal with the project at hand. This entails engineers, draughtspersons and administrative staff that will be required to run the project
- Financial Position – Whether the organisation has the capex and opex to execute the project. This entails the funds needed to pay salaries of employees between the time the project kicks off and the first invoice is paid
- Capital raising capability – Whether the organising has a good enough credit record to raise the funds if there isn't capex. This entails being able to source funding to support capex and opex between the time the project starts and the first invoice is paid
- Industrial contacts – If the organisation is in contact with the correct stakeholders in order to execute the project. This entails having good relationships with contractors and the professional team in order to ensure cohesion throughout the project life-cycle
- Foreign collaborations – Where necessary the organisation should have the correct foreign contacts to execute the project (Klastorin, 2003)

Weaknesses

- Lack of experience – If the organisation does not the required experience will it outsource or hire more staff. This entails being able to form joint ventures with other consultants or contractors who may have knowledge of the specific field
- Lack of trained personnel – is the current organisational staff adequately trained to work on the particular project
- Inability to cope with newer technologies – if new technology is being used during the project will the organisation invest resources to training the new staff or will it outsource. This entails for instance when a new communication platform is being used to store and distribute drawings for the project that requires the draughtsperson to be trained
- Inability to raise huge investments – if the organisation is unable to raise required funds will it seek new investors or loan resources. This entails for instance if the organisation requires a printer for large drawings (A0, A1 size) and needs to seek investors for this equipment
- Inability to forecast market trends – if the company is unable to forecast market behaviour in the near future then it will not be able adjust their business model accordingly (Klastorin, 2003)

Opportunities

- Emerging Technologies – does the company explore new ways of being more efficient through technology. This entails for instance the EE making use of excel to calculate building loads instead of using hand calculations in order to save time and minimize error

- New Products with new markets – does the company conduct sufficient research to explore new products that can be sold to the client. This entails the EE exploring for instance new LED products that are available on the market in order to achieve the required energy savings
- New processes with better features – has the organisation explores procedures and processes that could make design and implementation more efficient
- Special financing schemes – In cases when the organisation is unable to secure external investors, are the owners able to approach government for start-up funding in order to purchase the required equipment
- Government and other incentives – does the organisation adhere to government empowerment policy for the previously disadvantaged. This entails the organisation employing and given ownership to enough persons of colour in order to achieve the required criteria (Klastorin, 2003)

Threats

- Competitors - the company should identify its competitors and find ways to get a leading edge over them
- Poor state of the economy – the organisation should find ways of expanding its portfolio to ensure multiple streams of income. This entails constantly marketing the organisation to prospective new clients for construction and other projects
- Outdated process and technology – the organisation could save time and money and be more productive if more efficient technologies are used. This entails the organisation making use of computer aided tools that will assist the EE in completed his functions more efficiently
- Unprofessional management skills – the organisation should ensure that it uses the most efficient and effective management skills throughout the project lifecycle in order to obtain and maintain a leading edge over their competitors. That entails having documented procedural strategies on how more effectively and efficiently conduct a project
- New product and services – the organisation should stay abreast of emerging technologies that could threaten the need for the organisation's service (Klastorin, 2003)

2.4 PROJECT PHASES

Every project contains phases that are characterized by their inputs and outputs. One of the most important factors to ensuring project success is ensuring that all the stakeholders work according to the same specifications, processes and procedures. These are usually laid out at the beginning of the project by the Project Engineer/EE. This will ensure that communication amongst all the stakeholders takes place efficiently throughout the project lifecycle, particularly when the stakeholders work from different locations, time zones, countries, etc. The phases are carried out in sequence where the next phase is dependent on certain tasks being completed or partly completed from the previous phases. In many projects the phases need to be revisited and some specification revised during the process lifecycle. (Thomspon Jr & Strickland 3, 1998). The process lifecycle of any project can be broken down into the following stages:

2.4.1 Project Conception

This process takes place when the initial idea of the project comes to life. The need for the project is established and agreed upon and all the key stakeholders are notified. In our context this entails when the client approaches the Project Engineer/EE with the request for power to a certain site. The client then briefs the Project Engineer as to the extent of involvement that he's needed for. The concept of the project needs to be agreed upon and signed off by the client. The Project Engineer then draws a general plan on how to approach the particular project, the stakeholders that will be involved as well as the best strategy to approach the project (PMI, 2013).

2.4.2 Project Definition

Once the need has been established and the concept agreed upon, it is then necessary to define the client specifications and requirements. These are communicated clearly at the beginning of the project to the Project Engineer/EE. The specification has to be signed off by both parties. Once the specifications are signed off it is necessary for the Project Engineer/EE to compile a list of objectives that have to be achieved at the end of the project. For a typical project that involves an MV and LV installation, a high level objective may include installation of the following equipment: BMK, mini-subs, MV cable connecting the BMK to the minisubs, main DB's, sub-Db's, LV cables from minisubs to main DB's and sub-DB's (Barrie & Paulson, 1992).

For the purpose of this study the scope of work will start at the BMK as the point of supply and end at the DB as the point of use. The PE/EE would then have to design the network from the point of supply to the point of use. This entails taking into consideration the type of building it is, the size of the building and the client specifications. Thereafter the PE would determine the amount of power required in the building in kVA. This would then be used to determine the sizes of the sub-DB's, main DB's, mini-subs and the BMK. Also the cables between all these services can be sized adequately depending on the calculated currents. All this forms the distribution network of the project in that power is distributed from the source (BMK) to the end user (sub-DB) (SABS, 2017).

2.4.3 Project Planning

Once the design of the network is done and signed off by the client, it is then time to conduct the planning of the project. Planning forms one of the most important, if not the most important phase of the project. Planning affords the PE the opportunity to layout the procedural structure of the project. It also helps in identifying any risks that may be encountered throughout the project lifecycle. This is ideal for identifying the mitigating strategies for these risks so that they do not hinder the project progress should they occur (PMI, 2013).

Once the risks and mitigating strategies are recorded in the risk register it is then time for the PE to identify the key stakeholders in who will execute the work. This entails identifying reputable subcontractors who will be included in the tender and RFQ lists. The client and main contractor may also want to add organisations that they've worked with before. The PE then compiles the relevant tender documentation which will be issued to all the relevant sub-contractors for pricing in accordance with the specification. The sub-contractors usually have between a week and 2 in order to source pricing from their suppliers and complete the BOQ. The tenders have to be returned by a certain date and all contractors who miss the deadline are disqualified (Barrie & Paulson, 1992).

Once the tender has closed, the PE conducts a tender adjudication. This entails assessing all the tender documents and ensuring that all the sub-contractors adhered to the rules and specifications when compiling their BOQ. Any sub-contractors who deviate from regulations may be disqualified. The PE thereafter has to record a BOQ summary of all the tender documents in order to determine who has the lowest rates. Thereafter a report is compiled to inform the client of the process that was followed and recommendations on which contractor should be appointed. It is then up to the client to send an appointment letter to the lowest contractor so that work can commence on site (Sawant, 2013).

2.4.4 **Project Launch and Execution**

Once the sub-contractor has gone through site establishment, it is then time for him to commence his installation in accordance to the PE's design. This is the crucial part of the project when the PE has to ensure that everything is done correctly and safely in accordance to his design. The EC has to receive the latest set of drawings and a drawing register. The drawing register is a record of all the drawings issued to site. It also keeps track of all the latest revisions and all the changes done on the drawings. This document is extremely important as it ensures that the EC installs according to the latest revision of drawings to avoid any discrepancies. It can also be used as a legal document during disputes (Barrie & Paulson, 1992). The PE has to constantly monitor the progress of the installation to make sure that it is within the program. Also any changes need to be implemented through change control processes that would have been defined during the planning phase. The PE is obligated to oversee this process to ensure the client's interests are taken care of (PMI, 2013). The PE also needs to keep track of the costs during the project and communicate any changes to the client and QS. All costs have to be approved by the client and QS before work is done due to change control.

2.4.5 **Project Closure**

Once the project has been concluded certain procedures have to be followed in order to ensure that a fully working product is handed over to the client. This includes testing and commissioning the DB's, mini-subs and RMU. This also entails issuing COC's for all equipment installed. These are legal documents that stipulate that the products installed have been tested in accordance with SANS and are safe to use. The installation must also be signed off by the PE to confirm that he conducted the design and is satisfied with the installation. The client also has to receive training for troubleshooting to ensure that he does not struggle should there be any issues (SABS, 2017).

2.4.6 **Post Project Evaluation**

When the installation has been concluded and the product has been handed over to the client it is necessary for the PE to “reflect “on the project in its entirety. This is often a process that’s neglected by the PE. However it is essential to document this process in order to reflect on lessons learnt and to use the experience as a reference for future similar projects. It also helps to communicate with the client to ensure that all the products that are installed are functioning optimally and reliably and to assist with troubleshooting. This will give the client the peace of mind and ensure future business (Thomspon Jr & Strickland 3, 1998).

The figure below indicates the effort vs time graph during the project lifecycle. It is evident from the graph that during the inception of the project minimal effort takes place. This is because during this stage ideas are still being thrown around and the project specifications are still being established. The effort increases somewhat during the planning phase when more work has to go into this important process. The most effort goes into the performing/implementation phase. This is the design stage when the specifications are implemented and the installation stage when the designs are implemented. More effort comes in when the PE has to monitor and control the EC’s installation and to ensure the quality of the installation is sound. The level of effort decreases again during the closing stages when the inspections and closing documents have to be created and issued to the client.

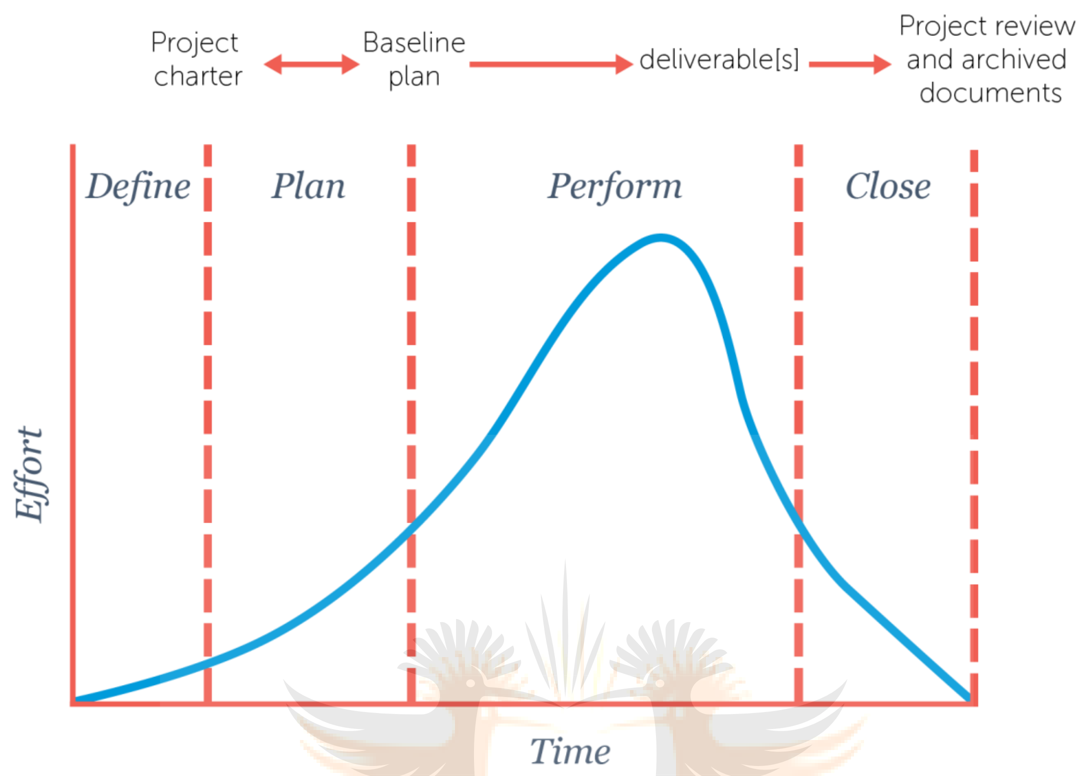


Figure 1: A variation of the generic project lifecycle, indicating effort expended during each phase

The phases described above can be considered as key strategies and they are the backbone of achieving project success. Although the phases are carried out sequentially it does not mean that that each phase is a once off activity. Phases are often revisited for whatever reason if required at the time. For instance once the design is done and the drawings are issued to site and the EC has commenced work, the PE may need to go back to the planning phase to correct a certain obstacle that has risen. Thus planning is a continuous task throughout the project lifecycle (Young, 2010). Project in the construction industry are born when there is a need for a certain product in the particular environment. For instance there may be a need for housing in a particular suburb due the influx of population into that area. Another example may be if an international investor wishes to establish a production plant in a particular industrial area (Snee & Rodebaugh Jr., 2002). In both cases there will be a need to provide electricity from council to the end user. It is therefore up to the PE to source and maintain clients from different industries in order to sustain the business and keep it productive. Failure to maintain client satisfaction at all times may lead to the business failing. This would in turn cause job losses which would be detrimental to the employees of that organisation, especially given the current state of unemployment in South Africa (PMI, 2013).

Projects form a vital part of Six Sigma. It is essential for an organisation to be able to select, manage and complete project successfully and to the client's satisfaction. A project should always be undertaken with the intention of completing it efficiently and with as few disruptions as possible (Barrie & Paulson, 1992). Before a project is undertaken it should be assessed to determine if it would benefit the organisation and whether it is in line with the organisational goals and objectives. Each project should also be assessed to determine its financial benefits to the organisation based on the organisation's resources and skills (Snee & Rodebaugh Jr, 2002).

2.5 Alignment with the Business Strategy

Projects should only be selected if they align with the organisation's future goals, strategy and long term objectives. They should be selected with the view to grow the organisation's image, skills and knowledge, reputation and finances (Snee & Rodebaugh Jr., 2002). It is therefore essential to compile a business case which outlines the need for the project and the benefits that will be realised. Before taking on a certain project the PE needs to ensure that the organisation has the equipment, skills, competence and more importantly the time to actually do the work. The PE himself needs to ensure that he has the technical know-how to take on the specific type of project. Once the specific project is selected the PE needs to invest sufficient time on the planning phase. A project that has been adequately planned often does not require much change control. This in turn means that fewer resources will need to be invested in the project to execute remedial work on defected areas. It is essential to keep a dynamic record of all the projects that are been undertaken by the organisation. This will also help with resource planning as well as financial planning (Barrie & Paulson, 1992)

2.6 Project Stakeholders

A project can only be successful if the people involved are employed from the beginning of the project and everyone's tasks are clearly defined and communicated to the respective parties. Clearly defining the roles of the individuals avoids confusion amongst people involved. It also prevents tasks being duplicated and therefore spending resources wastefully and fruitlessly, which could result in delays in the project. In the process lifecycle of getting power to site, the following stakeholders need to be established and communicated adequately to everyone involved: (PMI, 2013)

- Individual that needs to benefit – the client and/or end user
- Individual that commits to provide the resources – Electrical Contractor
- Individual who is responsible for achieving the benefits – Project Engineer
- Individual that is responsible for the project work – Electrical Contractor

The individuals above constitute the professional infrastructure of the project as well as the functional hierarchy. Their collective behaviour and attitude towards the project will determine the success thereof. The PE has to leave the project from the front. His enthusiasm and sense of urgency will influence all the other stakeholders and their perception towards the project. This is because the EE/PE also becomes the leader of the team. (Levitt, 2008).

The PE should try and instil a culture of morale, trust, support, respect, openness, integrity, optimism, recognition of hard work, sharing, commitment, pride, accountability, collaboration, team work, assistance, etc. It is essential for the PE to influence the entire team positively and on an ongoing basis throughout the project in order to achieve cohesiveness. This will influence the team to work together to work together towards a common goal. (PMI, 2013)

2.7 Managing Project Stakeholders

In this type of project there are numerous stakeholders that influence the outcome of the project. The PE will find it easier to achieve project success if he understands the different stakeholders and how to manage them. There are different groups of stakeholders that are involved in any project. These are company's stakeholders or project sponsors and customers/end user. Project sponsors/clients are mostly focussed on the project being completed within the specified time, budget and scope (Iron Triangle). They are also focused on growing their project and increasing their market share in the long run. The second group of stakeholders is the PE himself and all the professionals involved in the project. This group of stakeholders are responsible for the design of the project on behalf of the project sponsor. They are responsible for ensuring that the project is completed within the required time, budget and scope. They are legally responsible for looking out for the client's interests throughout the project lifecycle. They are also responsible for managing the project on the client's behalf and ensuring that a sound, reliable and safe product is delivered to the client/end user (PMI, 2013).

The third group of stakeholders are the companies that do the installation in accordance to the design. They are responsible for insuring that the installation is done safely in accordance to SANS regulations. Their main aim in the project is to make a profit. The last of the stakeholders in this type of project is the end user. These stakeholders are hardly involved during the project lifecycle. They are mostly involved once the project is handed over to the client. Their main purpose is to give feedback to the sponsor on the quality and reliability of the product and any defects that need attention. Their role is important as it give the client and team an idea of the success of the product and therefore the project (Young, 2010).

It is essential for the PE to clearly identify all stakeholders and establish are method of effective communication from the beginning of the project. The list of stakeholders may change throughout the project lifecycle so it is essential for the PE to review this list continuously to ensure that the correct information is communicated to the correct parties (Young, 2010). It is important to ensure that the project sponsor is involved and interested from the start of the project as he has the decision making powers that will influence the success of the project. The project sponsor provides support by doing the following: (PMI, 2013)

- Ensuring a rapid response on issues that require decisions and approval
- Ensuring that the project receives the correct amount of priority
- Ensuring that the project keeps in line with the organisational goals
- Maintaining a relationship with the professional team
- Ensuring that the necessary resources are available to the project when required
- Providing the necessary visible leadership

The professional team has to maintain a healthy relationship with all key stakeholders to ensure that communication channels are always active. Information should flow to the correct parties at all times. This can be done through site meetings, emails, telephone calls and other forms of media that will help to contribute to the success of project (Schwalbe, 2012).

2.8 A Six Sigma Project Management

The main aim of Six Sigma project is to improve the process lifecycle by reducing variation. There are 2 types of models in which to apply to a project. The first is a model generating quantitative data and the second generating qualitative data. There are some important issues that require special attention when selecting a Six Sigma project: (Muir, 2006)

- Will the project maximize profits?
- Will the project maintain the market share?
- Will the project consolidate the market position?
- Will the project open up new markets?
- Will the project maximize utilization of existing resources?
- Will the project boost the company's image?
- Will the project increase risk faced by the company?
- Is the project scope within the company's current skills and experience?

Many SS projects come about as a result of a certain customer need or expectation. The projects selected must be in line with the organization's medium and long term goals and objectives. It is guided by top end management, investors and directors whose bottom line is earnings and the development of future business leaders. Also at operational level management may also be interested in cost reduction, safety of employees, using assets efficiently, the introduction of new products and solutions, the effectiveness of sales and marketing and developing people within the organisation. When projects are aligned with organisational objectives it ensures that only the best projects are selected. (Muir, 2006)

Companies usually take on projects that demonstrate potential success of an overall improve effort. These are projects that aim to fully exploit areas of business that are full of opportunities. Also attention is paid to issues that arise from customer feedback and customer satisfaction (or dissatisfaction). These aspects sometimes form the crux for selection of projects. It is for these reasons that project selection is probably one of the most important aspects in any most business model. Projects that are selected should be completed in the given time frames to ensure client satisfaction and return clients. (Muir, 2006)

One of the main criteria for the success of a project is the quality and reliability of the product. This is one of the reasons reliability and quality is designed for from the conceptualisation of the project. This entails that the PE should incorporate reliability into his designs and specifications to ensure an efficiently working product that will not repairing or replacing once it is handed over to the client. When data is collected that contains mass information, it is essential to determine any patterns in the data that may contain the correct information to support that particular study (Lindsey, 1999). Therefore the main use of statistical models is to simplify data in a way that makes sense to the user so that the user can check the data at hand empirically. Whether the researcher is using qualitative or quantitative methods, the model can provide the following:

- A summary of the results which highlights the essential features
- The basis for predicting future observations
- Insight into whatever processes are in question (biological or social)
- Theoretical test to determine and prior relationship
- Different results can be compared with the said study
- Determining the precision of quantities in question (Muir, 2006)

The main principle of SS is to relate the output to the input (i.e. $Y = f(X)$). In simple terms it means the output from a business process is a function of the decisions by the process owners. In order to achieve the best model and results the researcher has to ensure that the results contain no irregularities and inconsistencies, therefore leaving very little chance for variation. (Lindsey, 1999). In general a good way to build a model is to:

1. Study the essential statistical descriptions, thus familiarising yourself with the data
2. Develop a reasonable workable model the results established in the previous step and from previous knowledge
3. Fit the model to the data to establish the relationship
4. Check how well the data fits the model
5. Go back to the second step if necessary in order to increase accuracy and reliability
6. Use the model to reach appropriate and reasonable conclusions

The main concept of modelling is to construct a model that is not only supported by that particular data but that will remain consistent with previous outcomes, including earlier empirical research. If the model is good enough it will also describe future observations to a good degree of accuracy (Lindsey, 1999).

