Cape Peninsula
University of Technology

RISK IDENTIFICATION IN MEGAPROJECTS AND ITS IMPACTS ON PROJECT MANAGEMENT CONSTRAINTS IN CIVIL ENGINEERING AND CONSTRUCTION COMPANIES

By

MACALENI MABASO

A thesis submitted in fulfilment of the requirements for the degree

Master of Engineering: Civil Engineering

in the Faculty of Engineering and Built Environment

at the Cape Peninsula University of Technology

Supervisor: Dr Coenraad Nel

Bellville

November 2022

Declaration

I, Macaleni Mabaso, declare that the contents of this thesis represent my own unaided work and that the thesis/dissertation has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

November 2022

Signed **Date**

Abstract

The South African megaprojects are facing a challenge to meet their objectives concerning time, cost, and quality. Most megaprojects projects often experience time delays, cost overruns, and poor quality. In the case of the public sector megaprojects particularly, time delays, cost overruns, and inferior quality result in additional expenses on the part of the government which uses taxpayers' money to fund these projects. This results in large amounts of funds being lost, considering that megaprojects are costly to develop. To deal with the problems facing the delivery of megaprojects, significant risks must be identified and mitigated. Therefore, this study aimed to investigate the risks that are affecting the successful delivery of megaprojects concerning time, cost, and quality.

To achieve this aim, this research study used a quantitative research method coupled with a questionnaire. A total of 22 risk factors associated with megaprojects were gathered from the literature review and presented in a questionnaire. The questionnaire was administered to construction professionals working for clients, consultants, and contractors involved in the development of megaprojects in South Africa. These professionals were purposely selected due to their experience and involvement in megaprojects. The data collected were analysed using the Mean Item Score (MIS). The MIS was calculated based on the impact that each risk factor has on the objectives of time, cost, and quality. The calculated MIS values were used to rank the significant risk factors affecting time, cost, and quality of megaproject development.

The findings of this research study highlighted that the critical risk factors affecting the time constraints of megaprojects were delayed supply of material and equipment, the financial condition of the main contractor, the client's slow decision-making, incomplete drawings, design errors, unavailability of labour, materials and equipment, delay in obtaining preliminary drawings, labour strikes, late issue of instructions, and unforeseen ground conditions. The critical risk factors affecting the cost constraints of megaprojects were the financial condition of the main contractor, incorrect cost estimate, design errors, unforeseen ground conditions, incomplete drawings, poor planning and scheduling, unavailability of labour, materials, and equipment, client's slow decision-making, inappropriate equipment and material quality, and increase in material cost. The risks affecting the quality constraints of megaprojects were inappropriate equipment and material quality, shortage of skilled labour, poor planning and scheduling, deviations between specification and implementation, incomplete drawings, supply of faulty materials, design errors, the financial condition of the main contractor, unavailability of labour, materials and equipment, as well as project complexity. The findings also revealed that the financial condition of the main contractor, design errors, incomplete drawings, and unavailability of labour, materials, and equipment affect all the project management constraints of time, cost, and quality.

This study also found that there are mitigations to minimize these identified critical risks. Moreover, the findings revealed that the common risk identification tools used in the South African construction industry are brainstorming, expert judgement, checklists, root-cause identification, and flow charts.

Keywords: Risk, Megaproject, Time, Cost, Quality, Construction, Risk management

Acknowledgements

I wish to thank:

- My Lord and Saviour Jesus Christ for the strength, perseverance, and wisdom He gave me to complete this research.
- My supervisor Dr Coenraad Nel for his guidance and contribution to this research study.
- The participants who contributed to this study, for providing valuable information at the expense of their time.
- Dr Reneda Basson for editing this thesis.

Dedication

Table of Contents

List of Figures

Page

Body

List of Tables

Page

Body

List of Abbreviations

Abbreviations	Explanation
ACSA	Airports Company South Africa
BBBEE	Broad-Based Black Economic Empowerment
CIDB	Construction Industry Development Board
CEC	Civil Engineering and Construction
CESA	Consulting Engineers South Africa
CRF	Critical Risk Factors
GDP	Gross Domestic Product
GFIP	Gauteng Freeway Improvement Project
DPE	Department of Public Enterprises
DWS	Department Water and Sanitation
ERRP	Economic Reconstruction and Recovery Plan
FIFA	Federation Internationale de Football Association
KSIA	King Shaka International Airport
NDP	National Development Plan
NMPP	New Multi-Product Pipeline
ODRWR	Olifants-Doorn River Water Resources
PICC	Presidential Infrastructure Coordinating Commission
PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
PPP	Public-Private Partnership
PWC	PriceWaterhouseCoopers
SANRAL	South Africa National Roads Agency Limited
SIP	Strategic Integrated Project
SOE	State-Owned Entity
USD	United States Dollar

Chapter 1 Introduction

This chapter outlines the background of the research study. The background provides the motivation for undertaking this research. Thereafter, the research problem, which outlines the problem that is being investigated, is stated, followed by the research question. This chapter further outlines the objectives and outcomes, the significance, and the context of the research. Lastly, the delineation, methodology, and layout of the chapters are presented.

1.1 Background

Time and cost overruns are the major challenges facing construction megaprojects worldwide (Tshidavhu & Khatleli, 2020). According to Aiyetan and Das (2022), African megaprojects are also suffering from time and cost overruns, and South Africa is no exception (Tshidavhu & Khatleli, 2020). The significant increase in cost and time delays results in megaprojects often failing to achieve their objectives (Hallock & Zack, 2018). Jobling and Smith (2018) also add that most megaprojects fail to meet their objectives.

Risks are the main contributor to time and cost overruns in megaprojects. Megaprojects are exposed to risks which risks contribute to cost overruns and time delays (Banerjee *et al*., 2017). Sanchez- Cazorla *et al.* (2016) also add that numerous risks cause delays in megaprojects. Risk not only results in project delays and cost overruns but contributes to discrepancies in the quality of the project. This means that risks in construction projects affect their objectives concerning time, cost, and quality (Iqbal *et al*., 2015). Quality is one of the key constraints for project success (Vadivel, 2016). If the desired quality of the project is achieved, it can be concluded that the project has met the expectations of the client, consultant, and contractor (Vadivel, 2016). On the other hand, poor quality can have serious consequences, such as damaging the reputation of the company (Jha & Iyer, 2006). Poor quality of projects may also result in companies spending additional costs to fix the defects. Therefore, megaprojects' failure is not only due to delays and increased costs. In addition, there is also a failure to deliver the expected product (Hallock & Zack, 2018).

The problems of increased cost, time delays, and inferior quality are evident from the few megaprojects that have been implemented in South Africa during the last decade and a half. These megaprojects have failed to meet the requirements of time, cost, and quality (Shunmugam & Rwelamila, 2014). Although there are a few megaprojects in South Africa, these projects have failed due to increased cost and time delays (Tshidavhu & Khatleli, 2020). These projects include the Gautrain Rapid Rail Link system, the Ingula pumped storage scheme, the Gauteng Freeway

Improvement Project (GFIP), the 2010 FIFA Soccer World Cup Stadiums, the Multi-Product Pipeline, Kusile and Medupi power stations, Mthombo Fuel Refinery, the Vetenia Diamond Mine, and the King Shaka International Airport (Watermeyer & Phillips, 2020; Aiyetan & Das, 2022).

The development of the 2010 Soccer World Cup stadiums in South Africa was one of the megaprojects that were implemented in the country. Upon completion, the stadia were US$ 267m over budget, although they were completed on time for the tournament (Baloyi & Bekker, 2011). The Kusile and Medupi projects within the energy sector also experienced cost and time overruns. The completion date for these megaprojects was 2015. Medupi was scheduled to be completed in 2021, while Kusile is scheduled to be completed in 2023 (Watermeyer & Phillips, 2020). The cost escalated to R 208 billion for Medupi and R 239 billion for Kusile. The two projects have not only suffered cost and time overruns but the quality of the projects has been affected too. There are technical defects that resulted in the underperformance of some of the units (Creamer, 2019).

Transnet's New Multi-product pipeline project had an initial cost of R 12.7 billion; this amount further escalated to R 23.4 billion in 2012 (Tshidavhu & Khatleli, 2020). The completion date was moved to the year 2013 (Ismail *et al*., 2014). The initially planned completion date was 2010. The Gautrain Rapid Rail System project had an approved budget of R 6.8 billion in 2005, this figure escalated to a final cost of R 25.2 billion at the time of its completion (Parrock, 2015).

Furthermore, risk management is an important aspect of management in megaprojects due to their complex nature (Aiyetan & Das, 2022) because it helps to provide knowledge of the risks involved in projects, and how to manage them (Zhi, 1995). Therefore, to meet the targeted project objectives, appropriate risk management strategies need to be put in place, without which megaprojects are bound to fail (Kardes *et al*., 2013).

Various research studies have been conducted on the topic of risk identification and assessment in megaprojects, internationally (Sanchez-Cazorla *et al*., 2016; Chattapadhyay *et al*., 2021). However, according to Aiyetan and Das (2022), limited research has been conducted on the construction of megaprojects in South Africa, especially relating to risks and possible solutions for successful megaproject delivery. There exists a significant gap relating to critical risk factors affecting the successful delivery of megaprojects and their possible solutions. As a result, this research study aims to investigate the critical risks that are affecting the successful delivery of megaprojects in South Africa. The findings emanating from this research will help to solve the problems that result in many construction megaprojects that fail to meet their objectives concerning time, cost, and quality, specifically in the South African context.

1.2 Research problem

Approximately 65% of the construction megaprojects in South Africa have experienced delays (Aiyetan & Das, 2022). In Southern Africa, well-known megaprojects have experienced 40% to 150% delays (Pwc, 2014). The project delays normally lead to budget overruns (Ismail *et al*., 2014; Pwc, 2014). Megaprojects often experience cost overruns of 50% or more (Pwc, 2014). Megaprojects not only face problems concerning time delays and increased costs but discrepancies in quality also occur. Time delays and increased costs as well as inferior quality are caused by the risks that are prevalent in megaprojects. Kishan *et al*. (2014) state that risk in construction projects affects the objectives of time, cost, scope, and quality. Large amounts of funds are lost, in addition to project delays, as a result of risks in megaprojects (Chattapadhyay *et al*., 2021).

The effect of the risks on the objectives of time, cost and quality are evident in the South African megaprojects that have been developed over the past decade and a half as outlined in section 1.1. These projects have failed to meet their objectives of time and cost. Eskom's recently completed Medupi project and the Kusile coal power plants that are currently underway have not only suffered time and cost overruns but are failing to achieve the desired quality. If the quality of a project is not according to the desired standard, faulty construction will result (Vadivel, 2016).

Quality problems can result in added expenses and delays in megaprojects (Pwc, 2014). For instance, at the Medupi power station, there were welding discrepancies and delays in the installation of the boiler safety mechanism software (Pwc,2014). To remedy the defects that were identified at Kusile and Medupi, will cost Eskom R300 million per unit (Khumalo, 2020).

There is one notable megaproject that is under construction in South Africa. This megaproject is the construction of the Msikaba bridge in the Eastern Cape province. This project is part of the N2 Wild Coast project undertaken by SANRAL (SANRAL, 2019). This project began in November 2017 and costs R 1.63 billion. The project was scheduled to be completed in 2020/2021 (Watermeyer & Phillips, 2020), however, it has suffered significant delays as a result of labour disputes and is now scheduled to be completed in 2025 (BusinessTech, 2022).

Therefore, to manage risks in construction megaprojects, it is important to use effective risk management tools. This is because risk management, when applied effectively and fully can ensure the successful delivery of projects. However, risk management is not fully applied in construction projects and Chihuri and Pretorius (2010) highlight that, in the South African construction industry, risk management tools have been applied by a limited number of projects

(Chihuri & Pretorius, 2010). Shunmugam and Rwelamila (2014) also add that globally risk management is not fully applied and generally not well understood, and the South African construction industry is no exception.

The problem statement can, therefore, be formally defined as follows:

South African construction megaprojects are failing to meet their objectives concerning time, cost, and quality due to various risks associated with these projects. Risks are problematic because they lead to time and schedule overruns combined with inferior quality. if risks are not managed effectively, megaprojects will continue to fail concerning time, cost, and quality. Therefore, mitigations are needed to minimize the risks that affect the successful delivery of megaprojects.

1.3 Research Question

By breaking down the problem statement mentioned above, the research question can be defined as follows: What are the risks that are resulting in the megaprojects failing to achieve their project goals concerning time, cost, and quality, and are there mitigations for these risks?

1.4 Objectives and Outcomes

This research study aimed at investigating the risks that are affecting the successful delivery of megaprojects concerning time, cost, and quality. The aim of this research study was achieved through the objectives as follows:

- To identify the risks to which construction megaprojects are exposed and categorize them into different groups.
- To examine the impact of risks on time, cost, and quality in construction megaprojects.
- To assess the tools used to identify risks in construction projects.

Overall, this research study will identify the risk factors that affect the successful delivery of South African construction megaprojects concerning time, cost, and quality. The primary outcomes emanating from this research study were as follows:

- Outcome 1: To identify the risks that affect the successful delivery of megaprojects concerning time, cost, and quality.
- Outcome 2: To identify the risks that affect all the project constraints of time, cost, and quality.
- Outcome 3: To identify the tools commonly used for identifying risks in construction projects.