2.8.1 **Probability Model-based Project**

It is a reasonable expectation that the main output variable (Y) should be specified in the protocol. It is directly observable in most trials; however it may have to be constructed in others. An example is establishing a baseline before any intervention is considered so as to have a reference point. In models of statistics, we expect the response variable to arise randomly in a certain sense. Therefore we cannot predict how each respondent will react to the respective intervention such that random fluctuations are not reproducible. In such cases the variance arises from the difference in human beings, as opposed to physics or chemistry studies where measurement error is predominant. A random variable is one that is subject to random variation or one that is randomly chosen. A probability distribution function is a description of all possible values of a random variable and of their corresponding probabilities of occurrence. A probability distribution is a mathematical function that smooths the curve of observations informatively without losing the basic shape. Many probability distribution functions have more than one unobservable and unknown parameter. (Lindsey, 1999)

2.8.2 **Regression Model-based Project**

When random variables come with systematic changes in response to certain conditions, they are called explanatory variables (i.e. X's). Upon examining how a probability distribution of a response changes under certain conditions, it can be converted into a statistical model. Assumptions may need to be made regarding the variables in the model. It is always assumed that the mean of the distribution changes under the conditions of interest and variance remain constant. If we assume a linear relationship between the response and explanatory variables, model building becomes an easy task. Unfortunately in reality this will not happen every time therefore the regression model has to be used. A model that combines a probability distribution with a linear regression function is known as a generalised linear model. (Lindsey, 1999)

2.9 Quantitative Project Management

The crux behind quantitative project management is: (Snee & Rodebaugh Jr., 2002)

- Ensuring that the project's quality and process performance objectives are established and maintained
- Ensuring that suitable sub-processes that compose the project's defined process based on historical stability and capability data found in process performance baselines or models are identified
- Selecting sub-processes within the project's defined process to be statistically managed
- Performing monitoring functions that would ensure that the project's quality and process performance objectives are being satisfied, and establishing appropriate counter measures to remedy this if they aren't
- Statistically managing selected sub-processes using analytic measures and techniques

- Using selected measures and analytic techniques to establish and maintain an understanding of the variation of selected sub-processes
- Determining whether selected sub-processes are capable of satisfying their quality and process performance objectives and establishing counter measures by monitoring their performance
- Keeping a record of all statistical and quality measurement data in the organisation's measurement repository

2.9.1 Organizational Process Performance

When following a certain process, its performance can be determined by measuring the actual results achieved. Process performance is determined by measuring processes such as effort, cycle time and defect removal effectiveness and products such reliability, defect density, capacity, response time and cost. Characteristics such as process and product can be measured and used to determine the actual performance of a project. The resulting measurements can be analysed and a distribution or range of results can be determined that characterise the expected performance of processes used during the project. A tool called data mining can be used to analyse existing data and to segregate for arriving at a process capability trend of the past which would enable us to predict the changes in the future (Kerzner, 2003).

2.9.2 Creating Organizational Baselines

By establishing the expected process performance, one can establish the project's quality and process performance objectives. These can then be used to establish a baseline against which actual project performance can be compared. This information can be used to quantitatively measure the performance of the project. At the end of each quantitatively measured project, actual results performance results can be made part of the baseline data for organisational process assets. (Kerzner, 2003)

2.10 Project Risk Assessment

In a project, a risk can be defined as any event that could prevent the project from realising the expectations of the stakeholder. Once a risk occurs it must receive prompt attention in order to maintain project schedule and time. Risk management is a tool that helps identify and control areas or events that have the potential of causing unwanted and unexpected changes to the project which would lead to unwanted and unexpected results. As a result of the complex nature of risks, it is impossible to derive a universal process for managing all types of risks. There are however 3 types of risks that are associated with any kind of project (Klastorin, 2003):

- Business risk – Viability and context of project
- Project Risk – related to the technical aspects of the work required to achieve certain outcomes
- Process Risks – related to project process, procedures, tools and techniques involved in controlling the project

The success of any project will depend on how risk managed. An efficient PE should be able to identify and evaluate risk and the ability to resolve any consequences that may arise should the risk take place (PMI, 2013). The table below indicates the risk ranking matrix:

Table 1: Risk ranking matrix

	IMPACT ON PROJECT		
PROBABILITY OF OCCURENCE	LOW (0.1 – 0.29)	MEDIUM (0.3 – 0.64)	HIGH (0.65 – 1.0)
LOW (0.1 – 0.29)	LOW	MEDIUM	HIGH
MEDIUM (0.3 – 0.64)	MEDIUM	HIGH	UNACCEPTABLE
HIGH (0.65 – 1.0)	MEDIUM	HIGH	UNACCEPTABLE

2.10.1 **Quantifying the Risk**

Once all possible risks are identified they are recorded in the risk register. Thereafter the PE together with the team has to determine mitigating strategies for each risk. The PE starts by determining the probability of occurrence of each between the values of 0 and 1, where 0 would be the lowest probably of occurrence and 1 the highest. Risks having low probabilities of occurrence are recorded as having the least impact on the project program. Risks having high probabilities have to be assessed carefully as they have the likelihood of affecting the project program (Kerzner, 2003). The effects of risks can be summarised as follows based on probabilities: (Lindsey, 1999)

- 0.1 to 0.29 – low probability - may have some impact on the schedule and minimal impact on the cost
- 0.3 to 0.64 – medium probability – may have a less serious impact on the schedule and a reasonable impact on the cost
- 0.65 to 1 – high probability – may have a significant impact on the schedule and on the cost
- Even though the above table indicates the impact for medium and high probability, in reality the impact of a high probability will pose more risk on the project than that of a medium probability

Once all risks are assessed they can be categorized using Table 1. The contingency plans can be summarized as follows: (PMI, 2013)

- Low risk – PE to review continuously for ranking
- Medium risk – PE to review at every project meeting for ranking. Also continuous monitoring is required
- High risk – PE to review regularly and carefully while constantly following the mitigating actions

- Unacceptable risk – PE has to take immediate action to remedy this risk otherwise the project would not be able to continue

Any project allowed to continue with an unacceptable risk has a very high potential of failure. This is the very reason why all risks, especially the unacceptable ones, have to be identified as early as possible and communicated to the project sponsor. The sponsor has to be involved in developing the mitigating strategies and these may affect his operation. Most risks have time related cost implications and if left unattended, could sink the entire project (Schwalbe, 2012)

2.11 Critical Evaluation of a Project

The CPM and PERT are strategies of evaluating the project critically. The main purpose of these methods is to establish the shortest route to complete a task or project. These are derived from the network diagram, which is a graphical representation of how the tasks of a project are related and interdependent. This is a method of scheduling tasks during a project to ensure that they are completed on time so that the project in its entirety is completed on time. Using the node method, the user should begin at the START nodes and navigate through each possible path though the diagram to the FINISH nodes. The total duration of time between nodes should be tallied. The path that contains the longest path is known as the critical path of the project and consumes the least time to complete the project. All the tasks in the critical path should be completed on time else the project will be late (Klastorin, 2003). The table below depicts the activities in a particular project and their interdependence:

Table 2: Sample Project

Activity	Immediate predecessors	Duration (Months)
A	-	2
B	-	6
C	-	4
D	B	3
E	A	6
F	A	8
G	B	3
H	C,D	7
I	C,D	2
J	E	5
K	F,G,H	4
L	F,G,H	3
M	I	13
N	J,K	7

The corresponding network diagram is shown below:

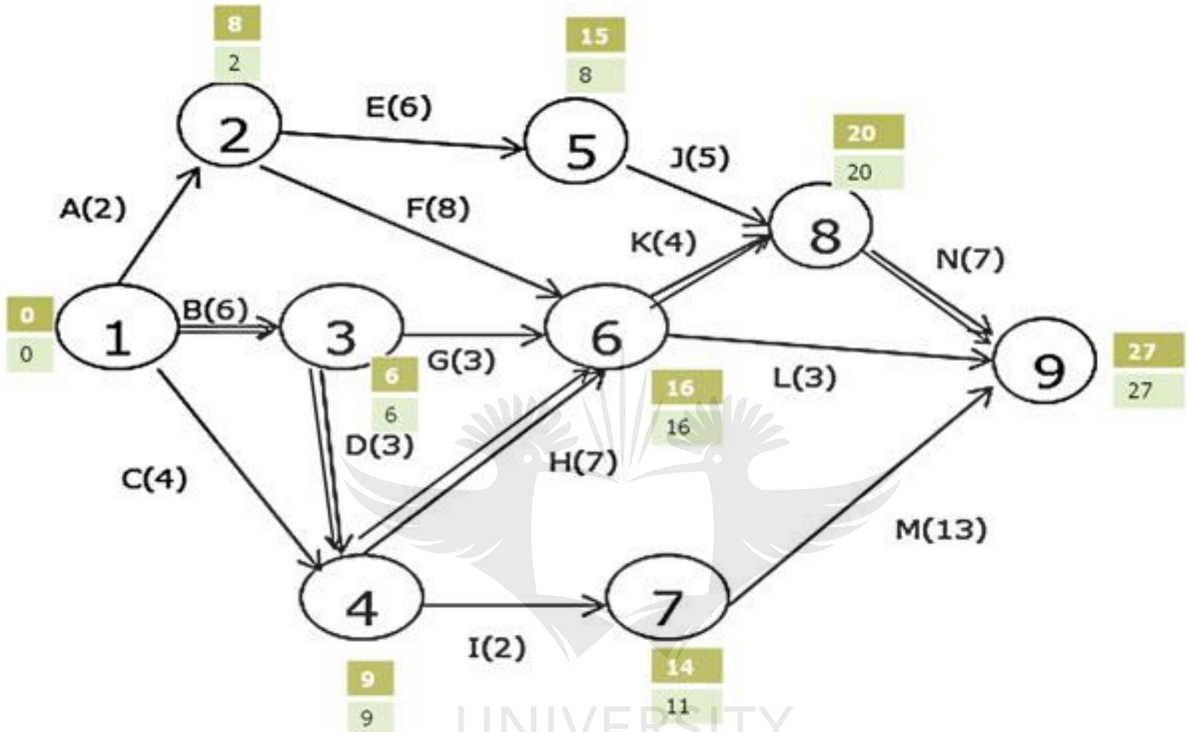


Figure 2: Network diagram

The critical path can be calculated in 2 easy steps:

1. Summing the durations from beginning to end – the forward pass
2. Subtracting the durations from end to beginning – the backward pass

The critical path can be described as one that corresponds to the events, where the time to begin and end coincide. For the project depicted above the critical path is 1-3-4-6-8-9. The CPM is used in projects where the activities are given fixed durations (deterministic durations). When using PERT each activity is assumed to follow a logical probability distribution (probabilistic durations). The main purpose of PERT is to simplify planning and scheduling in big and complex projects (Klastorin, 2003). PERT has the following advantages: (PMI, 2013)

- PERT chart defines explicitly and makes visible all activity dependencies
- PERT identifies and makes visible the critical path
- PERT identifies early starts, late starts and slack for each activity

- PERT provides the potential for a reduced project duration due to a better comprehension of the task dependencies which eventually leads to an improved overlapping of activities and tasks where possible
- A lot of the project data can be presented in diagram form and used for decision making

CPM allows the PE to continuously monitor and control the schedule. This is an advantage as the schedule in any project changes on a regular basis. This also acts as an early warning system for the PM to identify activities that may cause delays, especially those in the critical path (PMI, 2013) . There are also ways of pruning activities in the critical path in order to shorten the planned critical path by prioritizing activities in order to short the project lifespan. These methods include fast tracking which entails performing mutually exclusive activities in parallel as well as crashing the critical path which entails completing critical path activities sooner by investing more resources. The latter may have cost implications which would require approval from the project sponsor. Crash duration is typically modelled as a linear relationship between the cost and the activity duration of the project. However in many cases a convex function or a step function is more applicable (Klastorin, 2003).

2.12 Role of Computing Technology in Project Management

It is extremely important to make use of computing technology in project management. Not only does this technology assist in providing computational support in a vast array of network scheduling calculations, it also makes it possible to generate and distribute online reports for effective monitoring and control. Numerous individuals are involved in a project at any given time, therefore it is essential for the PE to keep everyone well involved, even though it may be difficult. Some common forms of communication include email, internet, whatsapp, messaging and the internet (Klastorin, 2003)

These methods make it easier for the PE to communicate with all the stakeholders which makes it easier to accomplish the bottom line. In addition to easing communication, it also assists in minimizing the use of printed paper, which reduces the carbon footprint of the project. The use of technology in projects makes running the project more cost effective and efficient and may result in huge savings in manpower and finances. Many computer programs have been created to assist the PE during his design in order to save time. These programs also assist in minimizing errors in calculations that could lead to incorrect and unsafe designs being issued. These would obviously have a health and safety implication on the end user, which is an undesirable occurrence (Klastorin, 2003). There are a few major advantages of this kind of software which include:

- Activities are easily sorted and listed
- During the project lifecycle progress can easily be updated

- Reports and analysis can be done automatically
- Decisions regarding the resources available can be made easily
- Project constraints can be altered and modified in accordance with the project's priority (Klastorin, 2003)

2.13 Launch and Execution Process

When a project is launched and executed the following activities may be involved: (Sawant, 2013)

- Use the relevant tools to derive the duration and float of the project
- Determine a baseline schedule that will be used to resolve project risks and any other issues that may arise
- Create a communication plan to
  - Comprehend the progress of active tasks
  - Fault finding in the project
  - Identify the technical difficulties being experienced
- Establish and finalise meeting schedules
- Determine the change control processes
- Holding a kick off meeting
- Initiate project execution

2.14 Closure of the Project

At the end of the project certain processes have to be followed to ensure that the project sponsor and end user are left satisfied. These are often processes that are overlooked and taken for granted. However these tasks are essential for ensuring that the client is happy with the product and more importantly knows how to use it. If these tasks are carried out effectively enough then the client will have more confidence in the team and the product and will more likely use the services of the same team in future (PMI, 2013). Some tasks that form part of the project closure process include: (Barrie & Paulson, 1992)

- Ensure all project tasks have been completed
- Ensure all agreed deliverables and objectives have been achieved
- Ensure all testing commissioning is complete
- Ensure that all training manuals are prepared and handed over to the client
- Ensure that all equipment is installed and in perfect working condition
- Ensure all documentation manuals are completed and handed over to the client
- Ensure that all processes and procedures are completed and tested

- Ensure that all relevant personnel belonging to the end user organization are trained properly for troubleshooting

2.15 The Climate for Success

The success of a Six Sigma project depends on its climate for success. The formal definition success is the "attainment of objectives", or wealth, fame or position. Some of the most common synonyms of success are victory, accomplishments, prosperity, attainment, fruition, achievement, winning, etc. Success is often viewed in different perspectives depending on the stakeholder in question (Muir, 2006). For example the following stakeholders could view the success of a project in different perspectives: (PMI, 2013)

- Sponsor – success could be having a functional product that is delivered on time
- Project Manager – success could be project being completed within the Triple Constraint
- Project Team – transfer of skills, self-satisfaction, remuneration without penalties
- Resources manager – Efficient utilisation of resources without fruitless and wasteful expenditure
- Consumers – Fully functional product

The climate of success often depends on the culture of the structure and team in place. If the PE is a good leader then all the other subordinates will perform their tasks effectively. The culture of success starts from the top and filters down (Sawant, 2013). Many factors influence this kind of culture including: (Klastorin, 2003)

- Morale
- Mutual trust, support and respect for decision as well as freedom to make relevant decisions, openness and integrity
- Taking risks and being optimistic – recognising risks and in the success
- Having the freedom of action – through accountability, pride and participation in decision making
- Collaboration – Sharing in the benefits, allowing the team to work together and assist each other, minimizing stress as far as possible
- Training – transfer of knowledge on and off the job

Client support is crucial for the success of the project and the PE. This can be done through: (Thomspon Jr & Strickland 3, 1998)

- Prompt feedback regarding issues that require management input and approval
- Ensuring that the project is a priority within the organisation
- Ensuring that the project keeps in line with the organisational goals and objectives
- Ensuring a cohesive relationship with the project team
- Providing the necessary resources for the project when needed

- Duly influencing other stakeholders for the benefit of the project

Project monitoring and controlling is a continuous process that should be undertaken by all stakeholders, not just the PE. It may happen that the PE misses something and may need to be corrected by the EC. Similarly risk management is an essential part of the project and needs to be monitored throughout to minimise the chances of project failure (Young, 2010).

2.16 The Relevance of Managers/Project Engineers

Every project requires all stakeholders to be fully involved in order to achieve success. All the stakeholders should be committed to the project's success from inception right up until closure and post evaluation. In order to realise the relevance of a Six Sigma project, organisational structure, culture, strategy and stakeholder confidence is required. A Six Sigma project is a 2 pronged classification; model uncertainty and prediction models. The reason these models are good for PEs is because they can facilitate both inferential and predictive results. Project risk assessment in the form of project risk, process risk and business should be attended to by the project engineer. PERT and CPM are 2 important tools of evaluating a project. These 2 tools are sound ways of supporting management issues throughout the project. In modern day projects it is almost vital to use computing technology in order to improve the efficiency of a project (Muir, 2006).

3 CHAPTER 3

LITERATURE REVIEW: DESIGN CONSULTANT GUIDE

3.1 INTRODUCTION

This chapter is intended to investigate and outline the functions and duties of the Design Consulting Engineer (DCE) throughout the project lifecycle in delivering MV and LV switchgear to the client/end user. It will also highlight certain elements that are essential to ensuring that a safe and reliable product is delivered to the client. This chapter will also document a step by step process from project inception to commissioning and handover of the final product. This is intended to give aspiring professional engineers a guideline to ensuring that they conduct their projects efficiently and effectively. Even though every project is unique, this process is intended to ensure that all design criteria are met in all design projects.

3.2 BACKGROUND

In South Africa there are organisations that exist to govern the engineering consulting profession in order to ensure adherence to safety and ethical standards in providing the client with a safe and reliable product/service. ECSA is a "statutory body established in terms of the Engineering Profession Act (EPA), 46 of 2000. The ECSA's primary role is the regulation of the engineering profession in terms of this Act. Its core functions are the accreditation of engineering programmes, registration of persons as professionals in specified categories, and the regulation of the practice of registered persons." (ECSA, 2000). This is the only body in SA that has the right to register engineers as professionals and give them titles such as PR.Eng, PR.Tech, etc. The main function of ECSA is to ensure that registered individuals can: (ECSA, 2000)

- Apply their skills and knowledge in their line of work in order to enhance the public and environment
- Use professional conduct to execute their functions with integrity and honesty
- Have the public's and profession's interest in mind when conducting their work
- Continuously working hard to improve theirs and their subordinates' knowledge and skills
- Strive for excellence within their profession
- Not to compromise public health and safety when conducting their functions

Competency

Any registered person must be competent in the work they do. This entails that they conduct themselves diligently, skilfully and with due care towards their employers, clients, associates and the general public. This also means that they can only take on work that they have sufficient education, training, experience and competency to do, and within their registration. Professionalism must be adhered to at all times when a registered person conducts their work. All registered people must avoid all acts of dishonesty, corruption or bribery. Any professional should avoid conflicts of interest with their employers, clients or business associates. Wherever any potential conflicts of interest may occur, the professional shall notify the relevant persons in writing of their business interests that may create the conflict. The professional person shall also provide their professional indemnity to the client when requested to do so (ECSA, 2000).

The engineering consulting profession is an extremely technical field that requires in depth knowledge and experience before it can be mastered (if at all). It also has an impact on the end user's health and safety. If not designed correctly it could have devastating consequences which could put the lives of the end users at risk. It is therefore essential that nobody in the profession should misrepresent their professional or academic qualifications or their experience or competency. Whenever a professional engineer gives advice or opinions these should be based on fact and should be done honestly and objectively. Neither bribes nor unfair practices should be taken on in order to unfairly obtain work or contracts. Professionals should also ensure that all work that has been signed off or approved has been properly and professionally inspected and/or reviewed to insure that it is free of errors. It is also extremely important for professionals to not divulge information regarding the project, client or professional team unless required by law. Any professional that has the potential of being liquidated before the project is completed should notify the client and council. The same applies if there is any change in management or directorship with the organisation that may affect the project. (ECSA, 2000)

Integrity, Public interest, Environment

The functions and responsibilities of a professional engineer do not stop with the work required for a particular project. The professional engineer should always have the health and safety of the general public in mind. When giving advice to clients and the general public and this advice is not accepted, the professional engineer must advise the client of the consequences of not adhering to the advice given. When designing for a project, the professional engineer must do so in such a way as to minimise the impact of the installation on the environment. The PE should also specify equipment that will have the least negative impact on the environment as possible. The PE should design for the future generations in mind. This entails being innovative with the designs so that they can be future proof. (ECSA, 2000)

Dignity of the Profession

All registered professionals should conduct themselves with dignity and respect. This entails ensuring that the standing, dignity and reputation of the profession is upheld at all times. This also means that the PE cannot purposely injure the business or professional reputation of another registered person. Once another professional person has been appointed for a task, the PE cannot supplant or try to supplant that person in any improper manner. When marketing themselves or their business to the outside world, the PE cannot falsely or exaggeratingly do so in the attempt to secure work. The PE shall not review another professional's work unless; this review is done so for a different client, the other registered individual knows about the review, the PE receives written confirmation from the client that their contract with the other registered person has been officially terminated, the review is for the purpose of an official dispute or legal proceedings and written submission of this has been communicated or for routine mandatory checks. (ECSA, 2000)

Administrative

The PE may not destroy information on purpose within the first ten years of completing a project/work. The PE shall also detract from either placing orders or signing contracts on behalf of the organisation without prior written consent. The PE should ensure not to issue any information or allow any information to be issued by any person working under them unless the information contains the name of the organisation, the name of the registered person concerned as well as the date of the transaction. It is permissible for a PE to use electronic copies of his signature (No.25, 2002). When working in foreign countries the PE shall follow the same code of conduct as the Republic of South Africa as long it is not inconsistent with that of the country under discussion. It is the responsibility of the PE to supervise and take responsibility for work done by his subordinates, including individuals registered as candidates. In instances of disputes, the PE shall provide all information requested by the Council if this is pertaining to importer conduct by another registered person. The PE should also notify Council if his address changes. The PE should respond to all correspondence from clients, colleagues or Council within 30 days of having received it. (ECSA, 2000)

3.3 PROJECT INCEPTION

This is the first phase of any project and involves high level management from the client company as well as some members of the professional team. It takes place well before the first brick is laid, sometimes even years.

Identification

In this sub-phase the need for the project is established and assessed. In this case the client or property developer identifies a site on which he intends on constructing. This may be a vacant site or an existing building. In the case of a vacant site it follows that in this case the PE's scope would entail getting power from the closest substation to the site that the client intends to construct. In the case of an existing building, the PE would be required to investigate the current conditions of the power to that building to determine the suitability thereof to the intended project. The selected property/land then has to be assessed in order to determine the feasibility of erecting any structure there. It is important to note that all assessments have to have as little impact on the current environment as possible. This requires the services of some members of the professional team such as the Electrical Engineer (Project Engineer in this case), Land Surveyor, the Architect and in some cases the Project Manager. (CESA, 2010)

Definition

In this phase the feasibility of the project has to be determined. This means the professionals mentioned in the previous section have to conduct investigations to determine if it will be profitable for the developer to pursue that particular project. If it is on vacant land, the Electrical Engineer would be tasked with investigating the availability of power from the local energy provider (Eskom, City Power, Ekurhuleni, etc.) in that area. Firstly the EE would have to determine what the ADMD of the new development, which involves calculating the likely energy consumption of the building, based on the type of building it is and the floor area of the building. It is essential that the maximum demand AFTER diversity is used otherwise the maximum demand values will be too high. In addition to the ADMD, the EE has to determine the fault currents for the development from the source (transformer) to the point of use. The fault currents are dependent on the local provider's fault level, the transformers/minisubs used as well as the specification of cables used from the source to the end user. These fault levels will determine the prospective fault currents at each of the DB's. This information is vital in specifying the fault currents of the equipment in the DB's. That is, the amount of energy that the equipment can withstand between the time the fault takes place and the time it is cleared. Government has gazetted numerous maximum demand thresholds based on the type of building and the EE has to ensure not to exceed this in his designs. (COJ, 2017)

Thereafter the EE has to place an application for power with the particular energy provider and meeting with the appropriate representatives in order to determine if the closest substation has sufficient spare capacity in order to provide the required power to site. If it is found that the energy provider does not have sufficient capacity in the closest substation to provide energy to the development and the substation upgrading timelines fall outside the project time constraints, then the developer either has one of 2 options. The first is to pay for the infrastructure of getting power from the closest substation that has sufficient capacity to the development. The second option would be to cancel or postpone the project until such a time that the energy provider increases capacity in the closest substation. Many developers opt for the latter because of the exorbitant infrastructure costs. (CESA, 2010)

Feasibility

Part of the feasibility studies includes determining and advising the client on the financial constraints of the project. This enables the client to determine if the project is worth pursuing and what the investment return period is. In this case the EE has to determine what the connection fee and consumption deposits are that need to be paid to council in order for council to provide an electrical supply to the development. The point of contention comes about when the nearest substation does not have sufficient capacity. The EE subsequently has to determine the additional costs required to install cables that will reticulate power from which ever substation with capacity to the development. This is usually what makes or breaks a project. Developers usually are not prepared to fork out additions funds for reticulation from further substations. If this is the case then the project would have to be put on hold until the energy provider upgrades the electrical network in order to supply the required energy. However there have been cases when the developer was prepared to absorb the additional costs of reticulating power from a substation that was further away from the development. (CESA, 2010)

3.4 PRELIMINARY DESIGN/ CONCEPT VIABILITY

Viability

Once all the feasibility studies have been concluded and are positive, the project can commence. This entails the procurement of the services of the rest of the professional team in accordance to their functions. The professional team is involved in the design of the project and will ensure that it is done in a professional, safe, environmentally sound and cost effective manner. The services of these individuals are essential the country's GDP growth and global competitiveness as well as its environmental safety. The constitution requires that a fair, transparent, equitable, cost effective and competitive process be undertaken in order to procure the services of the professional team. The developer/Client should maintain a safe balance between the reasonable compensation of the professional and ensuring healthy competitive practices (Constitution(SA), 1996).

According to CIBD Best Practice Guideline A7 (Table A1, SFU): "The procurement of professional services should result in the award of a professional service contract on the bases of demonstrated competence and qualification for the type of services required, at fair and reasonable financial offers. Accordingly, the underlying principle is that professional service contracts are awarded to firms which have both capacity and capability to provide the quality of the service at a reasonable financial offer and not necessarily to those that are the least costly. The constitution requires that the procurement system be cost effective. This implies that best value procurement outcomes in terms of quality, downstream and lifecycle costs, timing and financial offer using the least amount of resources necessary to effectively manage and control the procurement process, should be strived for. Clearly selection on the basis of quality should not necessarily mean the best quality available but the quality appropriate for the assignment".

It has to be noted that this dissertation assumes the client is one in the private sector and that he has pre-selected the EE based on the financial offer, quality of previous work done and preference of the client. In cases where government tenders are to be undertaken a stringent tender process has to be undertaken to insure a fair and transparent process as previously described. Once the client has expressed the intention to appoint the EE, he (EE) has to prepare a fee proposal for the project. This entails the minimum fees that the client will have to pay the EE based on the initial scope of work. The EE estimates the value of the project based on the preliminary design, previous experience and the latest tender rates. The preliminary design could either be based on client specifications or minimum area allowances based on the type of project it is. The fees are then estimated based on the contract value using government gazetted fee calculation. The same method of calculating fees should be used for all professional engineers/EE's who practice in South Africa based on their respective disciplines. (CESA, 2010)

The EE has to prepare and submit his professional fee proposal to the client for approval. Once the fee proposal has been approved the client issues an appointment letter which is accompanied with an employment contract. This contract will stipulate amongst other things the scope of work, the fees payable, the duration of the project as well as the terms of employment. All this information is detailed in the PROCSA document which has to be signed by both parties. This document is drafted by the Principle Agent on behalf of the client and is legally binding between the client and the consultant/EE (CESA, 2010). These documents are either kept with the client or the QS throughout the duration of the project. When necessary they will be referred back to either during conflict or for any required clarity. At the same time the EE has to ensure that preliminary designs are approved. Depending on the time constraints of the project, the EE may be required to go out to tender using the preliminary designs which may be altered and refined at a later stage. If time allows for it the EE may still be able to conduct a more detailed design before going out to tender. It is more desirable for the EE to go out to tender using a more detailed design as this will ensure that the tender prices are more accurate and do not change over time. Thus the budget constraints would be easier to obey. (ECSA, 2000).

3.5 DESIGN

Once the EE has been appointed to the project as part of the professional team, the real technical work begins. An essential part of the design for any project is the scope. At this stage of the project the scope should be clearly defined based on the type of project it is and client specifications. For the sake of this study the scope of the project shall be restricted to MV and LV equipment up to and including the main DB in the building. It is during the detailed design that all the preliminary designs and assumptions can be refined. Once the scope is clearly defined and all the client specs have been signed off, the detailed design will make it easier to compile more detailed tender documents. This will in turn ensure that there are less VO's due to aspects that were left out. Although this study is based on MV and LV equipment which is mostly located outside the building, the equipment loads that influence the specification thereof is mostly located inside the building. This is where the detailed design commences. An essential part of the design is the load model. The load model can come in any form, however it is easier to navigate and update using MS Excel. The function of the load model is to combine the electrical loads (in kilowatts) of all the power and light points in the design, taking into consideration the diversity, power factors and load factors thereof.

Lighting

When designing the lighting layout of the building, the specification of the light fittings has to be agreed and signed off by the architect or client. Thereafter the EE has to design the number of light fittings required in the respective areas in accordance with SANS 10114-1. According to this regulation, lighting has to be designed in order to ensure the health and safety of its occupants while taking into consideration energy efficiency. It is also there to ensure comfortable and good viewing conditions for all occupants. Therefore in any building there are minimum lighting levels that have to be adhered to depending on the type of area and the activity that takes place in that area. The table below summarises the recommended lighting levels according to activity:

Table 3 - Activity vs Illumination Recommendations

Activity	**Illumination**
Public Areas	20 - 50
Simple Orientation for short visits	50- 100
Working areas (occasional tasks)	100 -150
Warehouse, Theatres, Homes, Archives	150
Easy office work, classes	250
Normal office work, PC, Library, Groceries, Labs, Showrooms	500
Supermarkets, Mechanical Workshops, Office Landscapes	750
Normal Drawing Work, Operating Theatres	1000
Detailed Drawing Work, Very detailed mechanical works	1500 – 2000
Working with small objects for prolonged periods of time	2000 – 5000
Conference rooms	300
Training rooms	500
Auditoria	150 - 200
Toilets	200
Electrical and Generator rooms	200
Kitchens	500
Physical fitness space	500
Child care centres	500
Parking areas	50
Staircase	200

The number of lights in the entire building is calculated based on the floor area, room height, ceiling, and floor and wall colours. The total electrical load is entered into the load model. (SANS10114-1, 2005)

Power

Similar to the lighting design, the load of all the power outlets is calculated based on regulation and client specifications. The EE conducts a standard power design based on the number type of area it is. A standard of 1 plug point (plug point that receives a live, neutral and earth conductor which is connected to earth leakage) per 10 square meters is used for general areas. In addition, offices and other admin areas receive a dedicated power (plug point not connected to earth leakage) as well as 2 data points. This is usually called a workstation power outlet. The power design also includes any additional power points that the client may require based on the client's specification. The type of (single/3 phase, isolators, industrial sockets, etc) and number of additional power outlets depends on the type of building it is. For instance, if the development is an office park then there will be more workstations for all the computers, printers and other administrative equipment. However if the development is a warehouse then the design will entail more specialised power points such as isolators, industrial sockets and hard connections for specialised equipment control panels such as refrigeration and HVAC. (SANS10142-1, 2009)

Circuiting and Distribution Boards

All the electrical loads are then recorded in the load model in order to determine the sectional and total load of the building. This information will be used to design the sizes of cables required to feed the respective sub-DB's from the main DB and the main DB from the miniature substation/transformer. It will also be used to design the sizes and quantities of the CB's in the DB's. After this process has been concluded the circuiting can be done in order to determine the number of circuits will be required in the DB. The lights are grouped together in zones in such a way that the electrical loads do not exceed 10 amps. This grouping forms a single circuit. Each circuit is connected to a CB in the DB. All the lights are grouped together to form the total number of lighting circuits in the DB. A similar process is undertaken with all plug points in the building. The number of plug points in a circuit is determined based on the type of equipment that is likely to be plugged in. For instance, in an office space the EE would have 5 plugs per circuit because computer screens and towers are likely to be plugged in. (SANS10142-1, 2009)

Cable insulation and protection

The total load on a typical power circuit should not exceed 20 amps because that is the size of the circuit breaker feeding that circuit. The main function of a CB is to protect the cable feeding from it. Over-current in any circuit could cause over-heating which would eventually cause damage to the insulation. Damaged insulation causes arching faults which produces temperatures of up 1000 degrees Celsius with as little as 1 ampere flowing through them. Arching faults break down the organic insulating material over time, thus releasing hydrocarbon vapours that make it possible for electricity to be conducted through air. This further aids the arching process. If any of the loads exceed the stipulated amperage the CB in the DB will trip in order to protect the cable. It is also essential to specify the correct cable insulation depending on the type of installation. There are many types of cables used in the industry and some are application specific. For the purpose of this study the cable network from the transformer to the end user shall comprise of PVC insulated copper cables. There are 3 types of arching namely line-to-neutral, line-to-ground and series arching. (CPSC, 2002). The following figures illustrate the likely causes of each arc fault:

Figure 3 - Example of how line-to-neutral arc fault is created (door pinching power cable)

The figure above shows a flexible power cable that may be bent and pinched in corners. Over a certain period of time the insulation between the conductors may be damaged, thus causing line to neutral arc faults. (CPSC, 2002)

Figure 4 - Illustration of Line-to-ground arc fault (Nail puncturing power cable)

The picture above illustrates a nail puncturing a power cable. This situation might occur when a nail is punched into a wall for hanging a picture in a home where the electrical cabling is reticulated behind dry walling. If the electrical cable has bare copper earth wire next to the live and neutral then nail coming in contact with the wires could cause a line-to-ground arc fault. (USFA, 2006)

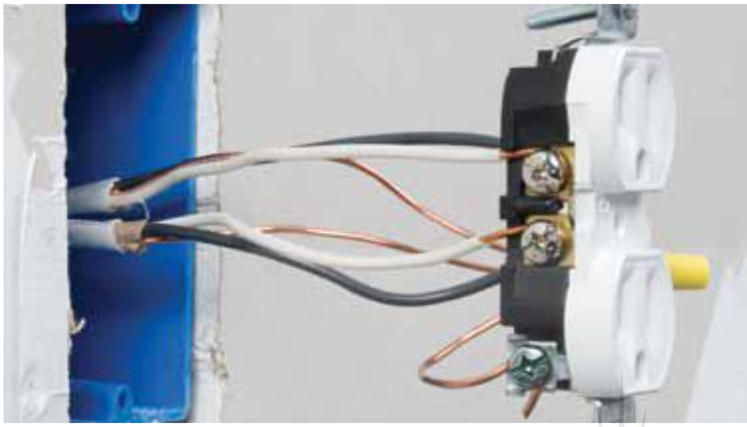


Figure 5 - Wire connection block not yet pushed back into draw box

By definition a series arc can occur anywhere in the line or neutral of a circuit. However the current flowing through an arc fault is limited by the load on the circuit. This type of fault usually occurs at the connection box of the circuit. This is usually termed a loose connection in the construction industry and takes place at the connection box. Even though a loose connection may carry current without arching after the installation, intermittent current flow occurs in electrical systems. This is caused by the on/off load cycles due to equipment being turned on and off. These cycles form heating and cooling cycles at the screws in the connection block which cause a thin oxidation layer on the surface. This layer forms an insulator, which causes electrons to jump the insulation gap when the voltage exceeds the insulation capacity. This ultimately results in a series arc fault. Regardless of the type of arc fault that occurs, each of them creates temperatures that can reach the thousands depending on the load. These temperatures are enough to ignite certain materials. The greatest danger of this process is that it happens in silence and invisibly. Such experiments have been conducted continuously in laboratories and similar results have been recorded. This is the reason why appliances and equipment that works well one day suddenly cause a fire the next day. It might be assumed that these types of faults and resulting fires are common in older installations; however they may also occur in new installations due to inefficient connections, misapplied equipment, abuse, loose and improper connections and the use of ageing equipment. (Bouakouir, 1987)

Single line diagrams/schematics

Once the circuiting is done the EE can then design the single line diagrams/schematics. This is the basis to which the DB's are manufactured. The single lines record amongst other things the number of lighting and power circuits and the sizes and specifications of the circuit breakers that will be present in the respective DB's. Another very important aspect of designing single line diagrams is to determine the short circuit capacity of the equipment. This is a major consideration in an electrical design that is often overlooked. The short circuit rating of equipment entails the thermal stress that the components of a DB can withstand during fault conditions before it fails. This rating is proportional to the square of the RMS current in a certain period of time (i.e. I^2t). These stresses are caused by the rapid heating up of equipment under fault conditions. All the equipment in the DB should be able to withstand the maximum prospective current under fault conditions for the time it takes the protective equipment to interrupt the fault. This includes the MCCB's, busbars, conductors and contactors. The protective equipment in this case would be the fuses or MCCB's. In order to reduce the thermal stresses the system either has to reduce the short circuit current or reduce the interruption time. (Fischer, 2005)

One of the ways of reducing the fault level is by avoiding the installation of large sized transformers and/or generators at one point. Also the further the transformers from the load the lower the fault levels will be. By using fuses and MCCB's the short circuit current interruption time is reduced 20ms. It should be remembered that the short circuit current caused when the insulation of conductors wear off is up to 20 times the rating of the transformers. This is why all faults should be interrupted as soon as possible. The EE has to ensure that the equipment short circuit rating is higher than the maximum prospective short circuit of the system. This is so that the equipment is not damaged during the time it takes the protective devices to interrupt the fault. This has to be balanced with the cost of the equipment because it escalates as the fault level increases, which ultimately affects the cost of the DB. Each DB in the building will have its own single. These will form part of the drawings that will be issued at tender stage. (Fischer, 2005)

Another important function of protective equipment is to prevent degradation of equipment downstream by overloading of current. By preventing this, the system also prevents health and safety hazards due to fires as well as prolonging the life span of the equipment by ensuring that it doesn't function above its capacity. Protective equipment is usually installed in inside the DB to protect equipment downstream. In most cases they are in the form of fuses and MCCB's. The basis of functioning for this equipment is to allow certain currents to pass and to block others over a certain set threshold. The most important function of these items in our case is to protect the cable from over current. Over-current causes the resistance on the cables to increase which causes the temperature in the cables to increase. Over time this causes the insulation around the conductors to wear out which will eventually cause an arc fault. This is also a fire hazard. (Abedare, 2008)

External Cable Reticulation

Once all the electrical points (lights and plugs) are recorded in the load model the total electrical load of the building can be determined. Each electrical entry takes into consideration the diversity/load factor and the power factor. The load entails the probability of all the electrical points being used at any given time. These values change depending on the type of equipment in question. For instance the load factor for factory lights would be unity (one) because they are likely to be on throughout the day. The same process is followed for all entries in the load schedule and the total load (in kVA) is determined. This load is used to calculate the required size and number of incoming cables from the transformer/minisub. The main factors to consider when calculating the size and quantity of main cables are the volt drop and the derating factors. (Abedare, 2008)

Derating factors include maximum sustained conductor temperature, ground temperature, ambient air temperature, ground thermal resistivity and depth of lying to top of cable or duct. Derating factors reduce the current carrying capacity of cables depending on where and how they are installed. These have to be factored in when calculating the quantity and size of cables. Many engineers make the mistake of overlooking the effects of derating factors on electrical conductors when doing their design. This could lead to the cables being over loaded and overtime this could reduce the life span of the cables and cause health hazards. The volt drop entails the percentage that the voltage is permitted to drop relative to the voltage of the system. The further the load is from the source is the greater the volt drop. The greater the current carrying capacity of a cable the let the voltage drop. The total permissible voltage drop of the entire system from source to the end user is 5% of the total system voltage. (Abedare, 2008)

External Switchgear

Although this section is being covered last, it forms the first point of entry of power into the development. Depending on the amount of power (in kVA) required for the entire building, the energy provider will either provide a LV or MV supply. For the purpose of this study it will be assumed that the energy required is high enough to warrant an MV supply in the form of a transformer or minisub. Electrical power is transmitted from power stations (Kusile, Lethabo, Majuba) using overhead high power lines that are suspended on towers. The ranges of voltages are as follows; 600 V and less entails love voltage, 600 V to 69kV entails medium voltage, 69 kV to 230 kV entails high voltage, 230 kV to 1100 kV entails extra high voltage and any voltage above 1100 kV entails ultra-high voltage. As previously elaborated, cables experience losses when transmitting power over long distances (voltage drops, attenuation, etc). Therefore it is necessary to increase the system voltage when transmitting power from substations which are located hundreds of kilometres from the load. The voltage of the current produced at the substation can reach 13.8 kV. Thereafter the voltage is stepped up to either 400 kV, 275 kV, 220 kV or 765 kV using step-up transformers. It is transmitted across the country through the overhead lines to different source substations where it is stepped down to lower voltages, and then to satellite substations where it is further stepped down. From the satellite substations the electricity travels via underground cables to local building transformers or mini-subs. At this point the voltage is usually stepped down to 11kV or 6.6 kV. It is at this point that the electricity finally reaches the development in this study. (Van Heerden, 2008)

Once power reaches the site it has to be stepped down to LV. The architect will decide whether to have a transformer room or a mini-sub based on his overall design. For this purpose we will assume a mini-sub was used. The size of the mini-sub (in kVA) is taken from the load model which was previously mentioned. The value determined in the load schedule will be rounded up to the nearest standard value in order to determine the size of the minisub. Standard sizes of mini-subs from council are 315, 350, 500, 630, 800, 1000, 1500, 3000 kVA. The EE has to locate the most appropriate 6x3 meter servitude at the boundary along which the main council MV cable runs. During the application process the EE would have liaised with council to determine where the MV route is. Once this is determined council then cuts into the MV cable and connects the cable to the RMU of the minisub. The RMU has 3 spurs; one coming in, another going out and the third going into the transformer. The transformer steps down the incoming voltage to 400V. Council's work stops with the installation of the minisub which has the main circuit breaker which will be used to feed the main DB. From the LV side of the transformer of the minisub the correct size cables are connected to the top of the CB (Fischer, 2005). This will be switched off until it is safe to switch it on. The same size cables connect the bottom of the main CB to the main LV busbars. From these busbars cables transmit the current to the main DB that was described earlier. This concludes the process of getting power from the substation to our development. (Van Heerden, 2008)

After the EE concludes the design process he hands it over to the draughtsman who puts all the designs on drawings. These drawings will then be handed over to the client and architect for approval and sign off. The EE has to keep record of this in case of any disputes at a later stage. Once all the drawings have been approved and signed off it is then time to commence the procurement process which entails procuring the services of an electrical contractor who will be responsible for doing the physical installation on site.