1.5 Significance of research

This study will be significant for South African CEC firms working on megaprojects, as it will provide construction professionals with more information concerning the critical risks affecting the successful delivery of megaprojects. The need to assess megaproject risks has always been a high demand from industries (Esty, 2004). Knowledge of the critical risks will guide the construction management team when making decisions about the planning and execution of megaprojects (Chattapadhyay *et al*., 2021). This study will also be significant, as it will provide the construction project teams with possible solutions for the risks affecting the successful delivery of megaprojects. These solutions will help construction firms working on megaprojects avoid construction delays and financial loss.

1.6 Context of research

This research study falls within the Civil Engineering (Construction Management) discipline. This study focuses on the concept of risk in the delivery of civil engineering and construction megaprojects in South Africa.

1.7 Delineation

This study investigated risks in construction megaprojects. Only large South African civil engineering and construction (CEC) companies involved in megaprojects were considered for this study. Additionally, this study was limited to professionals working for large State-Owned Entities (SOEs), consultants, and contractors, in the public and private sectors. This research study considered large CEC projects with a minimum cost of R 700 000 000. Small and medium-scale CEC projects were not considered for this research study.

1.8 Methodology

This research study used a quantitative research method, coupled with a structured survey questionnaire. The questionnaire was administered to clients, consultants, and contractors working on construction megaprojects in South Africa. The questionnaire was used to identify the critical risks that are affecting the successful delivery of megaprojects concerning time, cost, and quality. The Mean Item Score (MIS) was the method used to identify critical risk factors. These critical risk factors were identified by ranking them in descending order based on the calculated MIS value. To achieve this, the respondents' perceptions of the impact of risks on project objectives of time, cost, and quality were obtained using a five-point Likert scale.

1.9 Organisation of thesis

This thesis consists of seven chapters as depicted below. Figure 1-1 shows the map of this document.

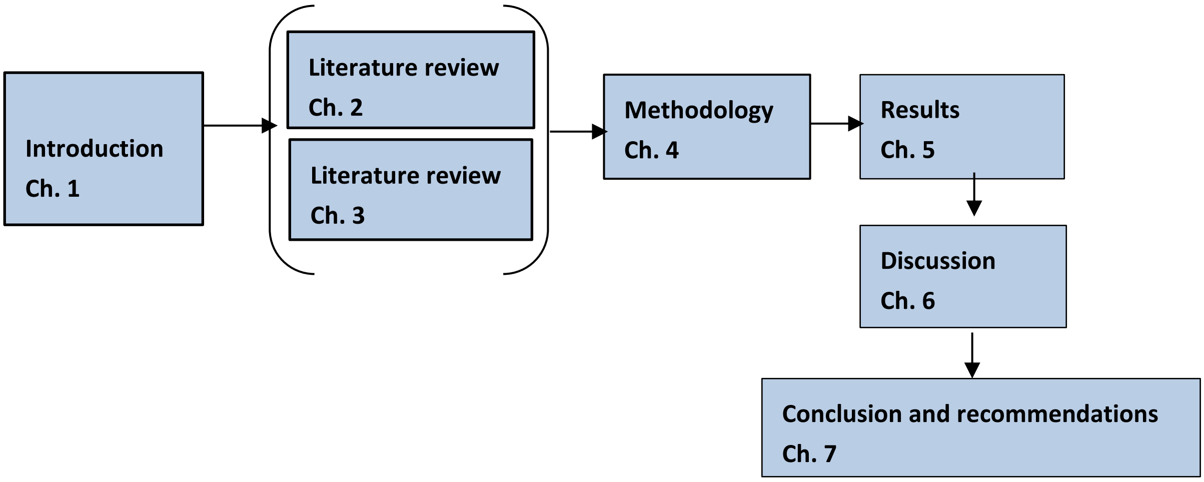

Figure 1-1: Document mapping

Chapter 1: Introduction

This chapter provides the background of the research study. Thereafter, the problem statement, the research question, and the aims and objectives of the study are presented. This chapter further provides the significance and the context of the research, and the delineation. Lastly, the methodology used in this research is briefly outlined.

Chapter 2: Literature Review

This chapter reviews the literature on risks associated with megaprojects. This chapter consists of two main sections. The first section of the chapter presents the definition, history, and characteristics of megaprojects. In the second section of this chapter, the risk factors associated with construction megaprojects are presented.

Chapter 3: Literature review

This chapter presents the existing literature on the impact of risk on project management constraints of time, cost, and quality. This section further highlights a few South African infrastructure megaprojects that have been implemented in the past, and how these projects have suffered cost and time overruns. This chapter also presents research on risk identification tools in construction projects.

Chapter 4: Methodology

This chapter presents the plan followed to conduct this research. The chapter outlines the procedures that were followed to serve the objectives of the study. The details concerning the type of data collected, the data collection process, the instrument for collecting data, and the data analysis method are outlined in this chapter.

Chapter 4: Results

This chapter presents and analyses the data that was collected through survey questionnaires from the clients, consultants, and contractors working on civil engineering and construction megaprojects. These results pertain to risk in megaprojects and their impact on time, cost, quality, and the tools used for identifying risks in projects. To find the critical risks affecting time, cost, and quality, a Mean Item Score was used to rank the risks. The data collected concerning the risk-identification tools used in the construction industry are also presented in this chapter.

Chapter 5: Discussion

This chapter presents findings from the results gathered through the questionnaires. These findings are related to the research problem, the research question, and the research objectives. The findings discuss the critical risks affecting time, cost, and quality. These risks are grouped into various categories and factors. The findings further present the mitigations for these identified critical risks. Lastly, the findings discuss the commonly used risk identification tools.

Chapter 6: Conclusion and Recommendations

This chapter presents the conclusions based on the literature review and the findings. Additionally, the limitations of the study, the research contribution, and the recommendations for further research are outlined.

1.10 Chapter summary

The objective of this chapter was to give the background of the study and the research problem. The research question emanated from the research problem. This was followed by the research aim, objectives, and outcomes. This chapter further presented the significance of the research, context of research, delineation, methodology, and the layout of the thesis chapters. This chapter provided an outline of the entire research project. The following chapter will review previous literature studies related to the risks in construction megaprojects.

Chapter 2 Literature Review

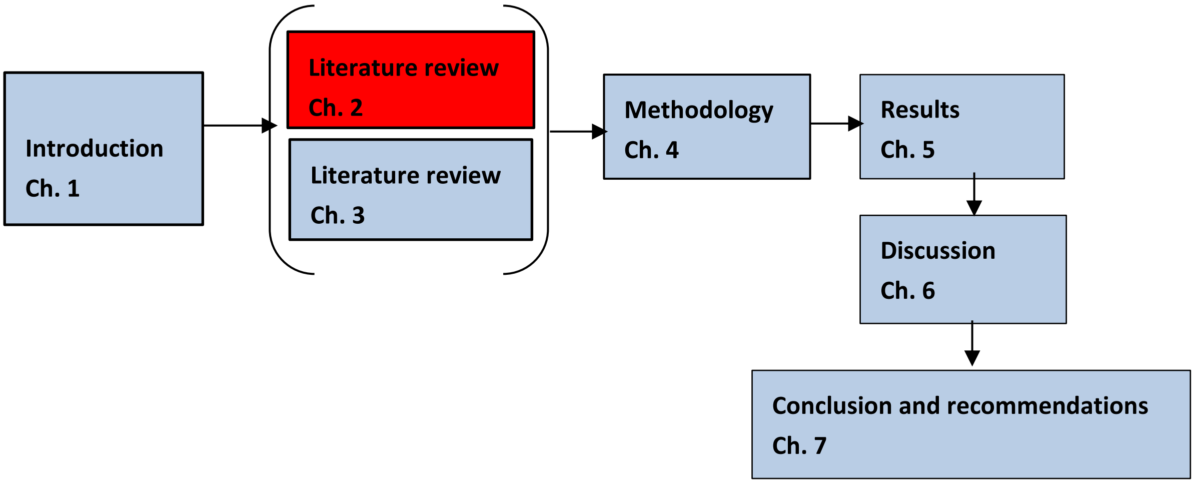

Figure 2-1: Document mapping chapter two

2.1 Introduction

The previous chapter introduced the study. The background of the study and the research problem was presented. The former provided the motivation for conducting this research, while the latter identified the problem that was investigated. Furthermore, the aim and objectives of the study were presented in the previous chapter. This chapter aims to present the literature study on risk in construction megaprojects. The risks considered are those that have an impact on the successful delivery of megaprojects concerning time, cost, and quality. From these studies, risks will be selected and presented in the research instrument outlined in chapter 4. The research instrument will aid in collecting the data to address the first objective of the study relative to risks in megaprojects.

2.2 Overview of megaprojects

This section will provide a brief overview of megaprojects by providing definitions of megaprojects, followed by the characteristics of megaprojects.

2.2.1 Defining a megaproject

Megaprojects can be defined as large-scale, complex projects that cost one US$ billion or more (Flyvbjerg, 2014), are usually completed over five years or more (Watermeyer & Phillips, 2020), carry a high level of risk (Kardes *et al*., 2013), involve multiple private and public stakeholders (Walsh *et al*., 2021), and generate high public attention (Watermeyer & Phillips, 2020). Megaprojects are multi-dollar projects, usually commissioned by governments and executed by private companies (Van Marrewijk *et al*., 2008). These definitions give a few characteristics of megaprojects that are discussed in detail in the following section.

2.2.2 Characteristics of megaprojects

Megaprojects are often characterized by huge capital investments, however, there are many other ways by which these projects are characterized (Sodurlund *et al*., 2013). For instance, Boateng *et al*. (2015a) characterise megaprojects as complex and expensive projects that frequently consist of various risk challenges to project management. Megaprojects involve intense planning, coordinated applications of capital, sophisticated technology, and political influence (Kardes *et al*., 2013). Watermeyer and Phillips (2020) state that megaprojects are characterized by uncertainty, technological sophistication, funding concerns, political influence, and complexity. Aiyetan and Das (2022) also add that megaprojects are highly complex undertakings. Therefore, high risk, political influence, and complexity appear to be the main characteristics of megaprojects as shown in Figure 2-2 below.

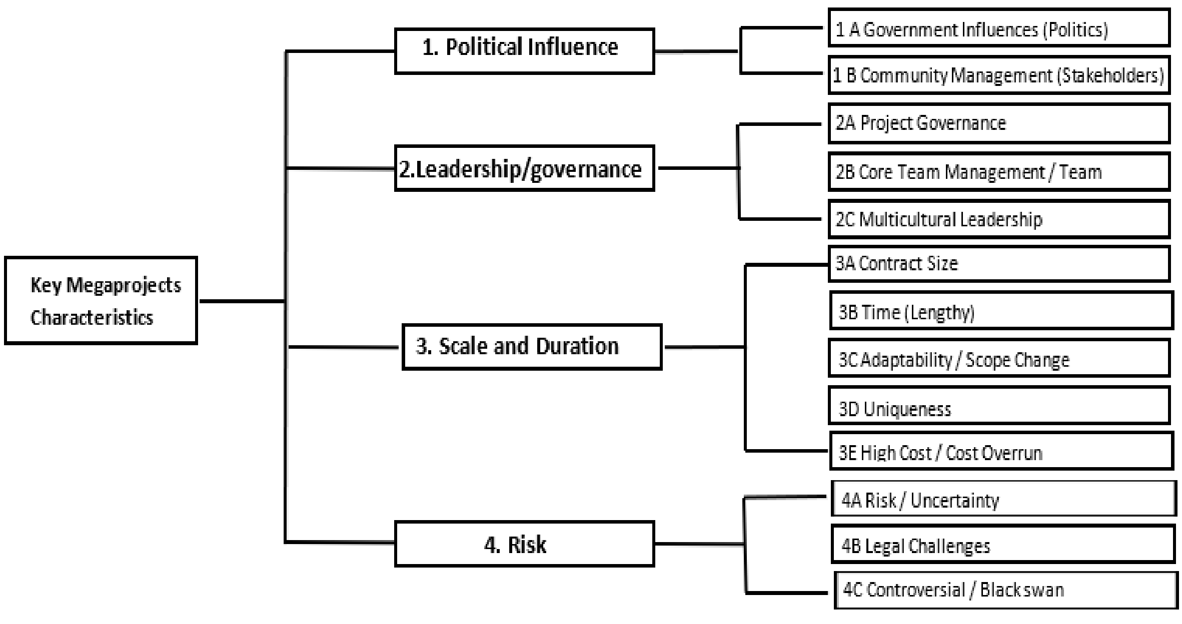

Figure 2-2: Key megaproject characteristics

(Walsh & Walker, 2021)

Complexity has become one of the notable characteristics of megaprojects. Practitioners have attributed megaproject failure to complexity (Damayanti *et al*., 2021). The complexity of megaprojects is caused by various factors, some of which include the involvement of multiple contractors and stakeholders, the long-term nature, the technology used, and the dynamism in the external environment (Kardes *et al*., 2013). The size of the project, extensive period, multiplicity of technological disciplines, the number of stakeholders involved and their interests, multi-nationality, increasing costs, risk, uncertainty, and political interest, are some of the key factors that contribute to the complexity of megaprojects (van Marrewijk *et al*., 2008). There are many ways to classify megaproject complexity. Maylor *et al*. (2013) classify the complexity of megaprojects into structural, social, and emergent, as shown in Figures 2-3. Structural complexity is associated with size, organization, design, the scope of work location, technology and other technical features (Damayanti *et al*., 2021).

Social complexity, on the other hand, includes teams, stakeholders, and cultural and political elements (Damayanti *et al*., 2021). As the divergence of people involved, level of politics, and lack of stakeholder commitment increases, social complexity also increases (Maylor & Turner, 2017). Lastly, emergent complexity consists of elements such as change and uncertainty in megaprojects (Maylor *et al*., 2013; Maylor & Turner, 2017).

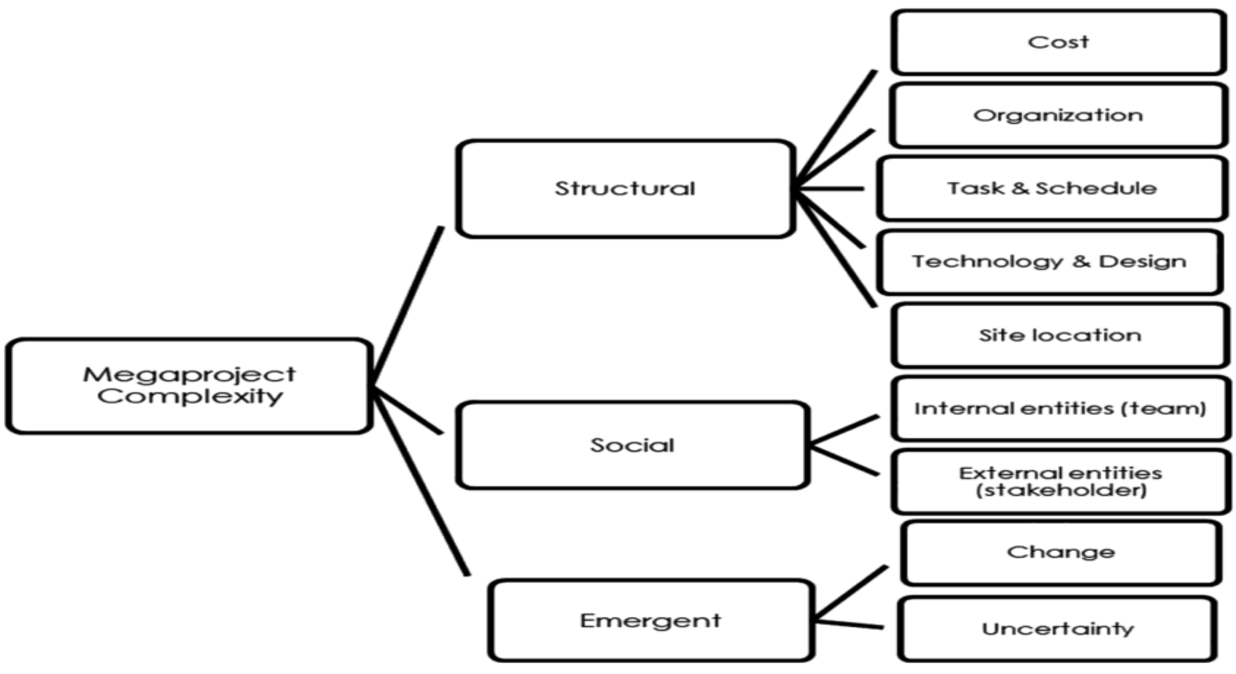

Figure 2-3: Megaproject complexity aspects

(Damayanti *et al*. 2021)

The complexity of megaprojects, according to Caldas and Gupta (2017), comprises the following features:

- The number of stakeholders.
- A large number of interfaces.
- Project geographical location problems.
- Inadequate supply of resources.
- The use of complex technology.
- Difficult regulatory constraints.
- Extensive infrastructure requirements.
- Geographically isolated teams.
- Political, economic, environmental, or social influence.

Furthermore, megaprojects are unique kinds of projects (Abdulmoneim *et al*., 2021; Hallock & Zack, 2018). As a result, Hallock and Zack (2018) identified key factors that distinguish megaprojects. They argue that these factors must be considered during the development of megaprojects since they largely impact the performance of the project. These key factors are presented in Table 2-1.

Table 2-1: Key differentiating factors of megaprojects

Item	Factor	Item	Factor
1	Logistical Problems	7	Inadequate Size, Skills, and Experience of Project Management Team
2	Jurisdictional Difficulties	8	Business Approach Differences across Stakeholders
3	Unavailability of Qualified Skilled Workers	9	Limited Capable Contractors
4	Unplanned Changes in Key Personnel	10	Cultural Differences between Stakeholders
5	Multi-location Challenges	11	Incompetent Contractor and Subcontractor
6	Optimism Bias		

(Hallock & Zack, 2018)

According to Gellert and Lynch (2003) megaprojects are divided into the following four types:

- Infrastructure.
- Extraction.
- Production.
- Consumption.

Megaprojects are usually commissioned by governments and executed by large private sector companies (Kardes *et al*., 2013). This means the development of a megaproject involves both public and private sector engineering companies. In most cases, the State-Owned Entities (SOEs) within the public sector commission megaprojects. The private sector companies specialize in design and construction services (Kardes *et al*., 2013). Contractors must ensure that they meet the objectives of time, cost, quality, and safety when delivering projects (Hallock & Zack, 2018). This means contractors are responsible for the execution of megaprojects. Megaprojects are normally constructed in remote areas (Watermeyer & Phillips, 2020) where there is adequate space to accommodate the size of the infrastructure being built. However, the disadvantage of building mega projects in remote areas is that site accessibility is problematic. In addition to challenges of site accessibility, climate and terrain also pose logistical and construction management challenges for megaproject development (Watermeyer & Phillips, 2020).

The development of megaprojects requires the involvement of numerous contractors, often from various countries (Kardes *et al*., 2013). These contractors must temporarily work together during the delivery of a megaproject (Walsh *et al*., 2021). In addition to the multiple contractors required in megaprojects, there are also funders, taxpayers, or investors who are also involved in the megaprojects (Walsh & Walker 2020). Several methods are used to fund megaprojects. These methods of funding include public financing, public-private partnership (PPP) financing, and corporate financing methods (Ismail *et al*., 2014).

Public financing is when a project receives funding from the government's budget (Ismail *et al*., 2014). In the corporate financing method, funds are raised by project sponsors (Ismail *et al*., 2014). This method is suitable for small-scale projects with less capital (Ismail *et al*., 2014). On the other hand, PPP financing is a relationship formed between the public and the private sectors when procuring an infrastructure asset (van Marrewijk *et al*., 2008; Grimsey & Lewis, 2005). In this financing method, funding is obtained from both parties involved in the project. Many countries adopt this type of financing method because project risks can be distributed across various public and private sector stakeholders (Calitz & Fourie, 2007). This means there are certain advantages to using the PPP method as depicted in Table 2-2.

Table 2-2: Advantages and disadvantages of PPP

Advantages	Disadvantages
Ease the strain on the government's balance sheet.	Transaction costs associated with PPP contracts are normally high and this discourages many small potential service providers from participating in the bidding process.
Introduce competition when bidding for infrastructure projects takes place.	Lack of a well-developed capital market can limit the development of a viable PPP market.
Restructure the public sector service by embracing private sector capital and practices.	Inappropriate risk transfer raises the perceived risk to investors and results in a high capital cost.
Achieve greater efficiency than traditional methods of providing public services.	PPPs hinder accountability, as PPP costs to the government are not reflected on the government balance sheet.

(Ismail *et al*., 2014)

Using the South African infrastructure megaprojects as an example, Table 2-3 below shows the infrastructure projects and their methods of financing.

Table 2-3: South African infrastructure projects and their financing methods

Project	Finance/Procurement method
Gautrain	PPP
Kusile	Corporate finance with government guarantees
Medupi	Corporate finance with government guarantees
Gauteng toll roads	Corporate finance with government guarantees
New multi-product pipeline	Corporate and public finance
OR Tambo international airport	Public finance
De Hoop dam	Public finance
Soccer world-cup stadia	Public finance
N4 toll roads	PPP
Standard Bank building (Rosebank)	Private sector finance and corporate finance

(Ismail *et al*., 2014)

As stated in the sections above, a megaproject is characterized by high risk. The following section will discuss the risks that are associated with a construction megaproject.

2.3 Construction of megaprojects and risks

This section focuses on risks in construction megaprojects and is divided into four sections. The first section defines risk. The second section discusses the concept of risk in construction projects. The third section identifies the risks that are associated with construction megaprojects. The fourth section presents the various risk categories.

2.3.1 Defining risk

There are many definitions of risk documented by various authors, for example, Barber (2005) defines risk as a threat that has an impact on the success of a project. The impact can either be positive or negative. Risk is a multi-faceted concept (Wang *et al*., 2004), which can be defined as an uncertain event that may occur, resulting in either a negative or positive outcome of a project (Enshassi & Abu Mosa, 2008; Baloi & Price, 2003). Aarthipriya *et al*. (2020) also define risk as any action or occurrence which will affect the achievement of project objectives. Barnes (1983) defines risks as uncertain future events, which if they occur, result in an additional cost or delay to a project.

From these definitions, the common recurring theme is that risk is an event that may have a negative effect on the objectives of the project. Although it is mentioned above that risk may have a positive outcome on a project, this research study is focused on the negative impact of risk on the objectives of the project. Since most risks usually have a negative impact, many individuals only consider the negative impact (Baloi & Price, 2003).

2.3.2 Risk in construction projects

There is a relationship between risk and project knowledge, as depicted in Figures 2-4. A lack of project knowledge, especially during the early stages of a construction project, will result in a higher degree of risk (Goh & Abdul-Rahman, 2013). At the beginning of the project, the level of uncertainty is seen to be the highest, and then it decreases towards the end of a project as knowledge about the project increases (Luque *et al*., 2015). The level of risk reduces with the increasing level of knowledge as the project progresses (Goh & Abdul-Rahman, 2013).

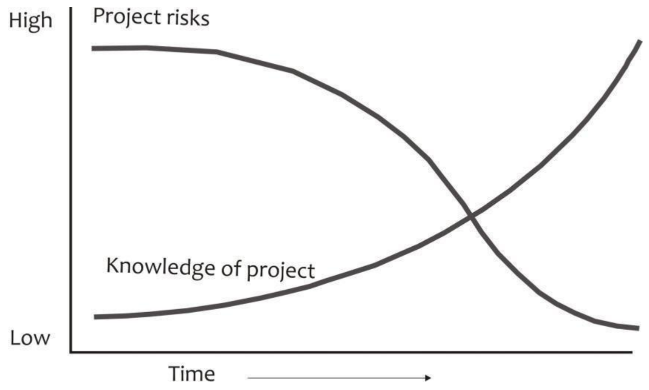

Figure 2-4: Relationship between project risk and the level of knowledge about risk

(Adapted from Luque *et al*., 2015)

As stated above every construction project is associated with risk, however, these risks were not specifically identified. Using prior research, the following section will identify the various risks associated with construction megaprojects.

2.3.3 Risks associated with megaprojects

Megaprojects, like any other project, need to be planned, designed, and constructed. However, the design, construction, and delivery of megaprojects are associated with various challenges such as engineering challenges, human development challenges, managerial challenges, political challenges, and sustainability challenges (Othman, 2013). These challenges emanate from different sources, they can be external to the project such as political challenges, or internal to the project, such as engineering and managerial challenges. Moreover, these challenges have the potential to contribute to the poor performance of megaprojects concerning time and cost constraints. Cost and schedule overruns are among the problems facing global megaprojects, even in South Africa (Tshidavhu & Khatleli, 2020).

Megaprojects, as previously stated, are associated with high risk. Therefore, various risks need to be considered in a megaproject (Sanchez-Cazorla *et al*., 2016). According to Zhai *et al*. (2009), the main risks associated with megaprojects are political, design, and economic risks. Additionally, execution risks, environmental risks, social risks, and technological risks are some of the key risks impacting construction megaprojects (Banerjee, 2020; Irimia-Diéguez *et al*., 2014; Chattapadhyay *et al*., 2021).

However, not all risks impact every megaproject in the same way (Chattapadhyay *et al*., 2021). This means there is a degree of impact for every risk. For instance, a mega construction project which is funded by private stakeholders will have fewer political risks (Chattapadhyay *et al*., 2021). This is because there is less public interest and fewer stakeholders involved who might be affected by the project (Chattapadhyay *et al*., 2021). On the other hand, a megaproject that is funded by the government will have more political risks (Chattapadhyay *et al*., 2021).

There is another megaproject risk that is underestimated or ignored by practitioners (Walsh *et al*., 2021). In their study, Walsh *et al*. (2021) discovered that cultural disagreement between principal contractors and project stakeholders can delay or disrupt the performance of megaprojects. They concluded that globally, culture has an impact on the successful delivery of megaprojects (Walsh *et al*., 2021). This makes cultural risk one of the factors affecting the successful delivery of megaprojects.

Megaprojects are associated with risks that have an impact on the successful delivery of the projects concerning time, cost, and quality. Up to this point, the above information provided the risks that are associated with megaprojects in terms of their categories. There is a need to identify the individual risk factors that have an impact on megaproject delivery concerning time, cost, and quality. According to a study conducted by Pwc (2014) on large capital projects in Africa, the risk factors that cause cost overruns in megaprojects are:

- Ineffective project management
- Unforeseen site conditions.
- Late design.
- Slow decision-making.
- Ambiguous contract terms.
- Ineffective decision-making process.
- Poor risk management strategies.
- Delayed payment.
- Unavailability of skilled labour.
- Low- experienced management team.
- Design errors.
- Insufficient planning and inaccurate estimating.