3.6 PROCUREMENT

As previously mentioned, this stage entails procuring the electrical contractor which will do the actual installation on site. This process starts with the EE compiling the tender documents. Tender documents form the legal basis for which the electrical contractor will be employed on the project. The tenders and subsequent contract are based in the JBCC agreement. The JBCC in conjunction with the PBA is used in all building contracts and should be accompanied by a BOQ, a standard tender document and drawings. The JBCC governs the appointment of nominated and selected subcontractors which binds them to the same contract conditions as the principle contractor. The content of the JBCC document also serves as a checklist that can be referred to throughout the duration of the contract in order to minimize disagreements and to maximize the amount of expensive man hours of all the stakeholders in the project (from contractors to professional team) (JBCC, 2018)

The tender documents are compiled by the EE and put together with the approved drawings. A list of prospective electrical contractors is agreed upon by the professional team based on accreditation, previous experience, working relationship and skill set. The most important function of the tender process is to source the lowest possible prices for the same specification. Through this the prospective contractor is forced to source the most reasonable prices and keep their profit margins reasonably low for the client. The EE is legally bound by the PROCSA agreement and ECSA ethics code of conduct to look out for the best interest of the client. This entails the EE ensuring that all contractors charge the lowest market related prices for their work. The tender documents are made up of 7 main parts namely; (CESA, 2010)

1. Part 1 – Notes to Tenderer
2. Part 2 – Form of Tender
3. Part 3 – Additional General Information
4. Part 4 – Standard General Technical Specification
5. Part 5 – Detailed Technical Specification
6. Part 6 – Bill of Quantities
7. Part 7 – Material on Site

The document is carefully assembled with all the client and project specific information on the cover page. It is then bound together neatly and handed to the client and QS for final inspection. After the documents have been approved sufficient copies are made for all the approved prospective sub-contractors. The tender documents contain information regarding the date and time that the tender is closing. Depending on the size of the project and the deadlines, the EE could opt to go out to tender from a period of 1 week up to a month. During this time the tenderers source the best prices from suppliers based on the specification. The process followed has to be transparent and ethical, and no price fixing should be undertaken. All the contractors should return the completed tender documents no later than the specified day and time. Any late submissions are automatically disqualified. A summary of all the BOQ's is recorded on a spread sheet so as to easily compare the respective sections. The EE should also ensure that no arithmetic errors are contained in the amounts. (CESA, 2010)

The EE should also take note of any qualifications that the tenderers may include because these could cause problems later on during the project. This process of assessing the documents to ensure that they adhere to the rules is called tender adjudication. Once the adjudication has been concluded the most appropriate tenderer has been established then the EE has to write a tender report to the client with his recommendations. The QS then instructs the main contractor to appoint the appropriate contractor based on the EE's recommendations. The new contractor will then be managed and paid by the main contractor who will subsequently claim from the client. Once the electrical contractor signs the relevant documents they are bound by the tender specification, electrical drawings and JBCC contract until the project is completed. (CESA, 2010)

3.7 CONSTRUCTION

Once the paperwork has been concluded it is now time for the EC to commence their duties on site. This is process is started with an official site handover where the main contractor briefs the electrical contractor on their expectations and duties. It is also advisable that the EE and EC also have a kick-off meeting so that the EE can brief the EC on his design rationale and any queries can be cleared. At the same time the EE should issue 3 full sets of design drawings to the main contractor on site. When this process is concluded construction can start. For the EC this entails installing all electrical services in accordance with the design drawings from the EE. The drawings are always accompanied by a drawing register. This is a record of all the drawings listed according to their number, the revision number and the date of each delivered revision. Another important aspect for the EE to remember is for the recipient of the drawings to sign the drawings, write the name and the date of receipt. This information is very important and should be saved and stored for atleast 10 years in case of any disputes. (JBCC, 2018)

The EC shall only install drawings according to the EE's drawings. Any extras requested by other consultants or contractors should be communicated to the EE so he can give the necessary instructions to the EC. The EC has to ensure that he sticks to the dates specified in the main contractor's program so that practical completion (PC) can be achieved. The EC should also identify and communicate potential risks on time to the EE and main contractor so that mitigating strategies can be devised. If the EC is not able to achieve the tasks within the specified dates and does not communicate this appropriately then the EC will be charged penalties in accordance to the appointment contract. When PC is achieved and the site is handed over to the client, the EC has 14 days to rectify all identified defects from PC date. Also the EC is responsible for issuing all the COC's and manuals for the installation. (JBCC, 2018)

In any new construction project, the installation starts with the external services. In this specific study the contractor starts his installation outside with any sub-surface services. These include but are not limited to sleeves for power and data services, and main external electrical cables from the mini-sub towards the building where the main DB is going to be installed. Once the building is ready the main DB is installed and the cables from the mini-sub are terminated. All the other electrical that were designed for are then installed as per the drawings. The EC starts with the first fix services that include all equipment that will be installed sub-surface inside the building (such as wireways). The EC then follows with second fix items that are installed in or on the wireways. Towards the end of the project the EC proceeds to install the final fix which entails the installation of all the equipment that will be seen by the public (such as light fittings, power sockets, etc). Once the installation is done the EE has to prepare the COC's for the minisub, the DB's and the installation as a whole. The EE also has to sign the COC's to indicate that he designed and checked the installation. All this information gets handed over to the client for safe keeping. (JBCC, 2018)

3.8 OPERATIONS AND MAINTENANCE /MONITORING AND CONTROL

This is a crucial part of the project which as it entails the most work of the project. This part also takes the longest as it takes place from the first day of the project to the day the client takes over the building. Depending on the size of the project the project manager may convene meetings weekly, bi-weekly or once every month. In this study it shall be assumed that the meetings are held every second week. Further to the design meetings the PM may also insist on holding site walkabouts with the team to assess the progress on the site. These meetings are crucial in that they ensure that communication channels are kept open to all stakeholders. This is the part of the project where the EE has to make use of soft skills in the project. The EE has to be able to communicate effectively with all the relevant stakeholders in order to succeed. The EE's social and communication skills are essential in running the project successfully to its conclusion. There are different types of communication activities that the EE should undertake. (Taylor, 2010) These include but are not limited to internal the following:

- Internal communication – this refers to communication that takes place between the members of the professional team e.g. minutes of the meetings being distributed, meeting requests being sent
- External communication – entails communication that takes place between members of the professional team and stakeholders outside of the project e.g. EE communicating with council (Eskom/City Power/Ekurhuleni) regarding permanent power
- Formal communication – refers to written communication that is distributed to stakeholders e.g. minutes of meetings, inspection reports, etc.
- Informal communication – this happens on an ad hoc basis and is usually not planned e.g. emails, memos, ad hoc discussions (Taylor, 2010)

The main task of the EE during this process is to ensure that the electrical installation is done in accordance to the drawings. It is also very important that the EE ensures that the quality of work by the EC is up to the required SANS 10142 standards. This is done by continuous and regular site inspections of the installation. In this case the EE starts by inspecting the external trenches to ensure that they have been dug to the correct dimensions. Once the cables/sleeves have been installed in the trench the EE has to inspect the installation before the trench is backfilled to ensure that nothing has to be redone. As and when the equipment inside the building is installed the EE has to ensure that the quality of the installation is satisfactory. Each inspection should be followed by an inspection report which should be emailed to the client, main contractor and the EC. It is then the responsibility of the contractor to make sure that the items listed in inspection report are resolved before the next inspection is conducted. (SANS10142-1, 2009)

A very important aspect of monitoring and controlling is managing and controlling the resources within the project. The most important resource in any project is the budget as it controls all other resources. A project that goes over budget can be considered a failed project in the client's eyes, unless the budget overrun is due to the scope or time change. This was described earlier while elaborating the Iron Triangle. The EE has to ensure that the project is completed within the cost estimate that was handed to client and QS at the beginning of the project. The EE also has to ensure that the client is kept up to date with project costs throughout the duration of the project. This is done through monthly cost reports that reflect the summarised original tender value as well any project variations (extras and savings). The EE also has to evaluate and process all the EC's monthly claims based on the current status of the installation on site. The EE has to ensure that all items claimed for by the EC are in fact installed on site. The EE also has to ensure that the quantities claimed for by the EC do not exceed those in the tender unless there is pre-approval by the client and QS. All items that are on the drawings but not in the tender have to be presented as VO's by the EC to the EE for approval by the client. Only once this process has taken place can the EE approve any items not in the tender or quantities that exceed those in the tender. The EE has to keep a stringent watch on the budget to ensure that it is not exceeded. Also the EE has to notify the client well in advance of any prospective VO's before they are claimed by the EC. (PMI, 2013)

Over and above site inspections, it is also important to inspect all the equipment that is to be installed in the building while it is still at the factory. The factory inspection should be done by the EE in the presence of the EC. The EE should ensure that the minisub is the correct capacity (kVA), is the correct colour, has the correct equipment inside and has sufficient space for the termination of the cables. During the DB factory inspection the EE should ensure that the DB is the correct physical size to fit in the required space on site. The DB's should be the correct colour as agreed with the architect. The number of CB's, the size (in amps) and the fault level of all the equipment in the DB's should be as per the drawings. Most importantly the EC should be present to ensure that the DB is the correct physical size to terminate the incoming cables. A similar process should be taken with approving all final fix aesthetic fixtures so that nothing is installed on site that has to be replaced. It is extremely important that all the above aspects be signed off by the client and architect before any equipment manufactured and delivered to site. The essence of monitoring and controlling a project is to ensure that all aspects run smoothly and to ensure that quality control is maintained so that the end product that is handed over to the client is reliable and satisfactory. It requires the EE to effectively manage the entire process together with the people and relationships in order to get the job done. (JBCC, 2018)

3.9 DISPOSAL OR RENEWAL/CLOSING/ COMMISSIONING

The end of the project is a crucial stage which is often taken for granted. It often determines the success or failure of the project in the client's eyes and could undo any good work that has been undertaken during the project lifecycle. It has to be noted that perception is key in any project and the client's perception of the project team could decide whether he gives more work to the same team in future. One of the most important aspects of this phase is the testing and commissioning of equipment that has been installed on site. It also assists in managing the integration of all the respective systems installed in order to determine their cohesiveness. This is in addition to the individual factory tests that would have been conducted as described earlier. This phase is critical in ensuring that any faults or defects are fixed and that the final product functions reliably. This phase will also ensure that the client/end user does not experience any delays in production that could be costly. It is for this reason that testing and commissioning is allocated its own space within the project lifecycle. (PMI, 2013)

In this study the EE has to pressure test all external main cables from the minisub to the main DB. The EE also has to test all the plugs connected to earth leakage to ensure that the CB's trip during fault conditions. All lights and switches have to be tested to ensure full functionality. The DB's have to be inspected to ensure that there are no loose connections that could cause arching and subsequent safety hazards. After all the tests are conducted the EC has to issue COC's of the components installed as well as a COC for the entire electrical installation. These also have to be accompanied by manuals for all the equipment so that the client's maintenance team can resolve any faults that may occur after the conclusion of the project. It has to be noted that the EC is obligated to avail themselves for a maintenance and defect liability period of a year from the date of official handover. Another very important aspect of the handover process is training the client company with all the systems that have been installed. This helps the client maintenance team resolved minor issues that may occur on a day to day basis. When all of these processes have been completed to the satisfaction of the client and the EE, the EE issues a signed completion certificate to the EC confirming that the project has been completed in accordance to the specification and design and that the client is satisfied. (JBCC, 2018)

4 CHAPTER 4

RESEARCH METHODOLOGY

4.1 INTRODUCTION

The purpose of qualitative research is to comprehend and break down social interactions. The research groups that are selected are smaller and not randomly selected. This type of research collects words, images and objects. The kind of data comes in the form open ended responses, interviews, participant observations, field notes and reflections. When qualitative research is used to prove a hypothesis the researcher looks for common patterns, features and themes within the collected data. The researcher has to be subjective when approaching the results. The reason for this is because the researcher and his biases may be known the individuals that participate, and conversely the researcher may himself know the characteristics of the participants. Results in this type of study are particular, specific and specialised in nature. The type of human behaviour in this study is usually dynamic, situational, social and personal in nature. The objectives in this type of research are usually to explore, discover and construct certain patterns. The researcher usually has a wide-angled and in depth view of the phenomenon. The sample area is one in which the participant is in his natural habitat and behaviour. In the final report the researcher will use a narrative approach which will contain direct quotations from research participants. (Lichtman, 2006)

The main purpose of quantitative research is to test a hypothesis, determine the cause and effect thereof and make predictions. This type of study is random in nature and is conducted over a larger and broader scale. This method focuses on specific variables. The type of data is numerical and statistical in nature. It is based on exact measurements using structured and validated data collection instruments. It is aimed at determining statistical relationships and is objective in nature. In this case the researcher and his biases are unknown to the subjects participating in the study, while the characteristics of the participants are deliberately hidden so that biases are not realised. These are also known as double blind studies. The results of these kinds of studies are generalised and can therefore be applied to other populations. The human behaviour in this case is regular and predicable. The objectives of this kind of study are to describe the problem, explain it and predict future results. The researcher has a narrow-angled view of the problem in order to test that specific hypothesis. This type of study is meant to be carried out under strict and controlled conditions. The point of the study is to get to a specific reality or result. Contents of the final report will be statistical in nature and will have correlations, comparisons and statistical significance to the findings. (Johnson & Christensen, 2008)

4.2 STUDY RATIONALE

This chapter is intended to outline and detail the manner in which the research was conducted. It also details the target location as well as the target market for the research in order to make it as credible as possible. The chapter also delves into the tools that were used to collect the data in order to ensure reliable and credible data to be analysed. In summary this chapter describes the how information was collected in order to establish how a project engineer can efficiently manage the process lifecycle of a project.

Another essential purpose of this chapter is to outline the method that will be used to investigate and prove the hypothesis at hand. A qualitative approach will be used in order to achieve the desired results. The main function of this chapter is to explore the challenges that are experienced by various professionals and stakeholders when inefficient and incompetent individuals are allowed to manage projects. This chapter will research the risks and dangers involved when the incorrect procedures are followed during a project and when short cuts are taken. It will also investigate the consequences that may occur when quality control checks aren't done throughout the project lifecycle.

4.3 RESEARCH DESIGN

Research design can be summarised as the structured plan on how the research will be conducted and how the data will be collected. "A research design is the arrangement of conditions for the collection and analysis of data in a manner that aims to combine relevance to the research purpose with economy and procedure" (Ahuja, 2010). A research design has the following characteristics: (Coldwel & Herbst, 2004)

- It specifies the source of the data as well as the type of information relevant to the research questions
- It outlines the strategy that the researcher will follow in order to gather the information
- It involves cost and time planning for the entire research period and these form an essential part of data collection.
- It involves specifying the techniques and procedures that will be undertaken in order to collect the data
- It also involves information regarding the population that will be studied
- Lastly it outlines the methods that will be used to process and analyse the data.

Research design can be broken down into several phases: (Ahuja, 2010)

- Outline and detail the problem to be researched
- Outlining the structure of the research
- Planning a sample space/ research area
- Collection of data

- Assessing and analysing the data
- Preparing and executing the report

It is necessary to briefly discuss the design of this particular research. The purpose of this study is to determine the effects and the dangers that may occur in a project when the process life cycle is not managed efficiently. The study also attempts to delve into some of the documented accidents that could have been prevented if the process was managed more efficiently. Another mission of this research is to determine the effects of an unqualified and/or inexperienced EE on the outcomes of the project (Triple constraint). This type of study shall be qualitative in nature as it will depend mostly on people's opinions. The strategy to this research entails conducting interviews and/or sending out questionnaires to professionals and stakeholders within the industry in order to determine if there is a basis for this research.

All interviews that are conducted shall be so done in Gauteng. This is because 55% of construction projects in South Africa are concentrated in Gauteng. Also Gauteng is the economic hub of South Africa and Africa (CIDB, 2009). Also the EE conducting this research is based in Gauteng and therefore it would be the most convenient option to do so. The questionnaires however will be boundless in terms of participants because they can be distributed electronically. Once the suitable participants have been identified they will be subdivided into those that will be interviewed and those that will be required to complete the questionnaire. During the interview the interviewees will be asked the same set of questions and the responses will be recorded through a voice recorder. The EE will then record the responses as they are in the dissertation. The questionnaires will be emailed to all relevant participants with a timeline specified for their return. Once the interviews have been concluded and the questionnaires have been filled out and returned all the information will be consolidated and recorded in the report.

The responses from the questionnaires will be recorded in an excel spread sheet and subsequent graphs will be produced in order to create a discussion and conclusion. The responses from the respective interviewees will be assessed to determine if there are any similarities. The conclusion to the assessment of the results will then be documented in a structured manner and presented. The EE has to be careful to report all the information collected in an unbiased manner. The trick is for the EE not to include his emotions or opinions in reporting the responses of the participants. That way the final report will be a true reflection of the responses of the participants. The same can be said about the manner in which the EE conducts the interviews and the manner in which he asks the questions and records the responses. It is therefore better for the EE to report all the responses word for word instead of trying to interpret then. Also the EE shall get written permission from all the interviewees to publish and distribute their responses.

4.4 AREA OF RESEARCH

As previously mentioned the research will be conducted mostly in the Gauteng area. This is mainly because some of the country's biggest most costly projects take place here. Another reason is because the EE conducting this particular research resides and works in this region and therefore has access to stakeholders that are involved in construction projects. Most if not all of the stakeholders that will be interviewed also reside and work in the Gauteng area. The researcher will target participants from Gauteng for he interviews as this the most convenient. However the researcher has the liberty to send the questionnaires to individuals all across the country. This is because the communication channel will be email and social media and therefore is boundless.

4.5 POPULATION TO BE TARGETED

According to Stats SA's quarterly labour survey, Gauteng has the majority work force in the South Africa in the construction industry. Migration statistics show that Gauteng's population increases at the highest rates amongst all the provinces in South Africa. This means that each quarter a greater percentage of people move from their provinces to Gauteng. The figure below depicts the percentage spend in South Africa based per province between 2017 and 2018. As can be clearly seen Gauteng has the highest construction spend in South Africa followed by Eastern Cape, Western Cape and Kwa-Zulu Natal. These 4 provinces collectively constitute 71% of the total formal and informal construction employment in South Africa (StatsSA, 2015).

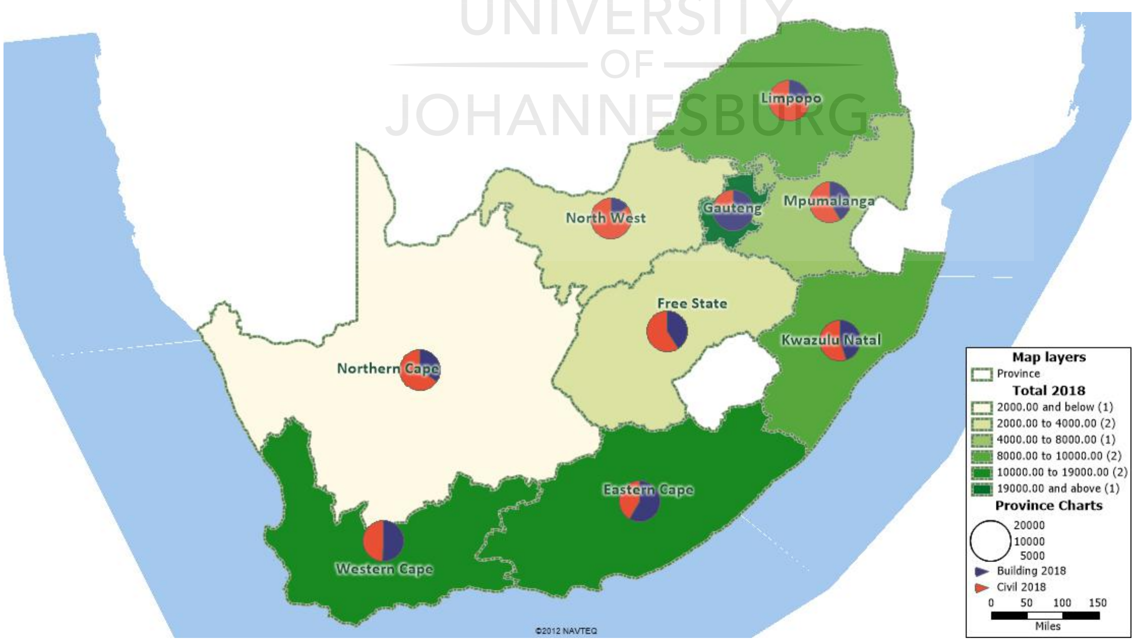


Figure 6 - Construction spend and employment in South Africa

It is because of the statistics described that Gauteng was the ideal place to conduct this research. It is for the same reason that the target market of participants will be in this area. It follows logically that a higher percentage of professionals would also conduct their business in Gauteng. Therefore the target market for interviews and questionnaires for this study will be this group of individuals. This will increase the probability of the information collected being of a reliable quality because the individuals that the information is collected from have got a broad understanding of the industry. The individuals targeted will all have over 5 years of experience in order to ensure that they have been through the necessary project challenges to be able to give credible information.