According to Chattapadhyay *et al*. (2021), the critical risk factors affecting megaproject quality are:

- Breakdown or failure of machinery.
- Unforeseen site conditions.
- Poor equipment performance.
- Low-skilled workforce.
- Poor site coordination.
- Unrecognized soil structure.
- Construction and implementation errors from faulty design.
- Inadequate design
- Design errors.

Moreover, Oyegoke and Al Kiyumi (2017) found the main causes of delays in megaprojects in the Sultanate of Oman to be the selection of the lowest bid, the financial condition of the main contractor, the client's slow decision-making, and the contractor's poor construction planning. Renault *et al*. (2016) concluded that the critical risks from the perspective of contractors in South African construction projects, not necessarily in megaprojects, are the supply of faulty materials, poor communication, and financial failure of the contractor. Tshidavhu and Khahleti (2020) conducted a study on the causes of cost and time overruns in the Medupi and Kusile energy megaprojects in South Africa. In their study, the factors that caused time and cost overruns were the following:

- Poor site management.
- Shortage of skilled labour.
- Unforeseen ground conditions.
- Poor material planning.
- Client's slow decision-making.
- Contractual claims.
- Variation orders.
- Changes in the scope of work during construction.
- Inaccurate material estimating.

From the discussion above, it is noteworthy to state that megaprojects are associated with risks that affect time, cost, and quality constraints. The following section will formally present and define various risk categories associated with megaprojects.

2.3.4 Classification of risks

There are different ways to categorize risks (El-Sayegh, 2008; Kartam & Kartam, 2001; Zou *et al*., 2007). Risks can be categorized into internal and external risks, while others are categorized into client risk, financial risk, design risk, contractor risk, material risk, etc. (El-Sayegh, 2008). According to PMBOK (2017), categorizing risk into groups is the most appropriate approach for identifying and responding to risks.

Sanchez-Cazorla *et al*. (2016) state that megaproject risk can be categorized into:

- Construction risks.
- Design risks.
- Material risks.
- Political risks.
- Operation and maintenance risks.
- Legal and contractual risks.
- Economic risks.
- Environmental risks.

In section 2.3.3, several authors categorized megaproject risks into political, design, and economic risks (Li Zhai *et al*., 2009), execution, social, cultural, and environmental risks (Chattapadhyay *et al*., 2021; Walsh *et al*., 2021). The definitions of various megaproject risk categories are provided below.

Construction risks: are significant in the whole life of the megaproject, not only in the construction phase. Cost overruns (or cost escalation), project schedules, coordination problems, and inappropriate design or accidents during construction are examples classified within this category (Irimia-Diéguez *et al*., 2014).
Economic risks: are those related to the funding and performance of the megaproject (Irimia-Diéguez *et al*., 2014).
Design risks: are those associated with the planning or design phase of the megaproject, such as delivery method, contract formation, and scope control (Irimia-Diéguez *et al*., 2014).
Political risks: are associated with changes in government regulations of the country in which the megaproject is developed (Irimia-Diéguez *et al*., 2014).
Environmental risks: These are natural risks such as unfavourable climatic conditions such as constant rainfall, snow, temperature, wind, etc. (Sanchez-Cazorla *et al*., 2016).

Social risks: These are associated with national and local-level factors that contribute to social instability such as levels of governance, security, and population size as well as project-specific issues (Sanchez-Cazorla et al., 2016).

2.4 Chapter summary

This chapter focused on the risks that are associated with construction megaprojects. The literature review highlighted the key characteristics of megaprojects, some of which include complexity, political influence, scale and duration, governance, and high risk. The objective of this chapter was to investigate the risks that are associated with megaprojects. These risks were presented under various name tags and categories. The risks that were considered in the literature study are those that have an impact on time, cost, and quality in megaprojects. The following chapter will focus in detail on the impact of risk on the project management constraints of time, cost, and quality.

Chapter 3 Literature review

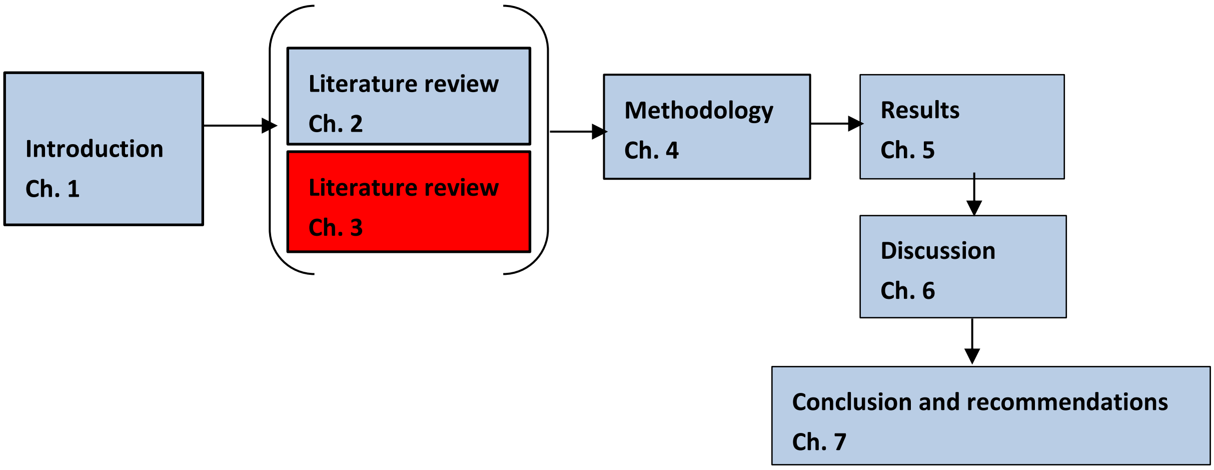

Figure 3-1: Document mapping chapter three

3.1 Introduction

The previous chapter focused on risks associated with construction megaprojects. This chapter focuses on the impact of risk on project management constraints. This chapter is divided into two sections. The first section presents the impact of risk on time, cost, and quality. In section 2.2.3, the literature study highlighted that there are degrees of impact for every risk in megaprojects. The review of the literature studies related to the impact of risk on project management constraints of time, cost, and quality assists the researcher to understand how other past studies have quantified the impact of risk on project management constraints. This information aided in the designing of the research instrument that was used to collect the data to address the second objective of the study relative to the impact of risks on project management constraints.

The second section of this chapter presents the literature review on project risk management. The review of the literature in this section focuses on the tools used for identifying risk in construction projects. From this literature review, the risk-identification tools were selected and presented in the research instrument that aided in collecting the data to address the third objective of the study relative to risk-identification tools.

3.2 Overview of project management

3.2.1 Project management

PMI (2017) defines a project as an effort taken to create a different product or service. On the other hand, project management is the use of knowledge, skills, and methods to achieve the requirements of the project (PMI, 2013). According to PMI (2013), project management is guided by five process groups as listed below, and shown in Figures 3-2.

- Initiation.
- Planning.
- Executing.
- Monitoring and controlling.
- Closing.

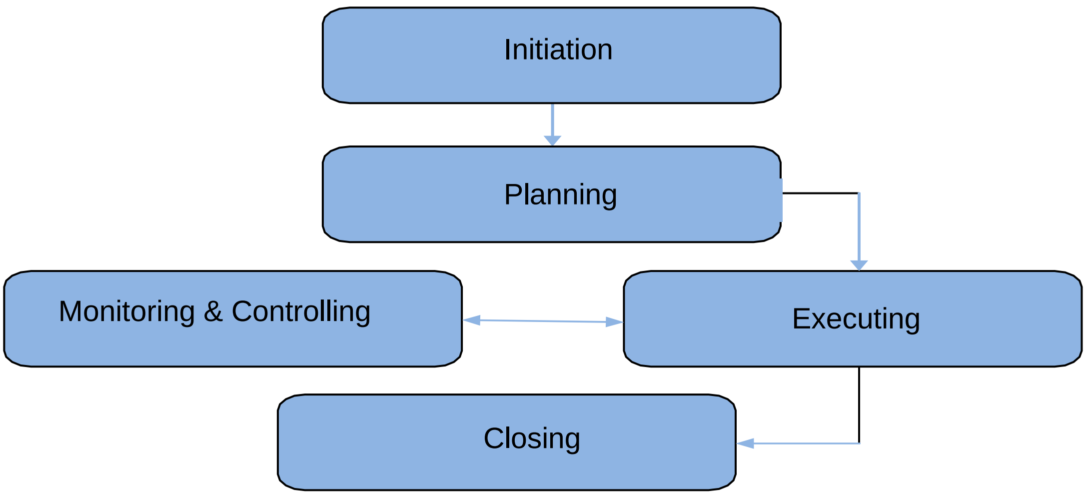

Figure 3-2: Project life cycle

(PMI, 2013)

The project management processes are listed and defined below:

- **Initiation.** This stage outlines the new project that is to be undertaken (PMI, 2013).

- **Planning.** This stage aims to define the scope of the project that is to be undertaken and the measures to be used to achieve the objectives of the project (PMI, 2013).

- **Execution**. This is the stage where the activities defined in the project management plan are performed (PMI, 2013).

- **Monitoring and controlling.** The purpose of this stage is to track the progress of the project (PMI, 2013).

- **Closing.** This is the stage where the project is formally completed (PMI, 2013).

3.2.2 Project management knowledge areas

In addition to the process groups listed above, processes are categorized by Knowledge Areas (PMI, 2017). The Project Management Knowledge Areas (PMKA) are the principles that are used to manage projects (PMI, 2017). According to PMI (2017), the ten project management knowledge areas are:

- Project Integration Management.
- Project Scope Management.
- Project Time Management.
- Project Cost Management.
- Project Quality Management.
- Project Resources Management.
- Project Communications Management.
- Project Risk Management.
- Project Procurement Management.
- Project Stakeholder Management.

For this study, Project Management Knowledge Areas refers to project management constraints. This thesis is focused on project management constraints of time, cost, and quality. This is because, according to Fahri *et al*. (2015), megaproject success is measured in terms of criteria of time, cost, and quality.

3.2.3 Impact of risk on project constraints of time, cost, and quality

According to Atkinson (1999), cost, time, and quality are some of the criteria by which projects can be measured, as depicted in Figures 3-3. Projects are undertaken to meet the objectives of time, cost, and quality, therefore it is the responsibility of every project manager to ensure that these objectives are met. This means that projects should be completed according to the planned schedule, within the estimated budget, and with acceptable quality.

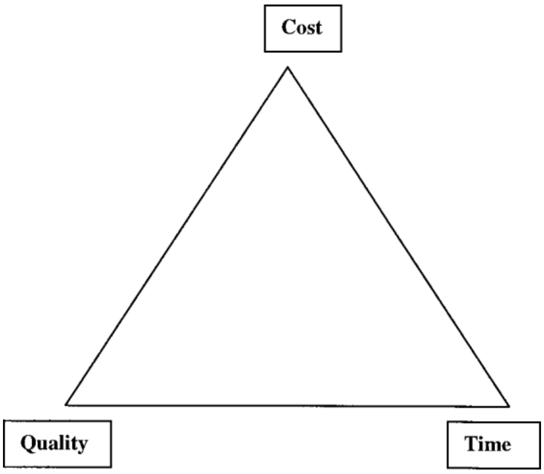

Figure 3-3: The Iron Triangle

(Atkinson, 1999)

Risk has an impact on project schedule and cost (Abdulmoneim *et al*., 2021). Risk not only affects time and cost constraints but affects the quality of the project. Table 3-1 below demonstrates how risks impact on time, cost, and quality parameters of a project.

Table 3-1: Impact values on time, cost, and quality

Impact Value	**Impact**		
	Quality performance	**Cost overruns (%)**	**Time delays (months)**
0.1 (low)	Minimal	Within budget	Negligible
0.3 (minor)	Small	1-10%	Minor slip (<1)
0.5 (moderate)	Moderate	10-25%	Moderate slip (1-3)
0.7 (significant)	Significant	25-50%	Significant (> 3)
0.9 (high)	Goals not achievable	>50%	Large slip

(Adapted from Nicholas & Steyn, 2011)

The foregoing section presented research on the impact of risk on project parameters of time, cost, and quality. The following section will expand on the previous section by highlighting practical examples of previously constructed South African infrastructure megaprojects that were not able to meet their baseline completion dates, cost, and quality requirements.

3.2.4 An overview of South African infrastructure megaprojects

There are many benefits that any country can obtain from infrastructure. A few of these benefits are outlined in Table 3-2. However, each of these benefits can only be realized on the condition that the country can deliver and effectively maintain the infrastructure (Ismail *et al*., 2014).

Table 3-2: Benefits of infrastructure

Outcome	Reason
Infrastructure contributes to economic growth	Diversifies the economy Provides access to modern technology
Infrastructure raises the quality of life	By creating amenities for citizens
Infrastructure develops economic potential	Where other inputs (labour and capital) in the production process become more productive
Infrastructure improves the macroeconomic climate	Due to efficient resource allocation
Infrastructure facilitates economic demand considerations such as service prices and demand elasticity	Reliability of services for users. Quality of services for users
Efficient infrastructure ensures user charges that reflect supply and demand conditions and non- market externalities as far as possible	To ensure infrastructure will be more economically efficient and favourable to the environment.