4.6 SAMPLE

To an inexperienced individual, the best way to describe a sample is “a finite part of a statistical population whose properties are studied to gain information about the whole. When dealing with people, it can be defined as a set of respondents (people) selected from a larger population for the purpose of a survey”. It then follows from the definition above that sampling is the procedure of selecting a suitable sample for the purpose of establishing a certain pattern of behaviour or characteristic of the whole population. The process of sampling is intended to draw a premise of that specific population based on the selected sample. The other purpose of this process is that it is cheaper and takes much less time to observe part of the population instead of the entire population. It goes without saying that observing the entire population would take an obscene amount of time and use a lot of resources, which are unavailable for this research. It has to be mentioned that sampling part of a certain population comes with the risk of encountering errors in the information collected and therefore rendering the information unreliable. There are 6 main reasons why a researcher would opt for sampling instead of a census of the entire population: (Webster, 1985)

1. The economy
2. Timeliness
3. Sheer size of an entire population
4. The inaccessibility of an entire population
5. Destructiveness of the observation
6. The accuracy

There are a numerous types of samples that exist and a few shall be discussed (Salant & Dillman, 1994):

- Convenience sample – results when the researcher selects an “easy” part of the population
- Judgemental sample – results when the researcher chooses a sample based on his familiarity to the characteristics of the population.

- Random sample – takes place when the researcher chooses his sample space haphazardly from the population. This type of sampling produces the most reliable results of the 3

As described by the theory above, it is of utmost importance to select the sample and sample size carefully in order to increase the probability of obtaining credible and reliable information. It goes without saying that the researcher in this particular study cannot interview all the professionals and all the stakeholders on site. It is therefore essential that the researcher select the correct sample of participants in order to ensure that the information collected can be reflected on the general construction industry population. It is for this reason that the sample space chosen for the interviews shall have experience over 5 years and shall be part of the professional team. The researcher will interview a professional electrical engineer, project manager, an architect, mechanical engineer, main contractor and a quantity surveyor. The reason for this selection is that all the above individuals have close interactions with the EE during any project and therefore can reflect constructively on the efficient functioning of an EE. The age of the professionals will not be considered because age is not necessarily directly proportional to experience in this industry. Race and gender is also irrelevant to this study.

The second sample space will be individuals that are not part of the professional team but are part of construction projects. These are individuals that may not sit in meetings with the EE but are directly or indirectly involved in the process lifecycle of the project. These include electricians, data cabling installers, council members (City Power/Eskom). These individuals will receive questionnaires to complete within a specified period of time. Thereafter they will be required to return the filled out questionnaires to the EE to be assessed.

4.7 SITE WORK

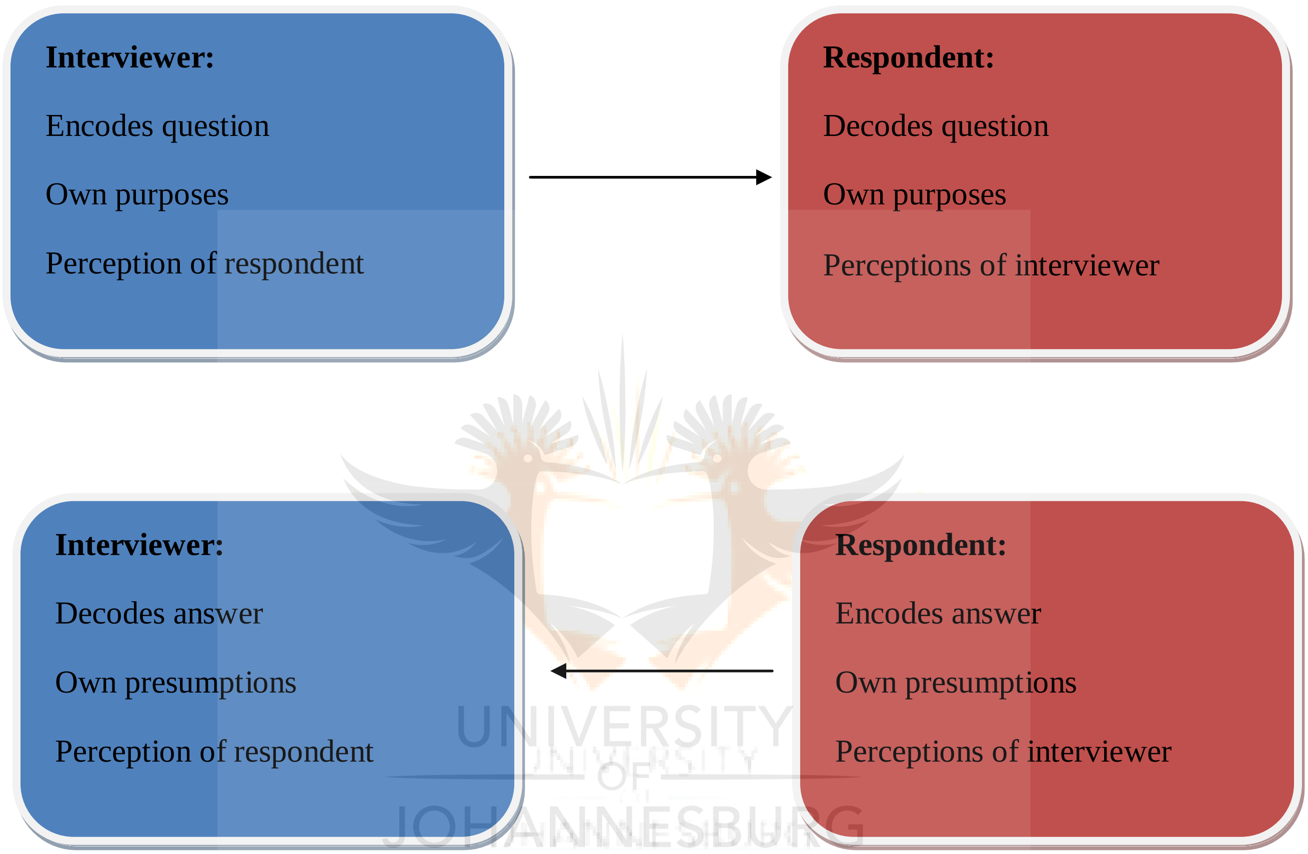
This section will be used to describe how the ground work will actually be conducted. As previously mentioned 2 types data collection methods will be used namely interviews and questionnaires. The interviews will conducted by the EE at the convenience of the participant. The same questions will be asked to all the interviewees by the EE. In order to ensure that the EE doesn't use bias when recording the responses a tape recorder will be used. The EE will then type out all the responses from the interviewees word for word.

The EE will compile a set of similar questions to the interview questions. However the respondents will have 5 predetermined responses to choose from so that they can complete the questionnaire easily. A free program called Survey Monkey will be used to compile and distribute the questionnaires. The questionnaires will then be distributed by email via Survey Monkey to all relevant individuals with a set time line for them to return them. The EE will then collect the filled out questionnaires and record all the responses.

4.8 METHODS AND TOOLS OF COLLECTING DATA

4.8.1 INTERVIEWS

Numerous ways exist of collecting data. As previously mentioned 2 methods will be used in this study namely interviews and questionnaires. Interviews are based on a simple principle of transmitter and receiver:



It has to be mentioned that there are different types of interviews. Telephone interviews entail the interviewer arranging with the respondent to prepare themselves for a telephonic interview. These will usually take place where both parties are most comfortable such as the office or home. Numerous applications exist that are able to record phone calls. Alternatively the interviewer could put the phone on loud speaker and use a secondary recording device. Telephone interviews have some advantages: (Sudman, 1982)

- They can be conducted fairly easier and quicker than surveys
- They cost much less than personal interviews because you don’t have to travel and/or book interview venues

They also have a few disadvantages:

- If the survey is aimed at lower socio-economic groups then it will suffer because not all have telephones.
- Telephone interviews have a time limit. Anything going on too long may render the respondent distracted and this may affect the responses given

Face to face interviews aren't as limited in terms of where they can be held. The parties can decide on anywhere where they are comfortable. The interviewer can also use computer assisted personal interviews (CAPI). Face to face interviews have a few advantages: (Fowler, 1993)

- Respondents are more likely to accepts invites to face to face interviews than telephone interviews
- The interviewer can press the respondent for more accurate answers if he is dissatisfied

Some disadvantages are: (Fowler, 1993)

- Individuals may not always be available for face to face interviews due to busy schedules
- Interviewers may ask their questions in a biased manner and subsequently lead the respondents to answer in a certain way

4.8.2 QUESTIONNAIRES

Questionnaires are an extremely essential part of surveys as they are usually the first point of contact with respondents. It is extremely important to get the design of the questionnaire right in order to attract prospective respondents. It is also important to design them in such a way as to elicit as much information from the respondent as possible. The main aim of questionnaires is to extract as accurate as possible information from respondents, ensure a standard form for responses to be recorded and to orchestrate the entry and processing of information through the use of credible methods. It has to be noted that a good questionnaire has to be carefully planned and thought through by an experienced/skilled individual with specialist's knowledge. For the purpose of this study only self-questionnaires will be used to gather information. A few basics have to be covered when designing a questionnaire: (Sudman, 1982)

- **Determining the objectives of the survey** – It is extremely important for the researcher to always remember what kind of information they wish to extract from the respondents. The objectives are always a good guide as to the type of questions to include. If the objectives are not clearly understood it is unlikely that the researcher will get any credible information from the respondent. (Sudman, 1982)
- **Layout of questionnaire** - the researcher needs to minimise clutter in order not to burden the respondents. The researcher should leave as much white space as possible in order for the questionnaire to be legible. (Sudman, 1982)

- **Title** – This is the first line of site for the reader and therefore should be as informative as possible to the respondent. (Sudman, 1982)
- **Accessibility and clarity** – Since the same questionnaire will be distributed to individuals with different levels of comprehension the wording should be kept as simple as possible. The questions should be as short and concise as possible, with minimal jargon or technical terminology. (Sudman, 1982)
- **Layout** – A simple and chronological order of questioning should be used in order to keep the respondent intrigued. This also helps with easy navigation through the document. This feeds back to keeping as much white space as reasonably possible. All instructions should be laid out legibly at the beginning of the document. The front page should contain information such as who is conducting the survey, why they are conducting it, why the respondents were chosen, confidentiality clauses, who should complete the survey and by when it should be returned, the reason why the data will be collected and contact details of the person conducting the survey. It is human nature to read as much of the question as the reader thinks is necessary. Therefore it is essential to keep the questions short and to the point. (Sudman, 1982)
- **Types of Questions** – There are many ways in which the researcher may pose his questions. The manner in which the questions are asks often determines the type of response from the respondent. Open ended questions entail that the respondent write in the own answer either in the space provided. They are used when the researcher requires an in depth response from the respondent. On the other end closed question offer the respondent set answers to choose from. This may be yes/no answers or a selection of a range of option that describe agreement or disagreement (range of numbers). This type of questioning is used when high level, quantifiable data is required. Here are some pros and cons of either type of questioning: (Sudman, 1982)
    - **Open questions:**
        - Pros - Include the fact that respondents can thoroughly elaborate on the answers in detail. Also the responses can give more elaborate answers on more complex questions. The types of responses may induce/expose creativity and logic from the respondents' side. (Sudman, 1982)
        - Cons - are that with more elaborate responses the researcher may find it more difficult to find common points to compare. The respondent may also lose the plot in their responses and steer away from the topic, especially if the question was not understood. Determining statistical data from qualitative responses can prove tricky and difficult. (Sudman, 1982)
    - **Closed questions:**
        - Pros – Closed questions are easier and faster to answer. It is also easier to compare answers from different respondents and analyse and code them. It is easier for respondents to respond to sensitive questions if they are

closed. Finally, individuals who are less articulate can answer as easily without being prejudiced. (Sudman, 1982)

- Cons – If the researcher misrepresents the question it could go unnoticed. Also respondents can be forced to give simplistic responses to complex questions. It may also happen that the options of answers presented are not what he respondent had in mind. In that case the respondent would choose just any response. (Sudman, 1982)

4.9 DATA COLLECTION PERIOD

There is no specific desired period for the collection of data for this study. The type of data collected can be done at any time of the year. Because of the timing of the study, it just so happens that the data will be collected between the months of March and April. Because of the limited time for the investigation to be done, the questionnaires will be issued first. While these are out the researcher will conduct the interviews. In this way the data collection will happen concurrently.

4.10 ANALYSING COLLECTED DATA

4.10.1 Qualitative Data Analyses

When dealing with qualitative data, the researcher has to deduce conclusions from a broad base of information from different sources. The researcher has to assess a lot of descriptive information and draw explanations and conclusions from it. The information in this research shall contain interview transcripts/recordings. Qualitative research relies mostly on the researcher's interpretation of the information at hand and therefore has to be done in the most transparent manner possible in order to render analyses credible. The researcher also has to focus on context, contradictions of views as well as frequency and consistency of ideas. The researcher has to have a pre-established framework in place on order to properly analyse qualitative data. The framework should reflect the researcher's aims, interests and objectives. This approach is relatively easy and only takes into account the relevant answers and discards the rest. Even though the data will be reported as is from the recording, it is essential for the researcher to familiarise himself with the collected data by reading it over and over again. (Pope, et al., 2000)

4.10.2 Quantitative Data Analyses

Quantitative data is numerical in nature and it much easier to collect and assess. The best way to analyse quantitative data is through graphs and tables. This analysis is statistical in nature and this adds to the ease thereof. It is assessed mostly uses methods such as proportions, percentages, rates of change, ratios, ranking, units and pricing. The researcher can use descriptive statistics to summarise the raw collected and inferential statistics to identify and separate different groups of data from the raw material. When analysing collected data the researcher makes use of one of 2 types of variables namely Categorical and Numerical variables. (Treiman, 2009)

Categorical variables are made up of groups of categories, e.g. sex (male/female) or quality of training (good, bad, average), comment on statement (extremely disagree to extremely agree). They describe the frequency of occurrence of that particular group. Numerical variables consist of counts of certain items (number of participants), measures (height of participants) or durations (time spent on survey). A frequency table describes the number of participants in each category. A proportion entails relative frequency and is calculated by dividing each frequency by the total number. Percentage is determined by multiplying proportion by 100. (Treiman, 2009)

Table 4 - Frequency table

Type of work	**Number of children**	**Percentage**
Street vendor	87	16.51
Car washing	92	17.46
Shoe-shiner	67	12.71
Scavenging	98	18.60
Begging	110	20.87
Domestic work	45	8.54
Other	38	5.21
Total	527	**100**

Numerical variables can be described using centre statistics and spread statistics. Centre entails a typical value while spread entails distance of data from a certain threshold. The following diagram elaborates this more clearly. Statistics used to analyse centre are the Mean and Median. The median entails the middle value of a given set. The mean is determined by adding all the values in the set and dividing by the number of elements in that set. (Treiman, 2009)

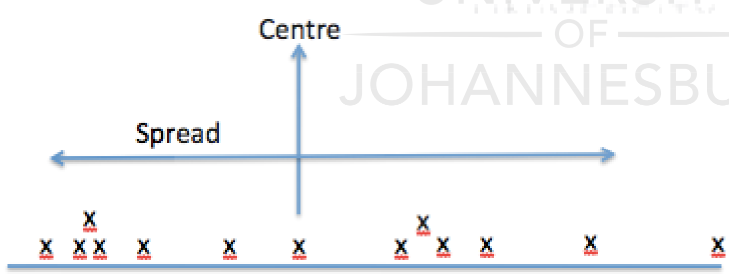


Figure 7 - Contrast between Centre and Spread

Spread is analysed using range and standard deviation. Range is the difference between the maximum and minimum value while standard deviation entails the average difference between each individual data point and the mean. If the values are close to the mean then the standard deviation is low. This means that the deviation between the values is small. It is not an easy task to determine standard deviation however it can be done rather simply through excel. (Treiman, 2009)

4.11 TAKING INTO CONSIDERATION ETHICS

"Ethics is rooted in the ancient Greek philosophical inquiry of moral life. It refers to the principles which can critically change previous considerations about choices and actions (Johnstone, 2009). When dealing with the dynamics of decision making, ethics is the branch of philosophy that one has to take into consideration when trying to decide what is right and not. When undertaking scientific research one has to consider individual, community and social values. Ethics are involved when dealing with the research's daily work, the subjects' dignity and publishing the data in the research. (Kelman, 1977)

From the above theory it is clear to see that the researcher has to conduct his research and present his findings in an honest manner. In this context it is important to ensure that the respondents are allowed to air their true opinions about the subject and that the same is documented in the dissertation. The researcher must be sure not to lead the respondent to agree with his (the researcher's) ideas or views. The respondents are there to independently prove or disprove the researcher's hypothesis. Therefore it is of utmost importance that the respondents do not follow the researcher's bias in order for the data collected to be considered valid.

4.12 CONCLUSION

In this research both qualitative and quantitative methods will be used in order to collect the desired information. This will enable us to get more all rounded feedback which will assist in the aim of the research. The research methodology has to be carefully planned and executed in order to ensure that the data collected is credible. The participants have also got to be carefully selected so that their experience is documented and assessed with the aim of answering the research questions. It is also important that the researcher use the correct methods to assess and analyse the collected data.

5 CHAPTER 5

RESEARCH RESULTS

5.1 INTRODUCTION

Following the extensive investigation that was conducted throughout the life-cycle of this research, this chapter will represent the most important of the information collected. The crux of this chapter entails collecting and documenting information from industry experts in the hope of proving the hypothesis that has been set out from the onset. This will be done using qualitative and quantitative methods of research. The qualitative methods will include interviews with individuals with vast experience in the building services industry in order to get in-depth insight in response to the research questions. The quantitative methods will entail sending well-structured surveys to several individuals who are also in the building services construction industry. The survey will be in the form of a questionnaire that will be emailed to all the individuals. The results will then be assessed for similarities and documented accordingly.

5.2 INTERVIEWS

As previously mentioned numerous professionals will be interviewed in order to obtain valuable and in-depth information regarding the subject at hand. The option of interviews was selected in order to allow the respondents to elaborate their responses in detail. This has the advantage of shedding more light on the questions posed as well as giving any additional information that the interviewer may not have considered. The following interviews were conducted:

5.2.1 INTERVIEW 1 – ELECTRICAL/PROJECT ENGINEER

Question 1:

What is your highest qualification?

Response 1:

"Higher national diploma for technicians from the old Technicon system"

Question 2:

Which professional organisations are you registered with and when did you register with that organisation?

Response 2:

"Professional Technical Engineer with ECSA in 1988, SAIEE in 2008, Institute for technologists… "

Question 3:

How long have you been practicing in your field of work?

Response 3:

"since 1978 as an engineering assistant in the laboratory of the railway…And since 1984 as a Professional Engineer…"

Question 4:

What are the skills and attributes that an Electrical/Project Engineer should possess in order to oversee the project lifecycle?

Response 4:

"Technical knowledge of the design…He should also know the SABS specification especially the wiring regulation…and your labour act and machinery act…Because you have to weigh your installation against some form of regulation in cases of disputes between the engineer and the contractor…"

Question 5:

What are some of the risks involved if a project is not managed effectively by an Electrical/Project Engineer?

Response 5:

"Well the risks are project dependant…But they can range from equipment not being delivered to site on time and therefore delaying the project…If you're not on the ball throughout the project you might miss something that could have a detrimental effect on the project…"

Question 6:

Do you think it is important for an Electrical/Project Engineer to have a formal education? Why?

Response 6:

"Absolutely…A formal qualification shapes your thoughts…It shapes your reasoning…It widens your field of knowledge…And it actually gives you a huge advantage against any person without a formal qualification…The argument is always between artisans and engineers…The artisans always think because they've got the practical know how then they've got the edge…But when you've got the theoretical knowledge you can see where they fall short…It's not always about tightening a bolt…So the higher the education the greater the advantage…For example give an artisan a report to write and see how they fall short… "

Question 7:

Do you think that an EE with vast previous experience in similar projects is more effective in managing a project? Why?