(Kessides, 1993)

3.2.5 South African infrastructure projects

The following list highlights a few South African former megaprojects and their performance. These projects include the Gauteng Freeway Improvement Project, the Gautrain Rapid Rail Link System, the Ingula Pumped Storage Scheme, the King Shaka International Airport, the New Multi-Product Pipeline, and the Kusile and Medupi coal power plants (Watermeyer & Phillips, 2020; Aiyetan & Das, 2022).

3.2.5.1 The Gauteng Freeway Improvement Project

The GFIP involved the upgrade of the existing main freeway network of approximately 193 km within the province of Gauteng in South Africa. This freeway conveys the bulk of commuter traffic around the metropolitan cities of Johannesburg and Tshwane, some 55 km, as well as Ekurhuleni, situated in the east of Johannesburg. The confirmed budget for the GFIP was R 11.4 billion. In 2010 the estimated final cost indicated that the project cost exceeded R 17.5 billion (Moloi & Khatleli, 2018).

3.2.5.2 Gautrain Project

The Gautrain is a project that was undertaken by Bombela and the Gauteng government. It links Tshwane, Johannesburg, and OR Tambo International Airport (Baloyi & Bekker, 2011). Rapid Rail System had an approved budget of R 6.8 billion in 2005, this figure increased to a final cost of R 25.2 billion at the time of its completion (Parrock, 2015).

3.2.5.3 Ingula Pumped Storage Scheme

Eskom's Ingula Storage Scheme is located on the border between the Free State and KwaZulu-Natal provinces. The project consisted of a lower reservoir (Bramhoek Dam), and an upper reservoir (Bedford Dam). Construction at Ingula started in 2006. The project had an initial budget of R 8.9 billion, this amount was revised to R 25.9 billion, and this figure further escalated to R 26.8 billion (Barradas, 2016).

3.2.5.4 King Shaka International Airport

The ACSA's King Shaka International Airport in KwaZulu-Natal province was the second-largest transport infrastructural megaproject after the Gautrain. The KSIA had an initial budget of R 3.15 billion and was revised to the final budget of about R 7.6 billion (Naidoo, 2010).

3.2.5.5 New Multi-Product Pipeline

Transnet's New Multi-Product Pipeline is South Africa's largest pipeline project. It was designed to transport fuel from Durban to Johannesburg (Tshidavhu & Khatleli, 2020). The NMPP project became necessary because the Durban pipeline was deteriorating and lacked the capacity for the increase in fuel storage (Ismail *et al*., 2014). The completion date of the project was moved from the year 2010 to 2013. The estimated total cost of the project increased from R 11.1 billion in 2008 to R 23.4 billion in 2010 (Ismail *et al*., 2014).

3.2.5.6 Medupi and Kusile Power coal stations

Medupi Power station is a dry-cooled, coal-fire station situated in Lephalale in the Limpopo province. On the other front, the Kusile Power Station is a coal-fired power station located in the Mpumalanga province (Tshidavhu & Khatleli, 2020). The Medupi and Kusile energy megaprojects were implemented to meet the struggling energy infrastructure that was unable to deal with the growing needs of the economy (Khatleli, 2016). Construction at Kusile started in 2008 and was expected to be completed by the end of 2014, but the project failed to meet this completion date and is now scheduled to be completed in 2023 (Tshidavhu & Khatleli, 2020). Construction at Medupi started in 2007 and was scheduled to be completed in 2012, but the project also failed to meet this completion date and ended up being completed in August 2021 and has taken ten years to complete (Barradas, 2021). Based on this data, the Medupi and Kusile power stations not only suffered cost overruns but construction delays as well (Tshidavhu & Khatleli, 2020).

3.2.5.7 De Hoop Dam

De Hoop Dam is in Sikhukhune in the Limpopo province of South Africa. The R 2.547-billion project was funded and implemented by the Department of Water Affairs (DWA) and aimed at supplying water to surrounding mines and communities (Smit, 2011). The Dam was implemented as part of phase 2 of the Olifants River Water Resources Development Project (ORWRDP), one of the Presidential Infrastructure Coordination Commission (PICC) projects aimed at fast-tracking infrastructure projects in South Africa. The construction of De Hoop Dam started in 2007 and was initially due to be completed in 2011, but some delays resulted in the project being completed in 2014. The project experienced cost overruns as shown in Table 2-8.

3.2.5.8 FIFA 2010 Soccer World Cup Stadiums

South Africa was awarded by FIFA to host the 2010 Soccer World Cup tournament. This resulted in the upgrading of five stadiums and the construction of new stadiums (Mpungose, 2017). Although all the stadiums were completed on time for the tournament, they were US$267 m over budget (Baloyi & Bekker, 2011). Table 3-3 illustrates the initial budgeted cost versus the final cost for all ten stadiums. Moreover, Baloyi and Bekker (2011) conducted a survey that aimed to investigate the causes of construction costs and time overruns during the construction of the 2010 FIFA World Cup Stadiums. Data was collected through a questionnaire that was distributed to clients, consultants, and contractors involved in the ten 2010 FIFA World Cup Stadiums. A total of 18 factors that contributed to cost overruns were analyzed, with the top ten factors contributing more than 85% of the cost overruns identified (Ismail *et al.*, 2014). Baloyi and Bekker (2011) identified the causes of cost overruns which are the following:

- Increase in material cost.
- Inaccurate material estimate.
- Shortage of skilled labour.
- Clients' late contract award.
- Project complexity.
- Increase in labour cost.
- Inaccurate quantity take-off.

Concerning time overruns, a total of 34 factors were analyzed, with the top ten factors contributing more than 80% of the causes of delay (Ismail *et al.*, 2014). According to Baloyi and Bekker (2011), the main causes of time overruns were the following:

- Incomplete drawings.
- Design changes.
- Client's slow decision-making.
- Late issue of instruction.
- Shortage of skilled labour.
- Poor planning and scheduling.
- Labour strikes.
- Shortage of manpower.
- Change orders by the client during construction.
- Delay in work approval.

Table 3-3: Budgeted versus indicated final cost of the 2010 Soccer World Cup stadia

Stadium	**Initial budget**	**Final cost**	**Cost overrun**
Soccer City: Johannesburg	R2.2 billion	R3.7 billion	41%
Ellis Park: Johannesburg	R240 million	R253 million	5%
Moses Mabhida: Durban	R1.6 billion	R3.1 billion	48%
Mbombela: Nelspruit	R600 million	R1 billion	40%
Green point: Cape Town	R2.9 billion	R4 billion	28%
Nelson Mandela Bay: Port Elizabeth	R2.1 billion	Not known	-
Royal Bafokeng: Rustenburg	R1.3 billion	Not known	-
Peter Mokaba: Polokwane	R360 million	R483 million	25%

Mangaung: Bloemfontein	R245 million	R359 million	32%
Loftus Versfeld: Pretoria	R122 million	R131 million	7%

(Baloyi & Bekker, 2011)

From the above discussion, it can be deduced that all the South African megaprojects experienced cost and time overruns. Table 3-4 further provides additional information on cost overruns in South African infrastructure projects.

Table 3-4: Project cost overruns in South African infrastructure megaprojects

Project	Initial budget (R billion)	Final cost (R billion)	Cost overrun (%)
Gautrain	25.1	30.5	21
Kusile	90	121	34
Medupi	33.6	105	213
Gauteng toll roads	6.3	90	1329
New multi-product pipeline	11.1	23.4	111
OR Tambo international airport	5.2	8.5	64
De Hoop dam	7.9	20	153
Soccer world-cup stadia	8.1	18.4	126
N4 toll roads	2	3	50
Standard Bank building (Rosebank)	1.1	2	82

(Ismail *et al*., 2014)

From this discussion regarding the performance of South African megaprojects concerning time, cost, and quality, it can be deduced that all megaprojects failed to meet their objectives concerning time and cost requirements. The projects were not delivered on time nor within the estimated budget. This supports the observation of Tshidavhu and Khatleli (2020) that cost and time overruns are the major challenges facing South African megaprojects. There is a need to manage construction projects in a manner that the objectives of time, cost, and quality will be met. The following section discusses risk management in construction projects.

3.3 Risk management in construction projects

The previous sections have highlighted that construction projects attract many risks. The literature study highlighted that megaprojects face many risks, due to their complex nature. These risks cause delays and cost overruns, combined with inferior quality of projects. This section is focused on risk management in construction projects.

3.3.1 Risk management processes

Risk management is the process used in project management to identify potential risks and reduce them (Serpella *et al*., 2014). The primary aim of applying a risk management system is not to eliminate all risks, but to minimise the risks to ensure that the objectives of the project are achieved. Risk management is vital when making decisions concerning project management (Tang *et al*., 2007). For decisions to be taken in the management of construction projects, there needs to be an understanding of the risks. Risk management is divided into risk identification, risk analysis, risk response, and risk monitoring and review (Junior & de Carvalho, 2013), as shown in Figures 3-4 below.

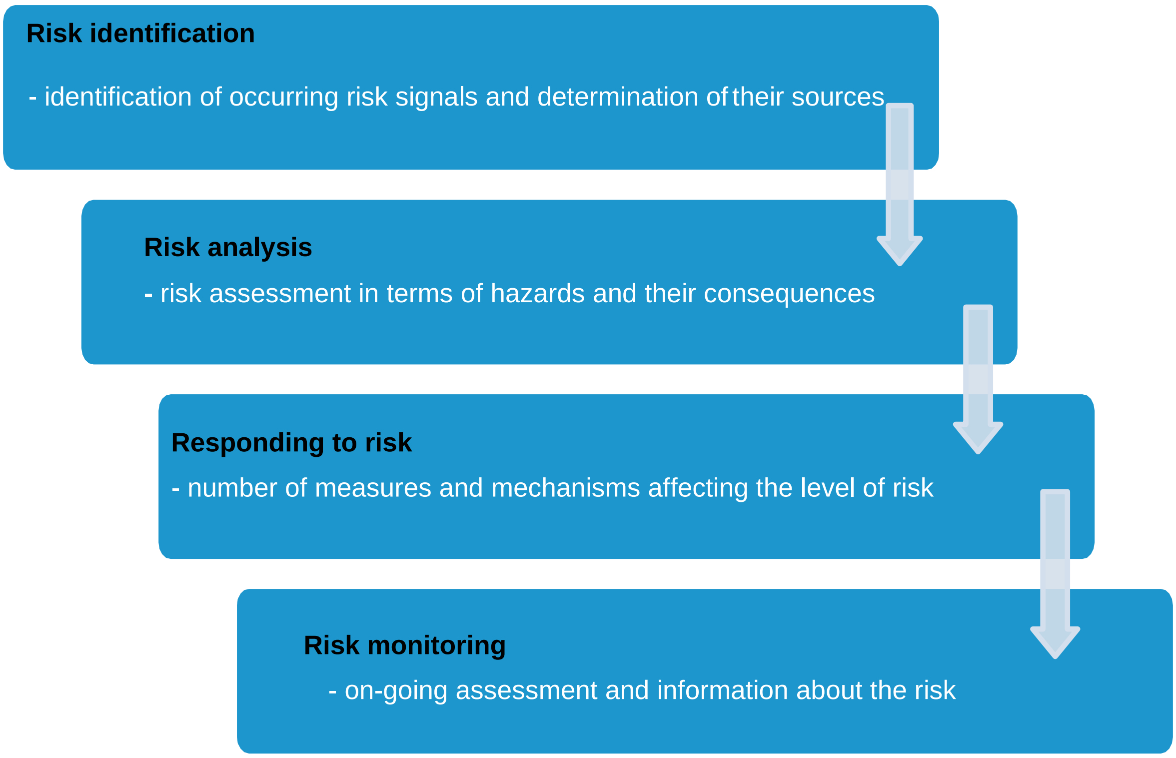

Figure 3-4: Risk management cycle

(Szymański, 2017)

The risk management processes are listed and briefly described below:

3.3.3.1 Risk identification

Risk identification is the first step of the risk management process, in which potential project risks are identified (Zou *et al*., 2007). It is the process that involves identifying individual risks and their sources and documenting their characteristics (PMI, 2017). According to Junior and de Carvalho (2013), risk identification is an important step in ensuring that project objectives are met. The risk identification stage occurs during the feasibility and design development stage, whereby any changes made to major decisions have the least impact on the project (Othman & Harinarain, 2009).

3.3.3.2 Risk Analysis

Risk analysis is the process between risk identification and risk response (Alattyih *et al*., 2014). This approach uses qualitative or quantitative methods to analyze potential risks and evaluate their potential impacts (Zou *et al*., 2007). Qualitative risk analysis is based on the correct estimation of project risk probability and impact. On the other hand, a quantitative analysis also helps to accurately determine the probability to meet deadlines or costs of the project and sets trends in further risk proceedings (Szymański, 2017).

3.3.3.3 Risk response and mitigation

Risk response and mitigation is the step that is required to reduce, eradicate, or avoid the potential impact of risks on a project (Flanagan & Norman, 1993). Risk response is classified into:

- Mitigate.
- Avoid.
- Transfer.
- Share.
- Retain.

3.3.3.4 Risk monitoring

This is a method to create a risk register where all risks and their management can be recorded. Risk monitoring is a continuous task to ensure that there is progress in action plans and that any critical potential risks are identified and managed (Chihuri & Pretorius, 2010).

Furthermore, according to Renault *et al*. (2016), an effective risk management approach does not only help to understand and identify potential risks but also how to deal with these risks throughout the project's lifecycle. Moreover, Serpella *et al*. (2014) add that without an effective project risk management method to combat risk, there will always be delays, high costs, and contractual disputes. Therefore, risk management assists in reducing delays and contractual disputes (Alattyih *et al*., 2014). Therefore, to increase the probability of project success, it is important for companies to understand the potential risks, systematically and quantitively assess these risks, and then choose suitable methods to deal with them (Mobey & Parker, 2002).

Tinnirello (2000) stresses the importance of applying risk management before the completion of the project to assist in the identification and mitigation of potential risks. Tinnirello (2000) further adds that it is important to assess risk at the project brief stage, as risks identified at this stage will aid in project success. The risk that is not identified at this stage will be problematic at some point during the life cycle of the project. Kishk and Ukaga (2008) concur with Tinnirello (2000) adding that the failure to identify risk at the onset may lead to dire consequences. Moreover, when risk management is applied earlier in the project, the more successful the project becomes (Tinnirello, 2000).

The risk management process needs to be constantly applied during the life cycle of a project (Luque *et al*., 2015). At the onset of a project, the level of risk is known to be the highest. Risks decrease towards the end of a project as knowledge about the project increases, as shown in Figures 3-5. Hence, risk management is most effective in the early phases of the project life cycle (Luque *et al*., 2015).

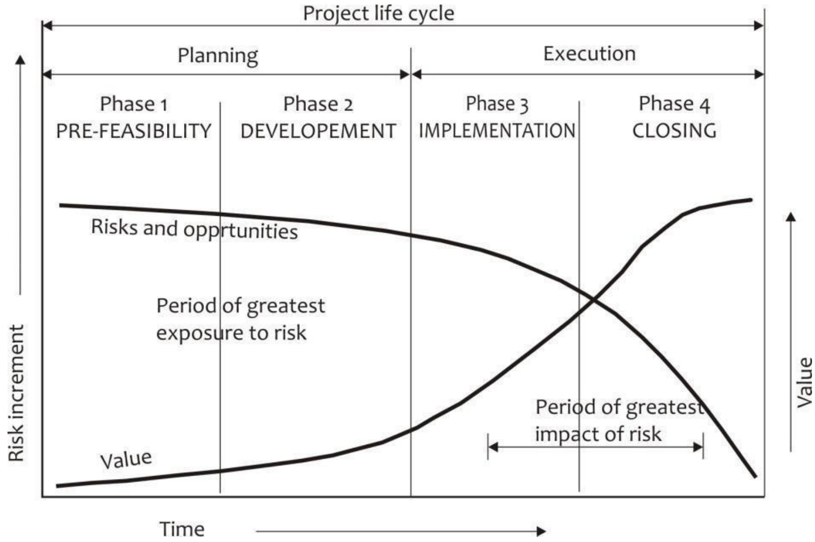

Figure 3-5: Risk during project lifecycle

(Wideman, 1992)

3.3.2 Risk identification tools

Risk identification is an integral step in project management as it helps to identify the risks that have the potential to affect the project (Chihuri & Pretorius, 2010). Several techniques are used to identify all probable risks which might impact the project (Kishan *et al*., 2014). This section focuses on the risk identification tools used in a construction project, not necessarily megaprojects. A few risk-identification techniques are listed and explained below:

3.3.4.1 Documentation reviews

This tool involves a detailed review of project documentation such as project plans and project files, including the assumptions made (Chihuri & Pretorius, 2010). A planned and detailed documentary review needs to be performed regularly, considering all the assumptions, plans, and previous project files, which could be used as indicators that reveal any entrenched risks in the project (PMI, 2013).

3.3.4.2 Brainstorming

This is one of the best-known risk identification techniques. The goal of this technique is to obtain a comprehensive list of project risks (PMI, 2017). This technique takes the form of an open discussion which is attended by the project team and other project participants. In this discussion, the existence of risks and their potential impact are examined (Renault *et al*., 2016). This technique is divided into two phases. The first phase is called the idea generation phase where participants generate as many ideas as possible. The second phase is where ideas are filtered, and only those ideas that are approved by the entire group, are retained (Morano *et al*., 2006). The risks that are identified are tabulated and the risk characteristics are detailed.

3.3.4.3 Delphi technique

The Delphi technique uses the opinions of experts through questionnaires with controlled feedback (Tamošaitienė *et al*., 2021). Several experts are chosen external to the project (Chihuri & Pretorius, 2010). Each expert is allowed to make an anonymous prediction on a specific topic. Each expert is then anonymously provided with the opinion of all the others and must then make new predictions, based on feedback.

3.3.4.4 Interviewing / Expert opinion

This technique utilizes individuals with specialized knowledge of similar projects. These experts are identified by the project manager to consider all possible project risks and their sources based on their previous experience and area of specialization (PMI, 2017). According to Chihuri and Pretorius (2010), this is regarded as one of the main sources of risk identification and data collection. Morano *et al*., (2006) state that this technique uses interviews conducted with individuals or a collective group consisting of experienced project members, experts, or project stakeholders. Moreover, interviewing experienced participants can help in avoiding or solving similar problems that may be encountered in a project (Renault *et al*., 2016).

3.3.4.5 Root cause identification

This is a graphical process used to investigate and categorize the critical causes of a project's risks and is divided into four phases: data collection, casual factor charting, root cause identification, recommendation generation and implementation (Morano *et al*., 2006). According to Chihuri and Pretorius (2010), this is an inquiry into the essential causes of a project's risks that allows the grouping of risks by causes, to facilitate effective risk responses to be developed if the root cause of the risk is addressed.

3.3.4.6 Checklist analysis

Checklist analysis as a risk identification tool generates a checklist of risks based on the historical information obtained from previous projects (PMI, 2017). The checklist should be reviewed during project closure to improve it for use in future projects (Chihuri & Pretorius, 2010).

3.3.4.7 Nominal group technique

The nominal group technique is composed through a silent generation of written ideas which are presented using simple sentences in postcards or paper bands. Discussions about each are recorded for clarification and evaluation (Morano *et al*., 2006).

3.3.4.8 Cause-and-effect diagrams

These are also known as fishbone diagrams. They indicate how various elements can relate to problems (PMI, 2013). The diagram is designed by listing the effect on the right side and the causes on the left side. There are categories for each effect, and the main causes must be grouped according to these categories (Morano *et al*., 2006).

3.3.4.9 SWOT Analysis (Strengths-Weaknesses-Opportunities-Threats)

A SWOT Analysis tool is applied to identify the strengths, weaknesses, opportunities, and threats of a company (Renault *et al*., 2016). This method is used to increase the scope of the identified risks by including risks that were generated internally for the project (PMI, 2017).

3.3.4.10 Scenario building

This is characterized by the development of hypothetical scenarios that represent the processes to be developed through the logical construction of each event, as well as its interactions and results. The process involves identifying the risk factor, computing the impact caused by risk triggers on the project's objectives, combining the occurrence of possible events, and determining the correlation among them through simulation techniques (Morano *et al*., 2006).

3.4 Chapter summary

This chapter aimed to present the literature on the two knowledge areas of this study, namely, the impact of risk on project constraints and risk management in construction projects. Combining the information in chapters 2 & 3, the following summary can be drawn concerning the key knowledge areas of this study:

- Megaprojects are large infrastructure projects characterized in terms of high cost, unique design features, sophisticated technology, and multiple stakeholder involvement.
- The key characteristics of megaprojects are risk, scale and duration, political influence, and complexity.
- Megaprojects are associated with many risks that affect their successful delivery.
- Time and cost overruns have been identified as major challenges in South African megaprojects.
- Most megaprojects in South Africa in the transport and energy sectors experienced massive cost overruns, as illustrated in Table 3-4.
- Risk management is vital for the successful delivery of construction projects.

Taking these into account, this research was aimed at investigating the critical risks that are affecting the successful delivery of megaprojects concerning time, cost, and quality. Furthermore, this research looked at how these risks could be minimized to ensure that megaprojects meet their objectives concerning time, cost, and quality. To achieve the aim of this research study, several risk factors were gathered from the literature review. From the risks obtained from the literature review, a questionnaire was designed. The questionnaire was sent to practitioners dealing with construction megaprojects in South Africa. The questionnaire aimed at identifying the key risks affecting the delivery of megaprojects. The following chapter will present the research methodology for this study.

Chapter 4 Methodology

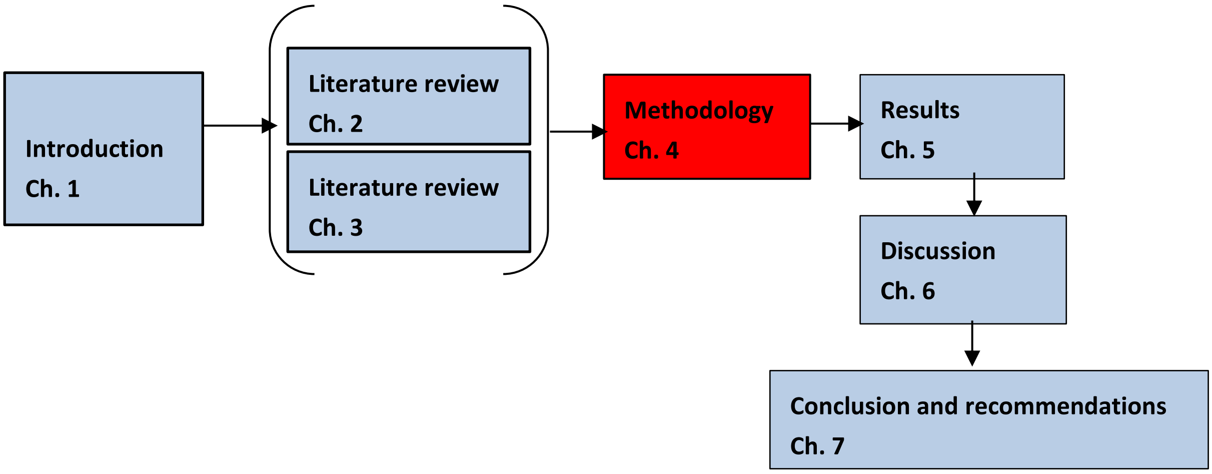

Figure 4-1: Document mapping chapter four

4.1 Introduction

The previous chapter presented research on the key knowledge areas of the study, namely, risks in megaprojects, the impact of risk on project management constraints, and risk management in construction projects. This chapter outlines the procedure that was used to collect the data to answer the research question.

4.2 What is research

There are many definitions of research documented by various authors in different fields of research. For instance, Kothari (2004) defines research as ''*a scientific and systematic search for pertinent information on a specific topic*." Research, according to Saunders *et al*. (2009) is defined as "*something that people undertake to find out things in a systematic way, thereby increasing their knowledge."*

From the definitions provided above, it follows that research is a planned project conducted systematically to obtain information on a particular topic. The following section will discuss the research types as viewed from the perspective of the objectives of the study.

4.2.1 Types of research study

According to Kumar (2011), there are three different perspectives from which to view the types of research. These three different perspectives are listed below and shown in Figures 4-2.

- Application.
- Mode of enquiry.
- Objectives.