Response 7:

"Absolutely…Because every project has got its own problems…Most of the problems develop because they are overlooked by the engineer…And then the next project you know where you screwed up and what to look out for…I should have double checked this calculation, I should have added this to the load sheet…Now it's the opening and certain DB's are tripping…So basically you learn from your mistakes and know what you should look out for…"

Question 8:

When do you think should reliability factored into the project lifecycle?

Response 8:

"Right from the beginning…That is where your specification comes in…That's very easy to say give me the most expensive items and now you've got the best…But that is not engineering…Engineering is to give the client a installation at an economical price which will last…And now your specification already tries to get to that point…For example ordering light fittings and inspecting samples for the look and feel before they are delivered to the client… "

Question 9:

Do you think it is important for the EE to implement quality control measures during project? If so what do you think would be the consequences on the project if they are left out?

Response 9:

"Quality as a such an additional function of the consulting engineers and the client has to pay additional fees to do that because it takes a lot of time to do that…And they don't want to do that…In my mind the only way you can do proper quality control is to check the quality of each and every electrical outlet, and the only way you can do that is a full time clerk of works appointed on site overseeing the installation as it takes place…And before anything is closed up the clerk must be called to inspect…The EE cannot do it with a visit to site every 2 weeks…But now with incompetent people on site we have to go there every second day…Which we don't get paid for…"

Question 10:

Who are some of the key stakeholders that need to be managed and communicated with by the EE throughout the project lifecycle in order to achieve project success?

Response 10:

"Architect because everything has to be co-ordinated with him…You have to design things that fit into his master plan…Then any discipline that has got any electrical equipment in their installation will need to be communicated with…And then of course the client…And the other one we don't like is the QS…He's always on my back because I'm not the QS…In fact he's the most important aspect of the project…"

5.2.2 INTERVIEW 2 – QUANTITY SURVEYOR

Question 1:

What is your highest qualification?

Response 1:

"Highest qualification is a grade 12"

Question 2:

Which professional organisations are you registered with and when did you register with that organisation?

Response 2:

"In the process of getting my RICS (Royal Institution of Charted Surveyors affiliation done"

Question 3:

How long have you been practicing in your field of work?

Response 3:

"From 2001, so about 18 years"

Question 4:

What are the skills and attributes that an Electrical/Project Engineer should possess in order to oversee the project lifecycle?

Response 4:

"I think a general understanding of what is exactly required from the client…Getting the brief down to a T…Understanding exactly what the client requirements are…The skills are passed on to the EE through his education…The workings of how everything fits together within a construction project…Simple example is our current project…How do you coordinate the electrical discipline with the mechanical in terms of the sequence of events…Basically the processes and procedures that are involved within a project…"

Question 5:

What are some of the risks involved if a project is not managed effectively by an Electrical/Project Engineer?

Response 5:

"There are several risks like things being left out of the design that were requested by the client…This will caused cause delays depending on how far the project is…You might also miss certain important things on site that need special attention…"

Question 6:

Do you think it is important for an Electrical/Project Engineer to have a formal education? Why?

Response 6:

"With the electrical field I believe it is because there is a lot of room for big mistakes…So a formal qualification will electrical definitely…"

Question 7:

Do you think that an EE with vast previous experience in similar projects is more effective in managing a project? Why?

Response 7:

"It's a difficult one…Previous experience yes…That's how I got where I am today, because of experience…It basically boils down to the understanding of what is required in a project and when and how…It helps a lot…It is not necessarily an exact science to say if you did it this way before then you'll achieve the same result each time, but experience gives you a bigger picture to know that if something is not done right at a certain time then it will affect other areas of the project…"

Question 8:

When do you think should reliability factored into the project lifecycle?

Response 8:

"Well, the difficult part is that the client budget and the client expectation is directly related to that…Ultimately I would say that whatever you are budgeting for, reliability has to be factored in from the beginning and the client must be aware of what exactly he is getting…Once you have the brief you have to factor in the reliability of what you are going to give them at the end of the project and how long it's gona last them, or the expected life span or whatever it is going to be…"

Question 9:

Do you think it is important for the EE to implement quality control measures during project? If so what do you think would be the consequences on the project if they are left out?

Response 9:

"Quality control is always a plus but it is difficult especially when you've got with most of your work it's more to do with the material is the big thing…The quality is more on the visual side and can always be fixed afterwards…But it is difficult with you guys (EE's) because most of your stuff is material orientated…And ultimately you do get your certification from the suppliers…As long as the installer knows what he is doing then you're safe…And if the quality is generally checked then it shouldn't be that big of a thing…"

Question 10:

Who are some of the key stakeholders that need to be managed and communicated with by the EE throughout the project lifecycle in order to achieve project success?

Response 10:

"The management side is definitely the main contractor and the subcontractor…It can also be the client depending on how involved the client is…The rest should be doing their own work"

5.2.3 INTERVIEW 3 – MAIN CONTRACTOR

Question 1:

What is your highest qualification?

Response 1:

"Diploma in Civil Engineering…"

Question 2:

Which professional organisations are you registered with and when did you register with that organisation?

Response 2:

"SACPCPM (South African Council of Project and Construction Management Professionals) this year and ECSA also this year…"

Question 3:

How long have you been practicing in your field of work?

Response 3:

"14 years…"

Question 4:

What are the skills and attributes that an Electrical/Project Engineer should possess in order to oversee the project lifecycle?

Response 4:

"The first thing is he needs the qualifications…The second one is the experience on site…Atleast a minimum of 3 years on site then he will know what needs to be done…There's a difference between designing and actual implementation on site…"

Question 5:

What are some of the risks involved if a project is not managed effectively by an Electrical/Project Engineer?

Response 5:

"you could find that certain things get left out of the drawings and when they are discovered it's too late…Like conduits that have to be cast into the slab…If the information is not on the drawings on time there will be an additional costs to cut though the concrete…"

Question 6:

Do you think it is important for an Electrical/Project Engineer to have a formal education? Why?

Response 6:

"He has to because he has to be educated to do the design part of it…You won't be able to get the whole picture just out of experience…You need to be taught how things work in order to design a project properly…"

Question 7:

Do you think that an EE with vast previous experience in similar projects is more effective in managing a project? Why?

Response 7:

"Not similar project per say but if you have experience in a couple of different project then they will give you an idea of what needs to be done…It doesn't have to be the same kind of project all the time…So experience in general (not necessary the same project) will give you an idea of how projects work…

Question 8:

When do you think should reliability factored into the project lifecycle?

Response 8:

"It must start from the design…The design must show…Sometimes the end user won't be able to see how reliable the product is at the beginning but reliability has to be factored in then… "

Question 9:

Do you think it is important for the EE to implement quality control measures during project? If so what do you think would be the consequences on the project if they are left out?

Response 9:

"Yes…The biggest risk is that the contractor will not install as per your design…If that happens there will be serious consequences at the end of the project…For example buildings can burn down or equipment can be damaged because they are not installed properly…So you need quality control from the beginning…"

Question 10:

Who are some of the key stakeholders that need to be managed and communicated with by the EE throughout the project lifecycle in order to achieve project success?

Response 10:

"The tenant/client because he needs to give input on what exactly he wants…The second would be the PM in order to advise the EE in case1 the Tenant/Client doesn't know what he wants…Also Consultants from other disciplines should be involved (for example the HVAC guy)…Anyone who needs power should be involved and have their input from the beginning…"

5.2.4 INTERVIEW 4 – PROJECT MANAGER

Question 1:

What is your highest qualification?

Response 1:

“”B-tech construction management…”

Question 2:

Which professional organisations are you registered with and when did you register with that organisation?

Response 2:

“SACPCPM (South African Council of Project and Construction Management Professionals)…Registration is ongoing…”

Question 3:

How long have you been practicing in your field of work?

Response 3:

“Under Construction Management for 14 years and Project Management for 5 years…”

Question 4:

What are the skills and attributes that an Electrical/Project Engineer should possess in order to oversee the project lifecycle?

Response 4:

“Registered with ECSA…A fair knowledge (good background) of construction…How to co-ordinate and be ahead of the construction process…”

Question 5:

What are some of the risks involved if a project is not managed effectively by an Electrical/Project Engineer?

Response 5:

“There are many risks…you could delay the project because you forgot to order something critical on time, like a transformer…You could run over on your budget because you didn’t manage the project costs properly…There are just a lot of things that could go wrong in a project if the EE is not on the ball…"

Question 6:

Do you think it is important for an Electrical/Project Engineer to have a formal education? Why?

Response 6:

"You have to have a formal qualification because your Professional indemnity requires a Professional Engineer to be formally educated…"

Question 7:

Do you think that an EE with vast previous experience in similar projects is more effective in managing a project? Why?

Response 7:

"Yeah definitely…For instance we've got an electrical consulting company and 2 of the guys are more involved in the data centre side of things and one only is involved in office blocks and factories…Now seeing the latter involved in data centres you can see where he is falling short because that is more specific to dealing with rectifiers and cut-overs as opposed to the more generalized building services installations…"

Question 8:

When do you think should reliability factored into the project lifecycle?

Response 8:

"At design stage or when the proposal is made to the client…"

Question 9:

Do you think it is important for the EE to implement quality control measures during project? If so what do you think would be the consequences on the project if they are left out?

Response 9:

"Yes you need quality control…For example in the current project if we had enough cable trays in the ceiling voids then you would have tied down the cables correctly rather than everything flaking… "

Question 10:

Who are some of the key stakeholders that need to be managed and communicated with by the EE throughout the project lifecycle in order to achieve project success?

Response 10:

"Obviously your Client in conjunction with the Principle Agent/Project Manager and your contractor/contracts manager or site agent who is involved in the day to day running of the project on site…The line of communication should be through the main contractor to the electrical sub-contractor…If you've got a good relationship with the electrical sub-contractor then obviously them too…But that line of communication needs to be held so that everybody is kept in the loop with what's going on…

5.3 SURVEY QUESTIONNAIRES

The survey was compiles using a free online program called Survey Monkey. The EE was given the opportunity to compile a total of 10 questions which would be distributed to potential respondents. The questionnaire was sent to all potential respondents using email via Survey Monkey. It was sent to a total of 366 email addresses and the respondents were given 11 days to complete and return the survey. Of the email recipients only 33 responded. This response was not as positive as anticipated. The researcher then created a questionnaire link through survey monkey and then distributed it to all relevant parties on his whatsapp contact list. The remainder of the respondents completed the survey through this platform. A total of 49 respondents completed the survey through both platforms. The survey responses were as follows:

Statement 1:

The Electrical/Project Engineer is more effective in a project if he/she has a formal engineering qualification

Feedback:

Strongly agree ***32*** *Agree* ***15*** *Neutral* ***2*** *Disagree* ***0*** *Strongly disagree* ***0***

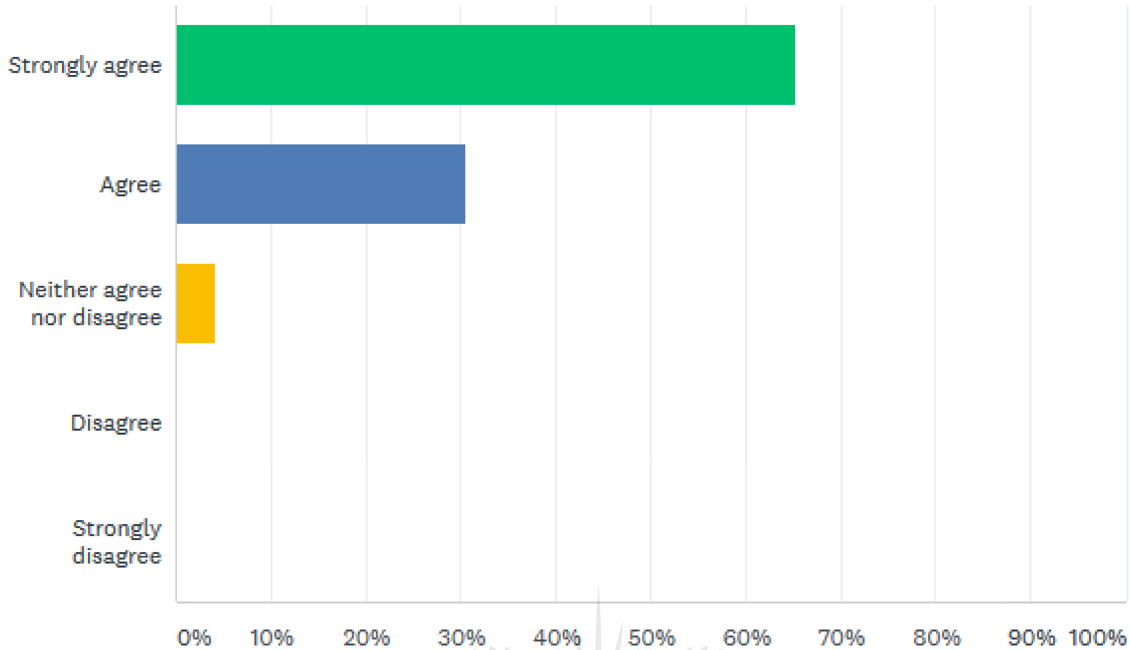


Figure 8 - Statement 1 response characteristic

Statement 2:

A project has a greater risk of failing if it is not managed efficiently by the Electrical/Project Engineer

Feedback:

Strongly agree ***25*** *Agree* ***17*** *Neutral* ***6*** *Disagree* ***1*** *Strongly disagree* ***0***

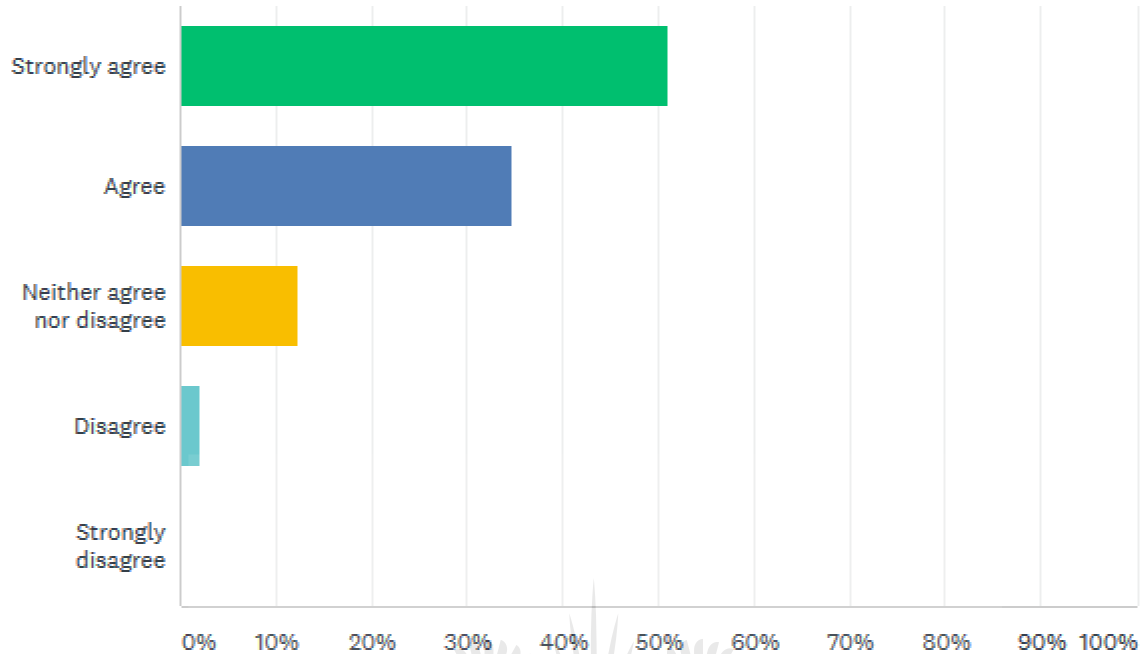


Figure 9 - Statement 2 response characteristic

Statement 3:

A project is more likely to succeed if the Electrical/Project Engineer has vast previous experience in similar projects

Feedback:

Strongly agree ***29*** *Agree* ***17*** *Neutral* ***2*** *Disagree* ***1*** *Strongly disagree* ***0***

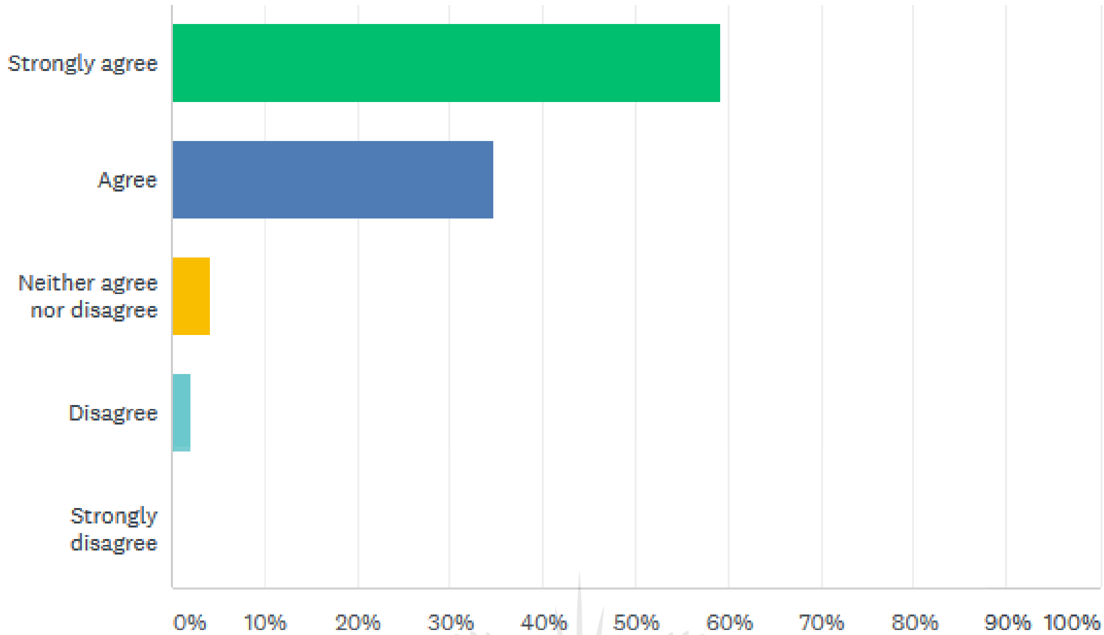


Figure 10 - Statement 3 response characterstic

Statement 4:

A project is more likely to succeed if the Electrical/Project Engineer has extensive knowledge of processes and procedures required throughout the project lifecycle

Feedback:

Strongly agree ***27*** *Agree* ***20*** *Neutral* ***2*** *Disagree* ***0*** *Strongly disagree* ***0***

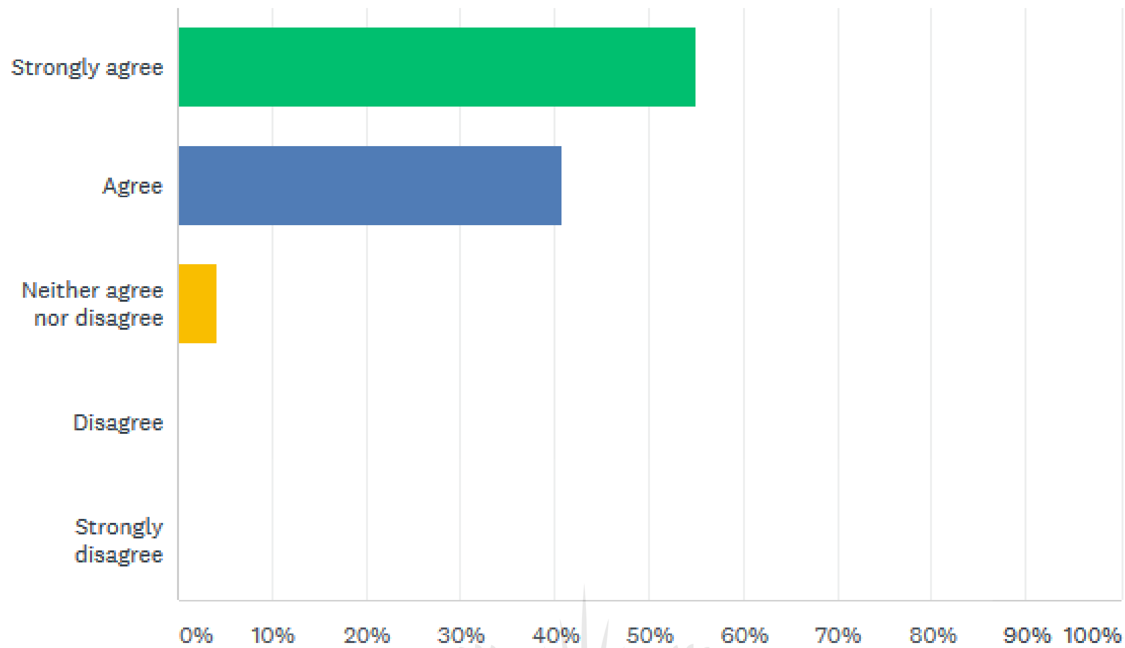


Figure 11 - Statement 4 response characteristics

Statement 5:

The Electrical/Project Engineer has to design with reliability in mind to ensure that the client has a reliable installation /product at the end of the project

Feedback:

Strongly agree ***34*** *Agree* ***14*** *Neutral* ***1*** *Disagree* ***0*** *Strongly disagree* ***0***

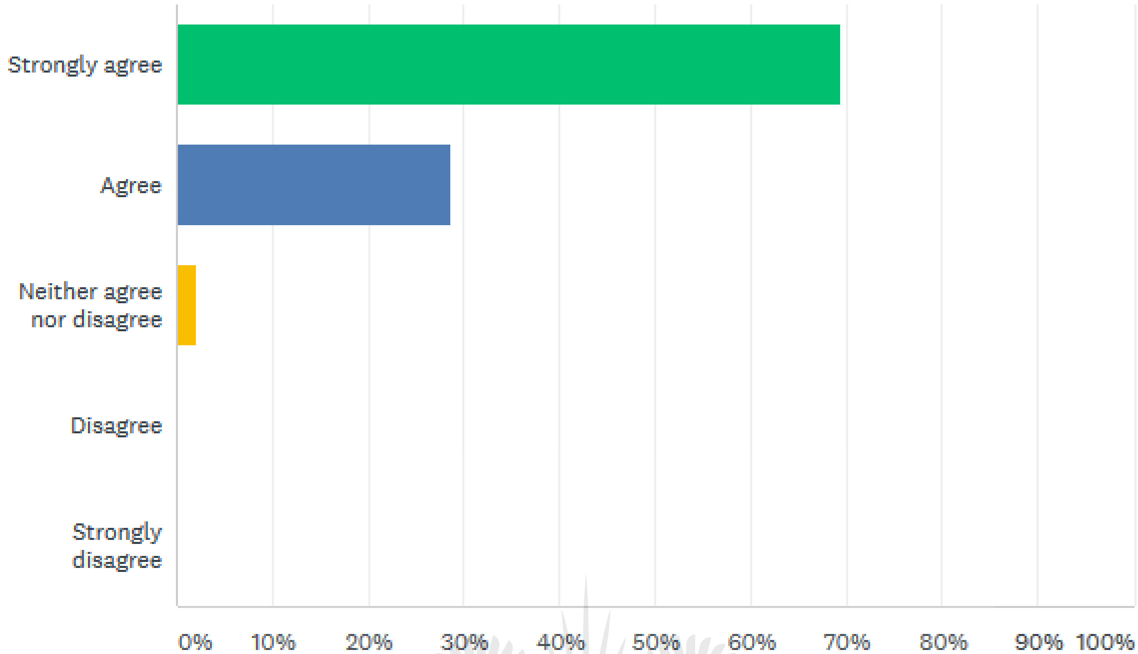


Figure 12 - Statement 5 response characterstic

Statement 6:

The Electrical/Project Engineer has to keep communication channels open and active with all relevant stakeholders throughout the project life-cycle to increase the chances of project success

Feedback:

Strongly agree 37 Agree 11 Neutral 1 Disagree 0 Strongly disagree 0

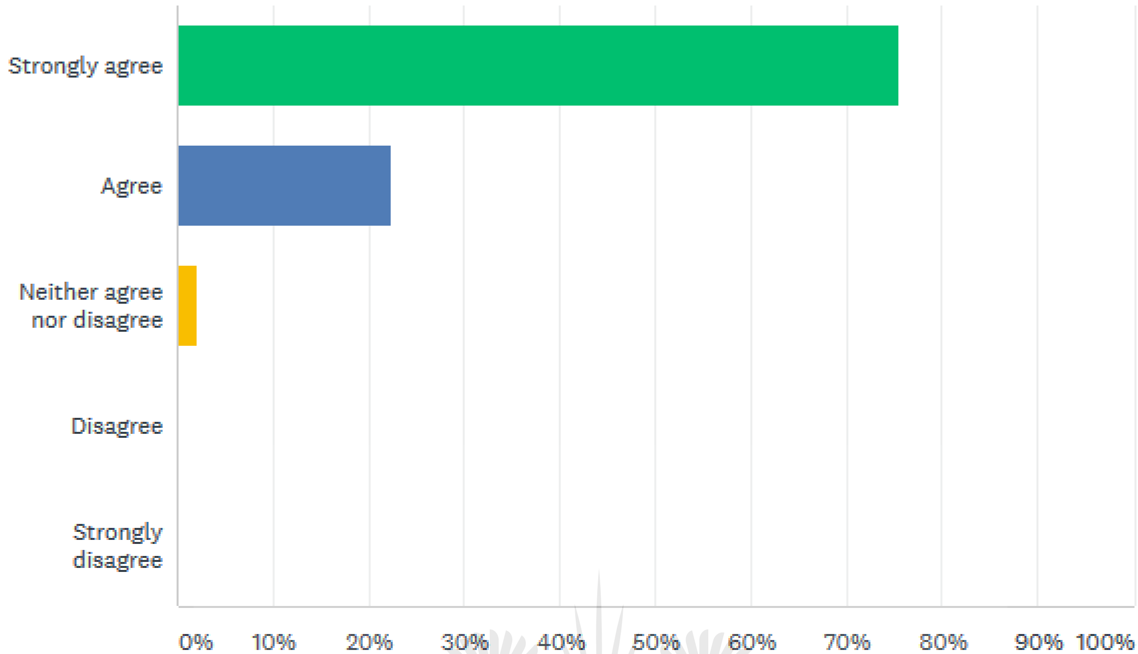


Figure 13 - Statement 6 response characteristic

Statement 7:

The Electrical/Project Engineer has to possess communication, financial and people skills in addition to technical skills in order increase the chances of project success

Feedback:

Strongly agree ***33*** *Agree* ***13*** *Neutral* ***2*** *Disagree* ***1*** *Strongly disagree* ***0***

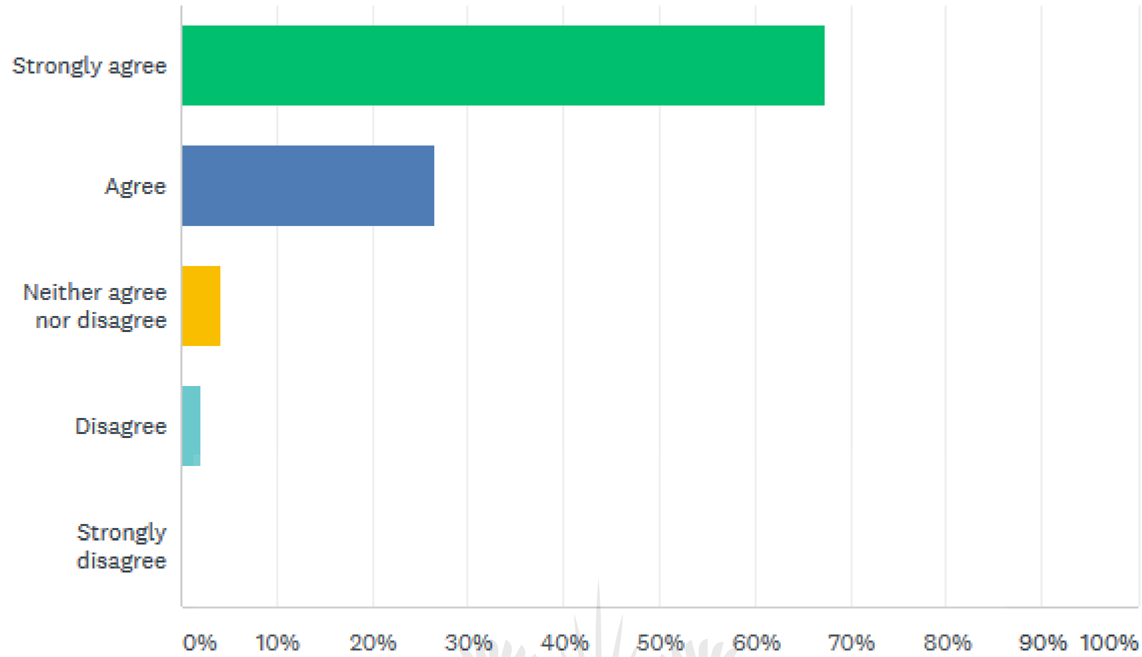


Figure 14 - Statement 7 response characterstic

Statement 8:

If the Electrical/Project Engineer follows a predetermined set of processes and procedures throughout the project life-cycle then the risk of project delays and cost overruns due to scope creep will be reduced

Feedback:

Strongly agree 18 Agree 23 Neutral 4 Disagree 4 Strongly disagree 0

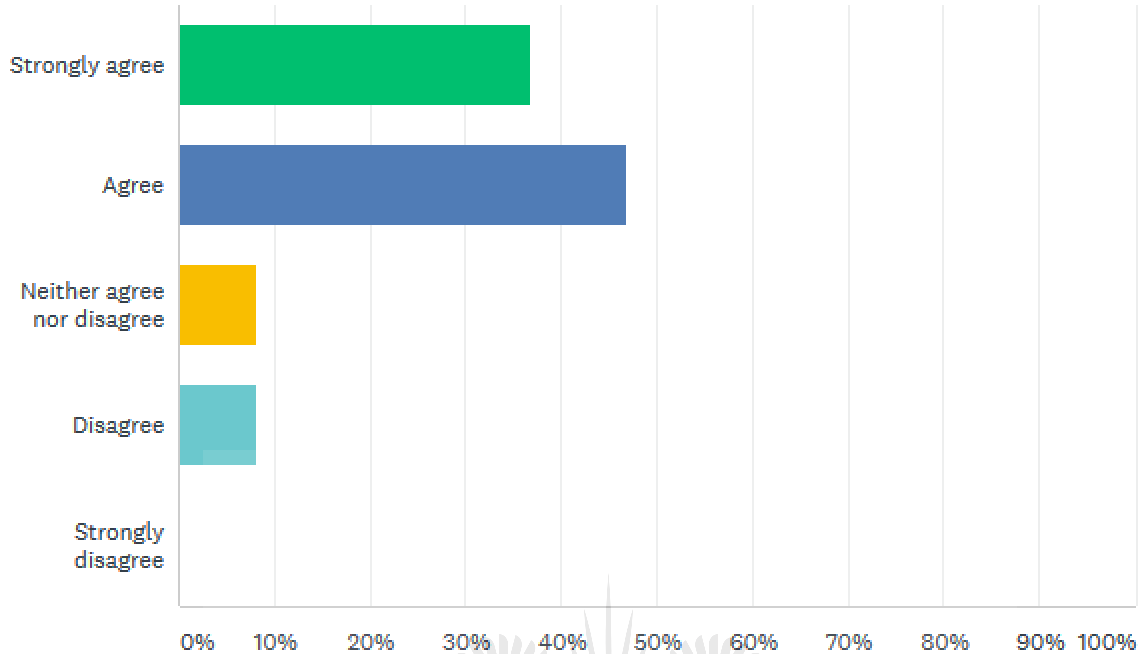


Figure 15 - Statement 8 response charaterstic

Statement 9:

The Electrical/Project Engineer has to implement quality control measures throughout the project life-cycle in order to minimize the risk of project delays and cost overruns due to corrective measures having to be taken for defective work

Feedback:

Strongly agree ***29*** *Agree* ***18*** *Neutral* ***1*** *Disagree* ***1*** *Strongly disagree* ***0***

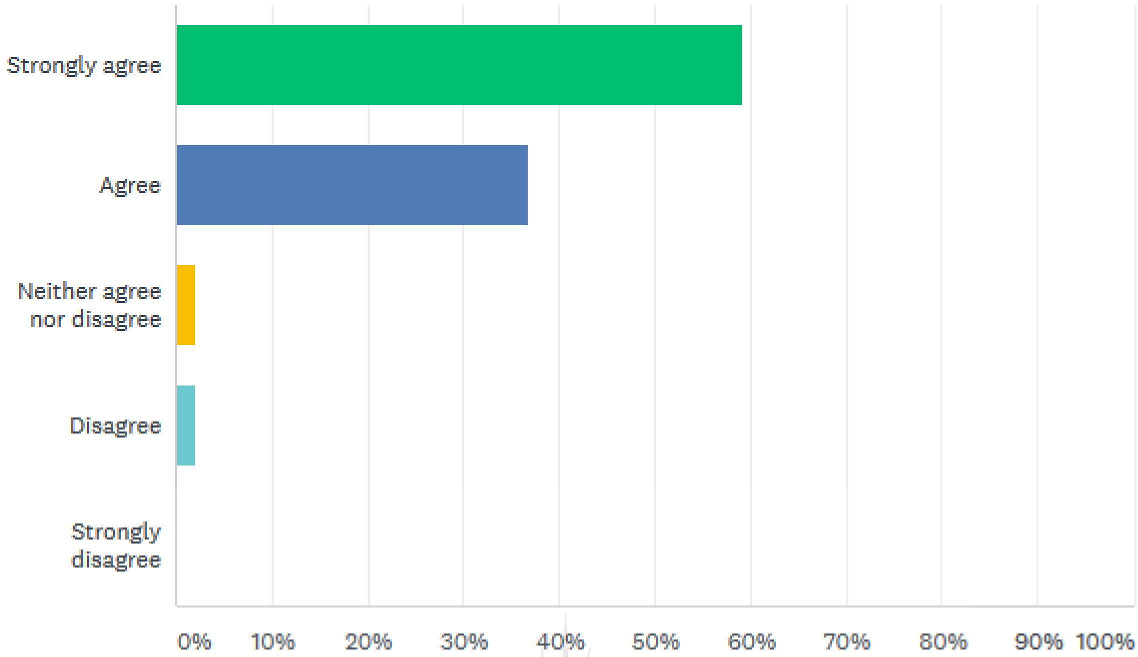


Figure 16 - Statement 9 response characterstic

Statement 10:

The Electrical/Project Engineer has to implement efficient record keeping methods throughout the project life-cycle in the event of disputes

Feedback:

Strongly agree 32 Agree 16 Neutral 1 Disagree 0 Strongly disagree 0

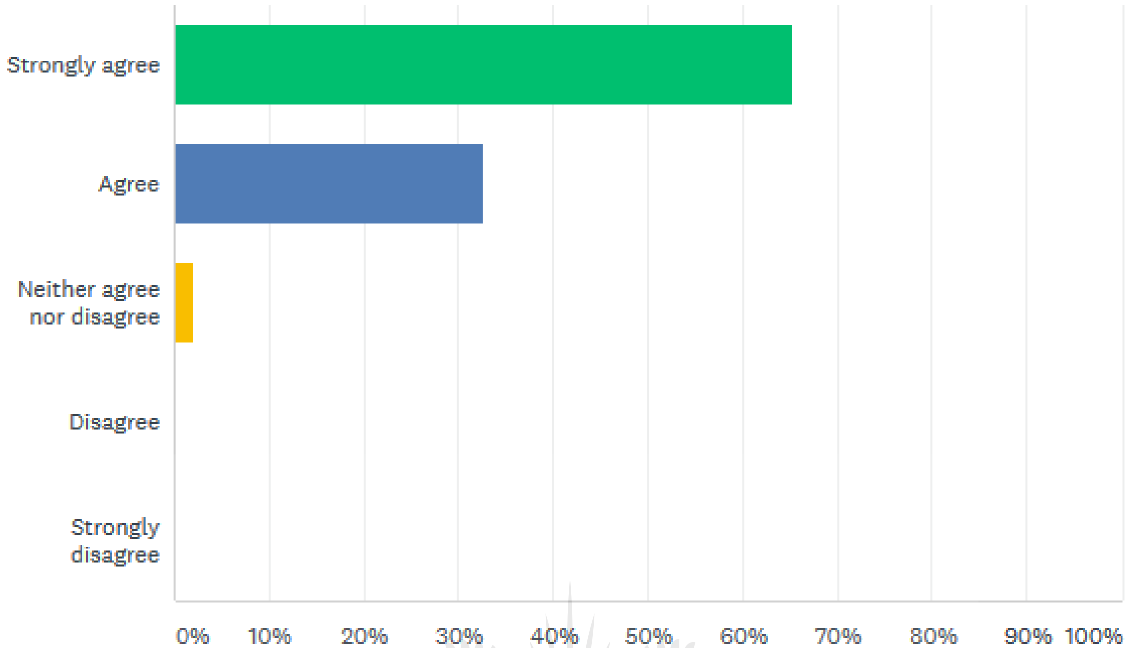


Figure 17 - Statement 10 response characteristic

5.4 CONCLUSION

This chapter involved collecting valuable data from interviews of experienced professionals and survey questionnaires that were issued to individuals that work in the building services construction industry. The manner in which the data was collected was structured and reliable, thus ensuring that the information gathered has got integrity. This entails that the information can be analysed and assessed, therefore allowing the researcher to draw inferences that will either confirm or reject the hypothesis. The following chapter will deal with the detailed analyses of the information collected, as well as the reasons and thought process behind the questions that were posed to the participants.

6 CHAPTER 6

ANALYSES OF RESEARCH RESULTS

6.1 INTRODUCTION

This chapter will entail the assessment and analyses of the results that were collected from the qualitative and quantitative research that was conducted. These results will either support or disprove the hypothesis that was set out at the beginning of the research. They will also shed light on the subject topic as well as the research questions. The researcher will also shed light on the reason for the type of questions that were asked to the respondents. He will also analyse and compare the responses to each question in the interviews and report on the similarities of the responses. The stats of the responses to the questionnaire will also be reported and analysed. Once the analysis has been concluded the researcher will be able to conclude his findings and advise if the mission has been concluded.

6.2 ANALYSIS OF COLLECTED RESULTS

6.2.1 INTERVIEWS

Question 1:

What is your highest qualification?

Reasoning:

This question was intended to determine the level of the individual's education. It is more desirable for a professional to possess a formal qualification because the building services industry is a technical one that impacts on peoples' lives. It is not related to RQ's.

Analysis of response:

75% of the respondents had a formal post graduate qualification. This means they had gone through the ropes of post graduate education and they realise the value of education within the field. Feedback from individuals with post graduate qualifications is more valuable for the purpose of this research.

Question 2:

Which professional organisations are you registered with?

Reasoning:

Similar to a formal qualification, being registered with the relevant professional bodies in the respective disciplines (such as ECSA) will help increase the individual's knowledge in that discipline through CPD points. These are points that the professional individual obtains as they explore their discipline further and learn about more aspects thereof. It is not related the RQ's.

Analysis of response:

All the respondents were either registered or in the process of registering with the relevant professional organisations in their respective fields. This is in line with this research and highlights the importance of being registered with relevant organisations in order to become a professional.

Question 3:

How long have you been practicing in your field of work?

Reasoning:

A professional person's experience is vital in their respective discipline in the engineering profession and the building services industry. This will make the interviewee's responses more reliable and shed better insight on the questions posed. It is not related to the RQ's.

Analysis of response:

All of the respondents had more than 10 years of experience in their relevant fields within the construction industry. This is important in order to get the desired insight into the questions that follow. The more years an individual has in the industry is the more experience they have with the processes and procedures within the project life-cycle. They have also experienced problems during projects which are the biggest teachers.

Question 4:

What are the skills and attributes that an Electrical/Project Engineer should possess in order to oversee the project lifecycle?

Reasoning:

Beyond technical knowledge and skills, this question seeks to determine what other attributes an Electrical/Project Engineer is required to possess in order to be more effective and efficient when executing their functions. This addresses RQ (a).

Analysis of response:

The general consensus from the respondents was that the EE/PE has to have a general understanding how a construction site functions. This feeds back to the managerial and oversight skills that the EE should possess in addition to technical skills in order to effectively manage a project. To summarize the response from the participants, the EE has to have a perfect balance between technical, social, managerial and financial skills in order to be the effective throughout the project life-cycle.

Question 5:

What are some of the risks involved if a project is not managed effectively by an Electrical/Project Engineer?

Reasoning:

The purpose of this question is to determine what problems the EE can expect to experience throughout the project lifecycle if he does not execute his functions in the correct manner. This will also inform the likely turnout of the project if this is the case. This addresses RQ (b).

Analysis of response:

The respondents cited the time, scope and financial impacts on the project. This is in accordance with the research in terms of the EE being a technical project manager. As per the research the EE has to play and over-arching managerial role to ensure that all tasks are completed by the respective entities responsible and on time. This is in addition to the technical functions that the EE himself has to complete.

Question 6:

Do you think it is important for an Electrical/Project Engineer to have a formal education? Why?

Reasoning:

This question is intended to establish the importance of a formal education in the electrical engineering fraternity. It is also intended to establish the effectiveness of an individual who has a formal education within a project. This addresses RQ (a).

Analysis of response:

All the respondents were of the opinion that it is extremely important for the EE to have a formal qualification. The respondents cited that because of the extremely technical nature of the work the EE has to have in depth technical and engineering knowledge in order to efficiently conduct the project. Formal education also gives the EE the ability to think out of box in solving problems on site and during the design. Formal degree is also a prerequisite in order to join professional organisations that are needed in order for the EE to reach professional status.

Question 7:

Do you think that an EE with vast previous experience in similar projects is more effective in managing a project? Why?