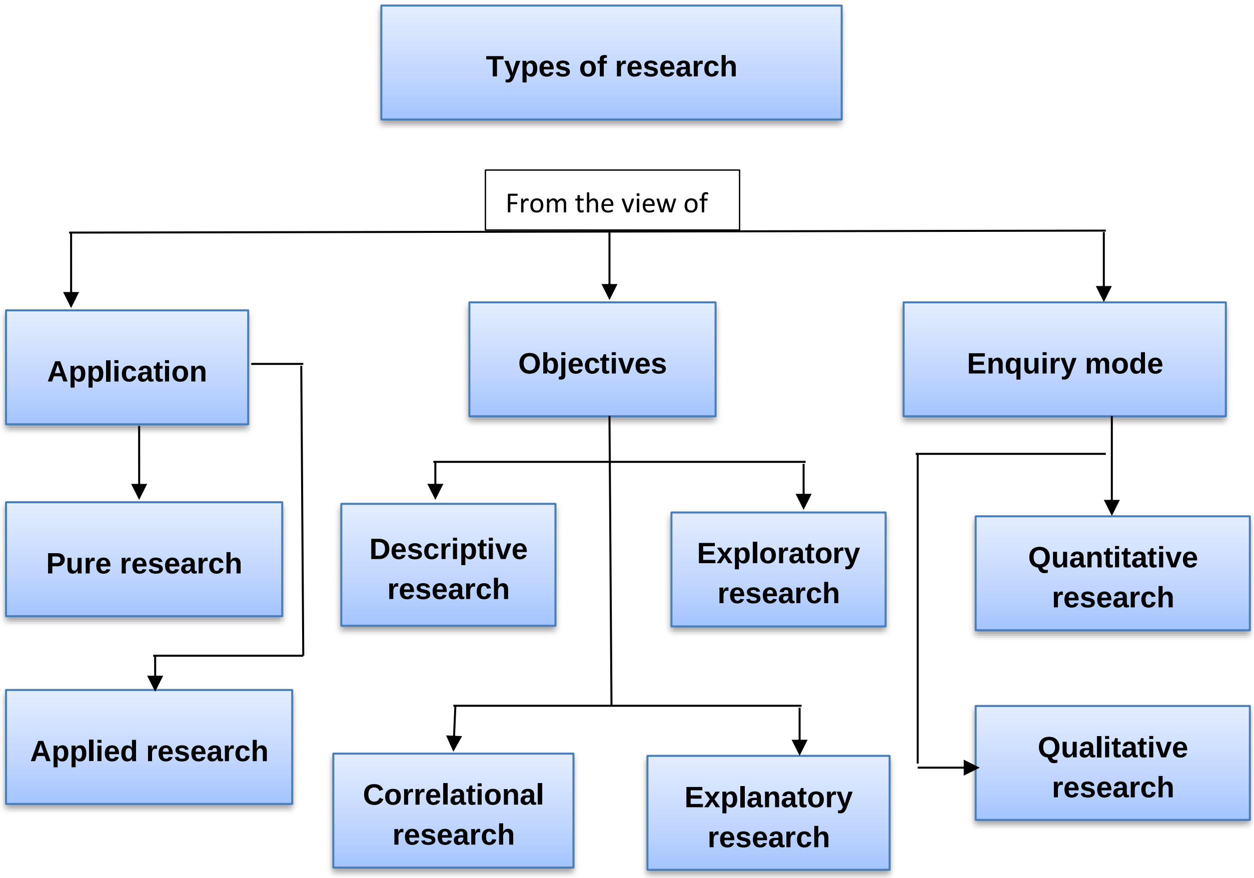

Figure 4-2: Types of research

(Kumar, 2011)

From these three perspectives mentioned above, this section will now discuss the type of research based on the objectives of the study. The objectives of this study are as follows:

- To investigate the risks to which construction megaprojects are exposed and categorize them into different groups.
- To examine the impact of risks on time, cost, and quality in construction megaprojects.
- To investigate the tools commonly used for identifying risks in construction projects.

According to Kumar (2011), a research study that is viewed from the perspective of its objectives can be classified into the following studies:

- Descriptive study.
- Correlation study.
- Explanatory study.
- Exploratory study.

The above four classifications of the research types as viewed from the objectives of the study will be discussed below. Thereafter, the type of research applicable to this study will be discussed along with the reasons why it is suitable for this study.

- **Descriptive research.** A descriptive study describes the situation that is presently taking place (Leedy & Ormrod, 2015; Crafford, 2007). This type of study may describe a situation in an organization or people's attitudes and opinions about a particular situation. The primary purpose of this type of study is to describe the prevalent issues concerning the problem being studied (Kumar, 2011).

- **Correlation study**. A correlation study examines the presence of a relationship between two or more aspects of a phenomenon (Kumar, 2011). This type of research study collects quantitative data concerning two or more characteristics of a group of people or other variables being studied (Leedy & Ormrod, 2015).

- **Explanatory study**. The explanatory study attempts to clarify why and how there is a relationship between two aspects of a situation (Kumar, 2011). It seeks to ask 'why' and 'how' questions (Gray, 2014). The explanatory study builds on exploratory and descriptive research and goes on to identify the real reasons why a phenomenon occurs. Explanatory research uses data to test a theory (Saunders *et al*., 2009).

- **Exploratory study.** This type of research study is conducted to explore an area where there is limited information about the topic (Naoum, 1998; Kumar, 2011). Exploratory research normally uses interview techniques as a method to collect data (Naoum, 1998).

In most cases, exploratory research may be needed to develop ideas that lead to research hypotheses (Zikmund *et al*., 2009).

4.2.2 The type of this research study

Taking into consideration the above discussion in line with the objectives of this research, this study can be considered explanatory, descriptive, and correlational. This research study is an explanatory type because it seeks to clarify why construction megaprojects are failing to meet their objectives of time, cost, and quality. Additionally, this research explains the risk factors that contribute to the failure of megaprojects concerning time, cost, and quality. Moreover, this study is descriptive because it describes the current problem that South African construction megaprojects are facing regarding their successful delivery. According to Crafford (2007), descriptive research seeks to answer the 'who, what, where, and how' questions. Therefore, descriptive research suits this study because it seeks to find out the risks that are affecting the successful delivery of megaprojects, and how these risks can be minimized.

This study is correlational (the second objective) since it examines the impact that the risks have on time, cost, and quality in construction megaprojects. In other words, the study examines the existence of a relationship between the risk factors and project constraints. For instance, the greater the impact the risk has on the schedule of the project, the more significant the risk. Additionally, explanatory, correlational, and descriptive methods are best applicable to this research study because a questionnaire is used as a method of collecting the primary data. Saunders *et al*. (2009) state that questionnaires are used for descriptive or explanatory research. The former enables the researcher to identify and describe the variability in different phenomena, while the latter enables the researcher to examine and explain the relationships between variables (Saunders *et al*., 2009).

4.3 Research Design

To achieve the aim and objectives of this research, and to answer the research question, this study comprised two stages. The first stage comprised a literature study on megaproject risks and their impact on project management constraints. In addition to the risks, a literature review was conducted on risk identification tools used in construction projects. The literature identified the risks that are affecting the successful delivery of megaprojects concerning time, cost, and quality both internationally and in South Africa.

After collecting the information from previous research studies, the next stage was to carry out a survey using a questionnaire. The questionnaire was designed from the information obtained from existing literature and distributed to construction clients, consultants, and contractors working on megaprojects in South Africa. The data collected were analysed using the Mean Item Score to identify the critical risk factors and their impact on time, cost, and quality.

This section details the research design which focuses on the research method, data collection, sampling, targeted population, and data analysis.

4.3.1 Research methods

There are three methods for conducting research: qualitative methods, quantitative methods, and mixed methods (Creswell, 2014). Quantitative methods generate data in a quantitative form that can be analysed statistically. Quantitative research methods measure concepts using scales that either directly or indirectly provide numerical values (Zikmund *et al*., 2009). According to Naoum (1998), quantitative data are not abstract but consist of measurements of tangible, countable, and sensate features of the world. In quantitative research, the investigator uses strategies of inquiry such as experiments and surveys and collects data on predetermined instruments that produce statistical data (Creswell, 2014).

On the other hand, qualitative methods collect the opinions, behaviour, and attitudes of certain groups, using in-depth interviews. Qualitative methods seek to understand a phenomenon through observing or interacting with a chosen participant in the study. Furthermore, qualitative methods generate descriptive data of the participants' opinions and focus on the reason why the phenomenon has occurred (Creswell, 2014). The mixed-method combines both the quantitative and qualitative methods in the same research study. This approach helps the researcher to answer the research question that cannot be answered using only qualitative or qualitative methods alone. Mixed methods provide a more complete picture by noting trends and generalizations as well as in-depth knowledge of participants' perspectives.

4.3.2 Selected research method for this study

From the above discussion, this research study used a quantitative method. This method was chosen because this research study uses a questionnaire as an instrument of data collection. The questionnaire is a quantitative method used to collect data from a sample representing a large population (Cooper & Schindler, 2014). The quantitative method was also used because it provides numerical data. The numerical data allowed the respondents to rate the impact of risks on time, cost, and quality by using a five-point Likert scale. This data was used to rank the critical risks affecting megaprojects concerning time, cost, and quality. The numerical data collected was analysed using a Mean Item Score. A quantitative method supports the use of Likert scales to measure data (Netemeyer *et al*., 2003). Several South African authors such as Tshidavhu and Khatleli (2020); Renault *et al.* (2016), and international authors such as Chattapadhyay *et al*. (2021), have used the quantitative approach in their research studies to identify and rank the critical risks in construction megaprojects.

A qualitative method was not deemed suitable for this research study. This is because a qualitative research method is often used in exploratory research studies (Zikmund *et al*., 2009). Additionally, in qualitative research, interviews are often used as a method of primary data collection to explore a problem being investigated. Therefore, this study did not use a qualitative method as it was not exploratory and interviews were not used to collect primary data.

4.3.3 Data collection

Data collection is classified into primary and secondary data collection (Kumar, 2011). Primary data is the original data collected by the researcher for the first time (Kothari, 2004). This type of data is collected either through a survey or an experiment. On the other hand, secondary data is the data collected and analysed by other authors (Kothari, 2004).

To achieve the aim and objectives of this research study, both primary and secondary data were collected. The secondary data were obtained from previous research studies concerning risks and their impact on megaprojects. The primary data was collected using a questionnaire survey sent to construction clients, consultants, and contractors. The type of primary data collected was numerical and descriptive. Numerical data were used to obtain the respondents’ rating of the impact of risk on time, cost, and quality. This rating was done using a five-point Likert scale. On the other hand, descriptive data were used to obtain possible solutions to minimize the risks.

The primary data collected should be able to answer the following research question:

What are the critical risks that are resulting in the megaprojects failing to achieve their project objectives concerning time, cost, and quality, and are there mitigations to minimize these risks?

The process that was used to collect primary data was as follows:

- A total of 22 risk factors gathered from the literature study were compiled as shown in Table 4-1. These risk factors were taken from the previous research conducted on megaprojects in South Africa, and internationally. These risks were then presented in a questionnaire as shown in Appendix A.

- By reviewing the relevant literature, the risks were classified into six categories. From these categories, the respondents were required to state the impact of each risk category on the successful delivery of megaprojects concerning time, cost, and quality. The respondents were required to state 'strongly agree', 'agree', 'neutral', 'disagree', or 'strongly disagree'.
- After stating their opinion about the impact of the risk category on time, cost, and quality, the respondents were required to rate the impact of each of the 22 risk factors on time, cost, and quality. The rating used a five-point Likert scale, as shown in Table 4-2.
- For risk factors that were rated 3, 4, and 5, the respondents were required to provide mitigations for the risk that they rated. No mitigations were required for the risk factors that were rated 1 and 2.
- Lastly, after rating the impact of risks on time, cost, and quality, the respondents were required to select the tools they used to identify risks in their projects.

Table 4-1: Megaproject risk factors

No.	Risk Category	Risk Factors	References
1.	Execution	Unforeseen ground conditions	(Chattapadhyay *et al*., 2021); (Tshidavhu & Khatleli, 2020)
2.		Inaccurate quantity take-off	(Baloyi & Bekker, 2011); (Chattapadhyay *et al*., 2021)
3.		Unavailability of labour, materials, and equipment	(Chattapadhyay *et al*., 2021)
4.		Shortage of skilled labour	(Tshidavhu & Khatleli, 2020); (Baloyi & Bekker, 2011)
5.		Client's late contract award	(Tshidavhu & Khatleli, 2020); Baloyi & Bekker, 2011)
6.		Supply of faulty materials	(Renault *et al*., 2016)
7.		Client's slow decision-making	(Tshidavhu & Khatleli, 2020); (Oyegoke & Al Kiyumi, 2017)
8.		Late issue of instructions	(Tshidavhu & Khatleli, 2020); (Baloyi & Bekker, 2011)
9.		Poor planning and scheduling	(Tshidavhu & Khatleli, 2020)
10.		Inappropriate equipment and material quality	(Chattapadhyay *et al*., 2021)
11.		Delayed supply of material and equipment	(Chattapadhyay *et al*., 2021)
12.	Construction	Deviations between specification and implementation	(Chattapadhyay *et al*., 2021)
13.	Technical and Design	Incomplete drawings	(Tshidavhu & Khatleli, 2020); (Baloyi & Bekker, 2011)
14.		Delay in obtaining preliminary drawings	(Chattapadhyay *et al*., 2021)

15.		Design errors	(Chattapadhyay *et al*., 2021)
16.		Project complexity	(Baloyi & Bekker, 2011)
17.	Economic	Financial condition of the main contractor	(Oyegoke & Al Kiyumi, 2017)
18.		Increase in material cost	(Baloyi & Bekker, 2011); (Rostami & Oduoza, 2017)
19.		Incorrect cost estimate	(Chattapadhyay *et al*., 2021)
20.	Environmental	Adverse weather condition	(Chattapadhyay *et al*., 2021)
21.	Social	Labour strikes	(Tshidavhu & Khatleli, 2020); (Baloyi & Bekker, 2011)
22.	Political	Lack of political support	(Chattapadhyay *et al*., 2021)

4.3.4 Questionnaire design

A questionnaire was the instrument that was used to collect primary data for this research. The questionnaire was designed based on the information obtained from the literature review. The process of designing the questionnaire began in October 2021 and ended in December 2021. The questionnaire was sent to construction clients, consultants, and contractors between January 2022 and May 2022. The methods used to administer the questionnaire were email and site visits. Follow-up emails were sent to the participants reminding them to complete the questionnaire. To increase the response rate, a drop-and-collect method was used.

A questionnaire was chosen because it allowed the respondents to quantify the degree of the impact of risk on the project management constraints of time, cost, and quality. This information was then used in identifying the critical risk factors. The advantage of using a questionnaire is that it is convenient and inexpensive (Kumar, 2011). On the other hand, the disadvantage of questionnaires is their low response rate (Kumar, 2011). In other words, not all the respondents will return them.

The layout of the questionnaire design is presented below.

Section 1. This section seeks to obtain the sociodemographic information of the respondents. The information includes anger, age range, years of work experience, position in the company, and the involvement of the organization in megaprojects.