Reasoning:

The point of the question is to determine the value of the EE's experience in the industry and how this experience ultimately contributes to the project. It is also meant to determine how past experience improves the effectiveness and efficiency of the EE in a project. This addresses RQ (a).

Analysis of response:

All of the respondents agreed that past experience within the engineering and construction field is an important trait that the EE should possess. They cited that experience in the construction industry assists the EE with planning and anticipating events that may occur during a project life-cycle. This in turn assists the EE with planning for risk and therefore establishing mitigating strategies in time. This is in-keeping with the research conducted because part of being a professional engineer entails having sufficient experience in the electrical engineering discipline. This experience is vital in grooming the EE into an all rounded professional who will be effective, professional, reliable, knowledgeable and efficient at delivering the final product to the client.

Question 8:

When should reliability factored into the project lifecycle? Why?

Reasoning:

This question attempts to determine the importance of reliability in a project and when it should be implemented into the project lifecycle. This is because a reliable product is one of the aspects that render a project a success, especially in the eyes of the client. This addresses RQ (e).

Analysis of response:

All the respondents were of the opinion that reliability has to be factored into the project life-cycle from the beginning of the project. This is in-keeping with the research that reliability has to be included in the design of the project taking into consideration the client specification and SANS standards. Reliability is also connected to the cost of the project, and the EE also has to inform the client as to the type of product to expect at the end of the project. As per the research a reliable product is one that is safe and adheres to client specifications and SANS standards.

This will also ensure that the client is satisfied which ultimately determines the sustainability of the organisation. In order to achieve this type of reliability the EE has to ensure that reliability is considered from project inception. The EE also has to keep constant communication with the client/end user as to the level of reliability that can be achieved with the cost, scope and time of the project.

Question 9:

Do you think it is important for the EE to implement quality control measures during project? If so what do you think would be the consequences on the project if they are left out?

Reasoning:

This question was intended to explore the importance of monitoring and controlling the quality of the installation throughout the project lifecycle. This will improve the quality of the product that is delivered to the client/end user because errors will be detected and rectified during the project before the official handover. This addresses RQ (f).

Analysis of response:

All the respondents agreed that quality control is an essential part of the project that needs to be conducted continuously throughout the project life-cycle. It was also cited that the main purpose of quality control is to ensure that the EC installs in accordance to the EE's designs. This is in-keeping with the earlier research that elaborates that the EE should ensure a reliable and quality installation on behalf of the client by constantly checking for defects in the EC's installation. However it was also cited that quality control in its true right is a separate discipline on its own. The true essence of quality control is to check each and every nut and bolt in the electrical installation to ensure quality. It entails each and every connection inside the plug points and DB's be checked to ensure that it has been done correctly. The person responsible for this function should be on site permanently throughout the project life-cycle to oversee the EC's installation as and when it happens before cavities are closed. Therefore quality control in its true form is not the responsibility of the EE. The EC should ensure that his installation is of sound quality because he has to issue COC's for it. The client should employ another entity if he wishes to have these measures checked. It would then be the EE's responsibility to co-ordinate the repairing of defected items as and when it happens. This would then ensure the EE's effective oversite of the project in order to ensure a satisfactory product at the end of the project.

Question 10:

Who are some of the key stakeholders that need to be managed throughout the project lifecycle in order to achieve project success?

Reasoning:

This is intended to establish which individuals need special or extra attention throughout the project in order to increase the probability of a smooth project. Certain influential stakeholders have to be closely managed throughout the project. This addresses RQ (g).

Analysis of response:

The respondents cited different key stakeholders in their responses. However there were a few common denominators that came up with most of the respondents. The most common was the client. This is in accordance with the research in that the client determines the specification of the product. It is from this specification that the time, budget and scope of the project will be determined. Therefore the client requires constant communication and to be managed as a key stakeholder. The second on the list of key stakeholders was the contractors. This is because these are the individuals that do the ground work based on the EE's design. They will require the most management and communication in order to ensure that the installation on site is as per designs. Also because of the uniqueness of each project, different problems are experienced on site and often need to be resolved by the EE. This is therefore in accordance with this document's research.

The last group of stakeholders that were cited as key by the respondents are the professional team, more specifically the PM and Architect. These individuals will also require management and communication throughout the project lifecycle. The PM has contact with all professional team members as his is the custodian of the client's specification. He has to ensure the client gets a final product as per agreement. Therefore his will require management and communication even after the project has been handed over to the client. Lastly the architect designs the building in its entirety and has the master plan. He is responsible for co-ordinating all other services to ensure that they fit in cohesively like a puzzle. The EE has to ensure that his designs fit into the architect's master plan aesthetically while ensuring that the client's specifications and SANS standards are met. Therefore the architect will require constant management and communication throughout the project life-cycle. This is also in accordance to the theoretical research conducted in the earlier chapters of this dissertation.

6.2.2 SURVEY QUESTIONNAIRES

Statement 1:

The Electrical/Project Engineer is more effective in a project if he/she has a formal engineering qualification. This addresses RQ (a).

Analysis of response:

From the results recorded majority of the respondents strongly agreed with the above statement. This feeds back to the hypothesis that a formal engineering education improves the quality and scope of knowledge that is instilled into prospective engineers. A formal education instils the elementary concepts that are required to become an effective engineer. A strong science and mathematical educational background is ideal to be able to understand the basics concepts of how electricity works. In relation to the research topic, the fundamental techniques that are required to design the entire electrical installation are learnt in school and later polished in the workplace. The practicals that are conducted throughout the schooling career form the building blocks that will be critical in an engineer’s future career. These practicals instil are deeper understanding of how concept and design meets the physical world. Once this is covered the practical work place experience becomes easier to comprehend.

Statement 2:

A project has a greater risk of failing if it is not managed efficiently by the Electrical/Project Engineer. This addresses RQ (b).

Analysis of response:

The respondents agreed with the above statement overwhelmingly as per the results in the previous section. This is because management of a project is a multi-facetted discipline that requires in-depth knowledge of processes and procedures. This requires the EE to oversee many smaller processes within the project efficiently in order to ensure minimize the risk of failure. In the building services industry, the electrical engineering discipline is affected by all other disciplines. That means that the EE has to deal with all other consultants who require power. All these processes have to be managed carefully and closely in order to ensure that all the power requirements by other disciplines are catered for. This requires extensive co-ordination between all the disciplines by the EE. If the EE is technically and socially skilled then the risks of project failure and reduced tremendously.

Statement 3:

A project is more likely to succeed if the Electrical/Project Engineer has vast previous experience in similar projects. This addresses RQ (a).

Analysis of response:

The feedback from the respondents was overwhelmingly in the positive. This is because experience in the field of work gives the EE something that he cannot receive while in school. Industry experience gives the EE problem solving skills through the experiences throughout the project. Every project is unique even if it is similar to the last one. Therefore the problems and issues experienced by the EE will change from project to project. These issues are the crux of the experience that the EE requires in order to become a professional engineer. The more projects that the EE undertakes is the more experience that he gets in order to better manage projects in the future. It also helps the EE to better plan and design for future projects in order to avoid similar issues. Project experience is almost as important as a formal education. All this will assist the EE in efficiently running any project and ensuring project success.

Statement 4:

A project is more likely to succeed if the Electrical/Project Engineer has extensive knowledge of processes and procedures required throughout the project lifecycle. This addresses RQ (a).

Analysis of response:

The response from the respondents was centred on strongly agreeing. That means that the respondents agreed overwhelmingly with the above statement. This because in order to manage any project efficiently there has to be a template of tasks that the EE should follow. This template is generic in the umbrella tasks. These tasks would fall under the following processes; Inception, design, implementation, monitoring and controlling and closing. Certain tasks are done strictly under the respective headings while others are conducted throughout the project life-cycle. If the EE has extensive knowledge of the processes and procedures that need to be undertaking throughout the project life-cycle, he is better able to plan for these in advance. This will assist in shortening the length of certain tasks if they are planned well enough in advance. This will also minimise project related risks due to insufficient planning. After all how would one be able to plan for something they have no knowledge of? This makes the EE more effective in running the project more efficiently as he saves valuable resources in doing things right the first time.

Statement 5:

The Electrical/Project Engineer has to design with reliability in mind to ensure that the client has a reliable installation /product at the end of the project. This addresses RQ (e).

Analysis of response:

The data collected indicates that the responses centre on the positive. This means most of the respondents agreed strongly with statement. As described in the research, the company's sustainability and relevance depends on the EE giving the client/end user a reliable product the first time round. This also means that no additional resources should be invested in altering the final product in order to make it work efficiently and reliably. In order to achieve this kind of efficiency it is essential that the product is designed adequately in accordance with client specification. This entails the EE having most if not all of the technical and aesthetical specifications of the intended final product at project inception in order to make the necessary provisions for this. It is for this reason that reliability should be factored in during the design stages even before manufacturing/ordering of any equipment takes place. Unfortunately the full specifications are hardly ever available at project inception, depending on the project. Therefore the EE has to factor in reliability as and when the information becomes available. This sometimes entails the EE having to allow for future expansion within the design within reason. If all these elements are factored into the project lifecycle it will ensure that the EE efficiently delivers the final project to the end user/client

Statement 6:

The Electrical/Project Engineer has to keep communication channels open and active with all relevant stakeholders throughout the project life-cycle to increase the chances of project success. This addresses RQ (a).

Analysis of responses:

The response from the research centred on agreeing strongly with the statement above. This is because communication is one of the most important key aspects in any project. In order for the EE to effectively manage a project he has to act as a conduit between the client specification/requirements and the actual work being done on site. That means that he has to ensure that the installation of all equipment on site is to the satisfaction of the client/end user. Electricity is central to the functioning of all other disciplines (HVAC, refrigeration, etc). This means without electricity none of these disciplines would be able to function. Therefore the EE also has to act as a conduit between the electrical requirements of the other disciplines and what gets installed on site. All electrical requirements from all other disciplines have to be communicated in detail to the EE at the beginning of the project. The extensive co-ordination with all relevant parties has to be managed effectively by the EE throughout the project life-cycle in order to achieve the desired results efficiently. This will also ensure that all systems are tested and commissioned on time and in time for the product handover to the client.

Statement 7:

The Electrical/Project Engineer has to possess communication, financial and people skills in addition to technical skills in order increase the chances of project success. This addresses RQ (a).

Analysis of responses:

The response to the above statement was centred overwhelmingly on strongly agreeing. This is because the EE has to apply more than just technical skills throughout the project lifecycle. During the project life-cycle the EE has to attend meetings, liaise with individuals from different races and cultures as well as keep the project costs updated. These tasks require the EE to be efficient at more than just technical skills in order to effectively complete the project successfully. The EE's interactions with other professional team members, the client and contractors will determine the kind of relationship he will have with those individuals throughout the project lifecycle. This includes the manner in which the EE sends and responds to emails and other forms of correspondence. The EE's ability to effectively manage the project budget is another essential aspect of the project. This feeds back to the point that the EE is obligated to deliver the project to the client in the most cost efficient manner. This entails making sure that the rates presented by the EC are market related and that the EC does not claim for more work than installed on site. Everything described above adds to the effectiveness of the EE in running a project efficiently.

Statement 8:

If the Electrical/Project Engineer follows a predetermined set of processes and procedures throughout the project life-cycle then the risk of project delays and cost overruns due to scope creep will be reduced. This addresses RQ (d).

Analysis of responses:

Majority of the respondents agreed overwhelmingly with the above statement. This owes to the fact that even though every project is unique in the events that take place, every project has the same skeletal structure and follows similar processes and procedures throughout the life-cycle. Also some processes are a continuation of previous processes. This can be seen if one has a look at the critical path of project program. Therefore the EE can follow a set of outlined processes and procedures that are common to all projects. This would also assist the EE in planning tasks for a project if he knows what the expected processes are for that particular project. Having knowledge of predetermined processes and procedures also helps the EE establish templates of documents and tools before the project that can be used during the project. This assists in avoiding repetitive work from one project to another and therefore allows the EE to use his time more efficiently during the project life-cycle. Therefore this assists the EE with time management during the project and ultimately leads to an efficiently conducted project.

Statement 9:

The Electrical/Project Engineer has to implement quality control measures throughout the project life-cycle in order to minimize the risk of project delays and cost overruns due to corrective measures having to be taken for defective work. This addresses RQ (f).

Analysis of responses:

The response from the respondents was centred on strongly agreeing with the above statement. This is in-keeping with the sentiment from the research that quality control is an essential part of the project life-cycle and should be conducted throughout the project life-cycle. This is because EC's often cut corners in order to save money or fast track the program. EC's also sometimes do shoddy work in the hope to get the work done faster. This can be a health and safety hazard in that essential items could be left out that could be detrimental to the safety of the end user. It can also leave the client/end user extremely dissatisfied which could jeopardize any future work that the client may have intended to give the EE and EC. All the above aspects are in keeping with the essential tasks that need to be conducted by the EE throughout the project life-cycle in order to effectively run and conclude it. It also assists the EE to manage his time and resources more efficiently by not having to go back on already installed equipment to rectify it.

Statement 10:

The Electrical/Project Engineer has to implement efficient record keeping methods throughout the project life-cycle in the event of disputes. This addresses RQ (e).

Analysis of responses:

A great majority of the respondents agreed strongly with the above statement. This is because in order to efficiently run a project the EE has to be able to access project information at any given time from the beginning of the project to 10 years after the project is handed over. This entails the EE saving project information on a secure platform in a structured manner where it can easily be retrieved as and when is necessary. Each project undertaken should be saved under a unique project number so as to easily retrieve any information required. Each project number has several folders that are labelled accordingly (meeting minutes, cost reports, inspection reports, council, emails, etc). The respective documents are subsequently stored in these folders in chronological order so as to be easily retrieved. Project documentation storage is also a legal requirement as per SANS regulations. Another very important aspect that cannot be avoided is disputes. During disputes certain claims may be made that can have contractual obligations on some of the parties. These claims often have to be supported by documentation such as meeting minutes or signed off drawings. Therefore these have to be stored efficiently in order to be retrieved as and when required. By having these documents in place the EE can efficiently conduct the processes throughout the project life-cycle thus making him more effective.

7 CHAPTER 7

CONCLUSION

7.1 INTRODUCTION

At the beginning of this research the main purpose was to determine the "The effectiveness of efficiently managing the process lifecycle of medium and low voltage equipment in building services". The aim was to establish the shortcomings that would be experienced by the EE/Project Engineer if the project life-cycle is not managed effectively. The main aim of this research however was to establish the ideal skills, knowledge and characteristics required by an EE/Project Engineer in order to effectively manage a project and deliver a reliable product to the client/end user. A list of research questions were established in the aim of attempting to prove the above hypothesis. Part of the research was to find a target market that would give feedback on the research questions.

The identified target market was individuals in the construction industry who had years of experience in different types of projects. These individuals were selected because they could give valuable insight towards the research bases on their previous experiences and encounters. Both qualitative and quantitative data was obtained in order to strike a balance in the type of data collected. The data collected was independent of the location of the respondents there the results could be applied to any project being conducted regardless of location. The secondary aim of this project was to educate prospective and aspiring professional engineers in the building services industry on the most effective and efficient ways of conducting a project. This research is intended to be a high level "how to" guide for engineers who have just graduated and intend on pursuing the construction building services career path. Last but not least the research was intended to highlight the important of safety and reliability in each and every project that one undertakes. These aspects should be considered from project inception and should be incorporated throughout the project lifecycle. The health and safety of the end user it a crucial element and if overlooked can result in death and legal consequences.

7.2 REFLECTION ON RESEARCH OBJECTIVES

- To highlight the risks involved if a project is not managed efficiently and effectively by the EE/PE

The objective was achieved through the research conducted from historical sources. This research also documented what some of the risks are that could be encountered of a project is not managed properly. These risks include a defected and unreliable product, risk to the end user's health and safety and well as scope, time and financial set-backs. These risks can be minimized if the project is managed efficiently and effectively by the EE/PE.

- To show that if the EE/PE follows certain processes and procedures then he will be more effective in delivering the final product (MV and LV equipment) to the client/end user

This objective was achieved by researching if there exists processes and procedures that should ideally be followed during the project life-cycle and if so documenting what they are. The research then highlighted what the set-backs are for not following these processes and procedures. Lastly the feedback from the respondents was in line with this objectives.

- To outline the complete role of the EE/PE in delivering safe and reliable MV and LV equipment to the end user

This objective was achieved through research of historical data as well as the feedback from the respondents. Both showed that the role of the EE/PE is not only technical but also social, financial and managerial. The research was able to show that the EE/PE plays an overarching role that not only involves his work but also the work of other disciplines. The research also showed that his roles involves communication and co-ordination with all the other disciplines within the project and some stakeholder who don't form part of the project. If the EE/PE masters this then he increases the chances of effectively and efficiently managing the project. The research also showed that there exists a set of predetermined general tasks that can be applied to every project in order to efficiently and effectively manage the project life-cycle. If this list of tasks is followed it helps minimize risk of tasks being forgotten and assists the EE plan for certain tasks in advance, thus also minimizing the risk of scope creep.

- To outline the ideal characteristics of a EE/Project Engineer in order to efficiently and effectively conduct a project that entails delivering MV and LV equipment to the end user

This objective was achieved through research from existing literature as well as the surveys and interviews done. The research showed the ideal path of a prospective professional engineer from the post graduate level until they attain their professional engineering status. The research showed that the EE/PE needs to have academic accolades in the field of engineering as well as managerial, financial and social skills in order to effectively and efficiently manage a project life-cycle.

7.3 LIMITATIONS ON RESEARCH

Management of a project has no blueprint. However if the skill and technique can be applied consistently then the EE can manage almost any project. This research was conducted in the province of Gauteng because this is where the researcher resides and works. The respondents from the surveys and interviews also reside and work in Gauteng. Even though this was the case both parties have experience of projects outside of Gauteng. Therefore the research can be applied to building services projects anywhere in the world. The research can also be applied to any magnitude of project. Therefore although the respondents of the interviews and surveys were limited to Gauteng at the time of the research, their experience spans well beyond the borders of this province. Therefore the results collected can be applied to any building services project anywhere in the world.

7.4 RECOMMENDATIONS

This research was intended to highlight the processes and procedures that the EE/PE should follow throughout the project life-cycle in order to minimize risk of scope creep, budget and time overruns, health and safety hazards, and to maximize efficiency and effectiveness, productivity and reliability of products to the client/end user. The EE/PE should strive to consistently expand his knowledge on engineering matters that influence building services. This is necessary because technology is constantly evolving and the EE has to stay abreast and maintain market share. Also technology is at the forefront of energy efficiency which is a vital in attempting to reduce the country's carbon footprint.

The EE should also invest as much time necessary to planning projects before the first brick hits the ground. Planning is an essential part of any project and if enough planning is done, many risks that could potentially derail the project can be minimized or eliminated. The EE/PE should also establish the correct communication strategy for every project by identifying all the stakeholders and establishing the appropriate communication methods for each. This will assist the EE/PE in staying ahead abreast at all times and being more efficient and effective in the way he manages building services projects

It is also recommended that the EE create a template of processes and procedures to follow throughout a project lifecyle. A blueprint of sorts that will outline the tasks that have to be completed during a project in order to increase the chances of a successful project and to minimise risk of stumbling blocks. Even though every project is unique this blueprint can be used to guide the EE in ensuring that all necessary tasks are completed and none are forgotten. The same blueprint will also assist the EE in determining the chronological sequence of tasks throughout the project lifecycle, thus ensuring that pre-requisites of certain crucial tasks are completed on time in order to avoid cost and time overruns. This type of template is created using experience from previous tasks, thus re-enforcing the importance of past experience in the building services fraternity.

In addition to work undertaken during the project life-cycle, this research has shown the importance of a formal tertiary qualification in the building services consulting industry. Therefore is recommended that an EE complete their tertiary Electrical Engineering qualification before practicing. This will give the EE sound technical engineering knowledge that will assist in the design work. A formal qualification will also go a long way in broadening the EE's thought mechanism and process, thus allowing the EE to solve complex engineering problems as may be required in any project. It also assist the EE in how to think out of the box. Lastly a formal tertiary Electrical Engineering qualification is the minimum requirement for being a Professional

Engineer. Therefore the ideal path for any EE to follow would be that which eventually results in them attaining their Pr.Eng. This registration has many benefits to the career of the EE which include financial and reputational gain, which would allow the EE to practice on their own and therefore acquire market share.

7.5 FUTURE RESEARCH

This research was based on high level analyses of the requirements of delivering MV and LV equipment to the Client/End User through management. It focussed mainly on the role of the EE as an individual and his ideal characteristics and attributes within the project and organisation space. This research can be expanded by investigating the tools and structures that can be put in place by private Electrical Engineering Consulting Organisations within the Building Services space in order to empower graduates who come into the work place for the first time after university. These tools and structures would assist in guiding these graduates on how to best perform their tasks at work while expanding their engineering knowledge and working towards being Professional Engineers. This kind of effort would be vital in situations when there aren’t enough mentors within an organisation to guide newcomers, considering the fact that the Consulting industry is a high pressure environment where the bottom line is profit. It is for this reason that there isn’t always time for senior personnel to pass on vital knowledge and skills to graduates. This type of research could go a long way in ensuring that EE’s design safe and reliable services for the Client/End user.

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