Section 2. This section is aimed at obtaining the respondents' perception of the risk categories affecting the successful delivery of megaprojects concerning time, cost, and quality.

Section 3. This section is aimed at obtaining the respondents' perception of the impact of risk on time, cost, and quality in megaprojects. A five-point Likert scale was used to rate the impact of risk on the objectives of time, cost, and quality. This section is comprised of 22 risk factors gathered from the literature study.

Section 4. This section comprises ten risk identification tools obtained from the literature study. This section aims to determine which tools the respondents used to identify risks in their projects.

4.3.5 Sampling

Sampling is the process of collecting information about an entire population by investigating a small portion of it (Creswell, 2014). Saunders *et al*. (2009) state that the population refers to the full set of cases from which a sample is taken. A sample is taken from its population (Zikmund *et al*., 2009; Naoum, 1998). It is not practical for the researcher to collect data from the entire population, hence a sample is necessary for a research project (Saunders *et al*., 2009). Sampling saves time, costs, and human resources (Kumar, 2011).

Various sampling techniques can be used for all types of research. Saunders *et al*., (2009) and Kumar (2011), divide sampling techniques into probability or representative sampling, and random and non-probability or judgmental sampling. Kumar (2011) highlights five commonly used non-random sampling methods which are:

- Quota sampling.
- Accidental sampling.
- Judgmental sampling or purposive sampling.
- Expert sampling.
- Snowball sampling.

4.3.5.1 Selected sampling method and target population

This research study used a non-probability or judgmental sampling technique, with a purposive sampling design. This is because the judgemental sampling method allows the researchers to use their own experience and knowledge to select a subgroup of experienced individuals within a population as a representative sample (Miller & Salkind, 2011). Therefore, the researcher used his judgment to purposely select companies that are directly involved in the development of construction megaprojects in South Africa. Purposive sampling is often used when working with very small samples (Saunders *et al*., 2009), as was the case with this research study.

The sample population consisted of large construction clients, consultants, and contractors in the engineering and building environment. Ten large companies were identified as the possible sample for this study, based on their involvement and experience in the development of megaprojects. However, seven companies participated in the research, and these constituted the sample for this study. The sample consisted of three large civil engineering consulting companies and two contracting companies, a large State-Owned Entity (SOE) within the Ministry of Transport, and the City of Cape Town metropolitan municipality. The consulting engineering companies were selected from the Consulting Engineers South Africa (CESA) database with Broad-Based Black Economic Empowerment (BBBEE) levels one and two. These consulting companies were also selected based on their involvement in the design and construction supervision of megaprojects.

Similarly, the large civil engineering contracting companies were selected from the database of the Construction Industry Development Board (CIDB) with a grading of eight and nine. In addition, the selected contractors were also selected based on their involvement and experience in the execution of various megaprojects in South Africa. The large SOE was selected because it is responsible for the commissioning of many of the megaprojects in South Africa, and acts as a client for megaprojects. The individuals from these companies who participated in this research study consisted of professional experts such as project managers, contract managers, construction managers, and quantity surveyors. Based on the respondents' professional backgrounds and the position they hold in their companies; the researcher concluded that the respondents had adequate knowledge regarding construction activities. Therefore, the identified respondents were considered suitable to aid in identifying megaprojects' risks and provide possible solutions.

4.3.6 Data analysis

The Mean Item Score (MIS) was the method used to analyse the data that was collected. The MIS was calculated based on the impact of risk on time, cost, and quality. A five-point Likert scale was used to rate the impact of each risk factor on time, cost, and quality constraints as shown in Table 4-2.

Table 4-2: Rating scale of impact of risk factors

Impact	Rating
extremely low impact	1
low impact	2
moderate impact	3
high impact	4
extremely high impact	5

Source: Adapted from Andrić *et al*. (2019)

A total of 22 risk factors obtained from the literature were presented in the questionnaire. The respondents were required to rate the impact of each risk factor on the objectives of time, cost, and quality, using a scale of 1-5 as indicated above. These ratings were used to calculate the MIS of each risk factor, which allowed for the ranking of the risks. The ranking of the risks enabled the researcher to identify the significant risk factors affecting the megaprojects concerning time, cost, and quality. Renault *et al.* (2016), used the Mean Item Score (MIS) to rank the critical risks in construction projects from the perspective of contractors, while Tshidavhu and Khatleli (2020) used the MIS to rank the causes of cost and time overruns in energy megaprojects in South Africa.

The Mean Item Score (MIS) is calculated as follows:

$$MIS = \frac{1n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5}{\sum N}$$

Where:

n_1= number of respondents for extremely low impact

n_2= number of respondents for low impact

n_3= number of respondents for moderate impact

n_4= number of respondents for high impact

n_5= number of respondents for extremely high impact

N= total number of respondents

The critical categories of risk affecting the successful delivery of megaprojects were ranked, using a Likert scale of 1 to 5, where 1-‘strongly disagree’, 2-‘disagree’, 3-‘neutral’, 4-‘agree’ and 5-

'strongly agree'. The same formula was used as shown above to calculate the MIS of the risk categories.

Where;
n_1= number of respondents who strongly disagree
n_2= number of respondents who disagree
n_3= number of neutral respondents
n_4= number of respondents who agree
n_5= number of respondents who strongly agree
N= total number of respondents

4.4 Chapter summary

In this chapter, the type of research applicable to this study was first presented. The nature of this research study was descriptive, correlational, and explanatory. After defining the nature of this research study, the research methodology was presented. The methodology focused on the research method, sampling, targeted population, data collection method, and data analysis. A quantitative research method was used with a survey questionnaire to collect the primary data. The primary data collected was numerical and descriptive data. Numerical data allowed the respondents to rate the impact of risks on time, cost, and quality using a five-point Likert scale. Descriptive data were used to collect the mitigations of the critical risks from the perspective of the client, consultant, and contractor.

A purposive sampling method was used to select the participants for this study. The participants for this research were professionals working for clients, consultants, and contractors involved in megaproject development. The organisations were selected based on their direct involvement in the development of megaprojects. The survey participants working for these organisations comprised a regional manager, project managers, a contract manager, construction managers, a quantity surveyor, civil technologists, and a site engineer. Lastly, the Mean Item Score (MIS) was the method used to analyse the data that was collected on the risks and their impact on time, cost, and quality. The following chapter will present and analyse the results of the data that were collected in the questionnaire.

Chapter 5 Results

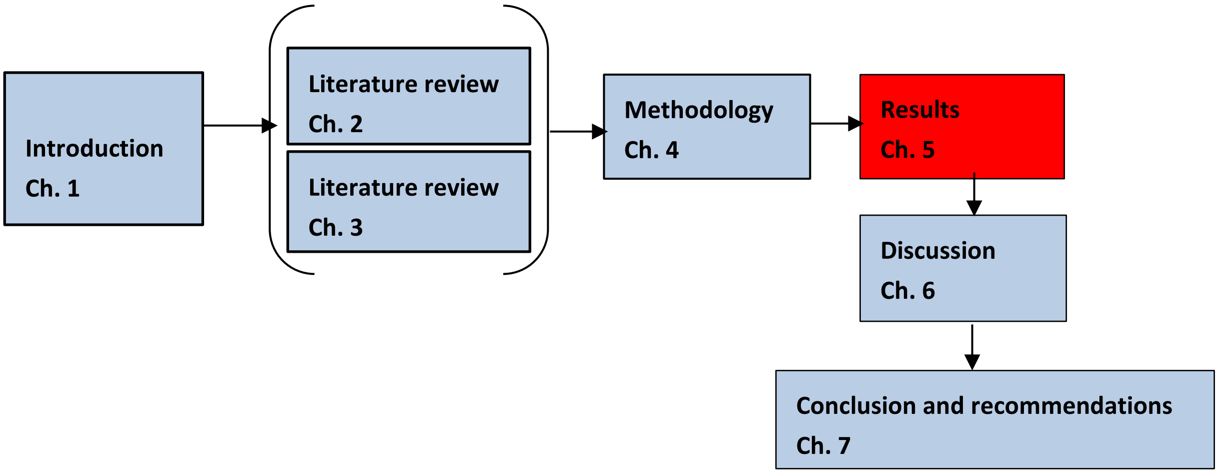

Figure 5-1: Document mapping chapter five

5.1 Introduction

The previous chapter presented the research methodology for the study. The objective of this chapter is to analyse the results of the data that was collected through a survey questionnaire. The data collected were in line with the objectives of the study. Therefore, the results are based on the objectives of the study as follows:

- To identify the risks to which construction megaprojects are exposed and categorize them into different groups.
- To examine the impact of risks on time, cost, and quality in construction megaprojects.
- To assess the tools commonly used for identifying risks in construction projects.

The analyses of the data relative to the first and second objectives of the study were done using the Mean Item Score (MIS). The MIS was used to rank the risk factors affecting the delivery of megaprojects concerning time, cost, and quality. The MIS values were used to identify the critical risk factors in megaprojects. This chapter also presents the analysis of the data relative to the risk identification tools used in construction projects. This data relates to the third objective of this study.

This chapter consists of four sections. The first section of this chapter consists of the distribution and response rate from the questionnaire. This section also presents a summary of the respondents' sociodemographic information. The second section of this chapter ranks the megaproject risk categories based on their Mean Item Score (MIS) values. The third section of this chapter ranks the risk factors based on their MIS values and their impact on time, cost, and quality. Lastly, the fourth section presents and analyses the results concerning the tools that construction professionals use to identify risk in projects.

5.2 Questionnaire distribution and response rate

Sixty questionnaires were administered to clients, consultants, and contractors involved in the development of megaprojects in South Africa. Email and site visitations were the methods used to administer the questionnaires to the participants in this research study. Out of the 60 questionnaires distributed, 22 responses were received. Out of the 22 questionnaires returned, 8 were from clients, 9 were from consultants, and 5 were from contractors. From these results, most of the respondents came from professionals working for consultants and clients. Table 5-1 shows the number of questionnaires distributed and the response rate.

Table 5-1: Questionnaire distribution and response rate

Organization	Number distributed	Number of respondents	% of responses
Client	20	8	36.3%
Consultant	21	9	40.9%
Contractor	19	5	22.7%
Total	60	22	100%

The response rate of the questionnaire was 36 %. According to Moser and Kalton (1993), if the response rate of the survey was lower than 20-30%, the results could be considered biased and of little significance. Moyo and Crafford (2010), state that the response rate ranges between 7% to 40% for contemporary built environment survey responses. Although the response rate (36%)

for this study was on the lower end of the range according to Moyo and Crafford (2010), the quality of the respondents, their job position, and the feedback they provided were taken into account. Therefore, this substantiates the response rate for this study.

5.2.1 Summary of respondents' characteristics

Table 5-2 demonstrates the sociodemographic characteristics of the respondents. The characteristics of the respondents consisted of gender, age group, job position, type of organization, and the sector within which the company operates.

Table 5-2: Characteristics of respondents

Descriptor	Participants	Number of participants	Percentages
Gender	Male Female	17 5	77.3% 22.7%
Age	21-30 years 31-40 years 41-50 years >50 years	5 7 9 1	22.7% 31.8% 40.9% 4.5%
Job position	Project Manager Contracts Manager Construction Manager Quantity Surveyor Civil Technologist Site Engineer Programme Manager Regional Manager Manager of the Corporate Project Management Unit	12 1 2 1 2 1 1 1 1	54.5% 4.5% 9.1% 4.5% 9.1% 4.5% 4.5% 4.5% 4.5%
Type of organization	Client Consultant Contractor	8 9 5	36.4% 40.9% 22.7%
Sector	Private Public	14 8	63.6% 36.4%

The results relating to gender reveal that the majority of the respondents were males with a 77.3 % response rate, while 22.7 % of the respondents were females. The results concerning the age group, 5 (22.7%) of the respondents were in the age group that ranged between 21-30 years, while 7 (31.8%) were in the age group that ranged between 31-40 years. The highest percentage (40.9%) came from 9 respondents with the age group that ranged between 41-50 years, and 1 (4.5%) were in the age group of 50 years and older.

The results relating to the current job position reveal that the majority of respondents were project managers 12 (54.5%). Since project managers are responsible for the management of megaprojects, they should be able to provide credible information related to risks in megaprojects. Moreover, the results reveal that 1 (4.5%) was a contract manager, 2 (9.1%) were construction managers, 1 (4.5%) was a quantity surveyor, 2 (9.1%) were civil technologists,1 (4.5%) was a site engineer,1 (4.5%) was a programme manager,1 (4.5%) was a regional manager, and 1 (4.5%) was a manager of the corporate project management unit. This information shows the diversity of professionals involved in the development of megaprojects. These professionals are involved in various phases of construction projects. As a result, they should have adequate knowledge about the risks that affect megaproject delivery.

The results relating to the type of organisation of the respondents reveal that 8 (36.4%) of the respondents work for organisations that act as clients for megaprojects. And 9 (40.9%) of the respondents work for consulting companies, while 5 (22.7%) work for contracting companies. The three parties are all involved in the delivery of a megaproject. Furthermore, the results reveal that 63.6 % of respondents work for companies in the private sector, while 36.4% of the respondents work for companies in the public sector. From the review of the literature, it was discovered that the development of megaprojects requires the involvement of government (public) and private sector entities.

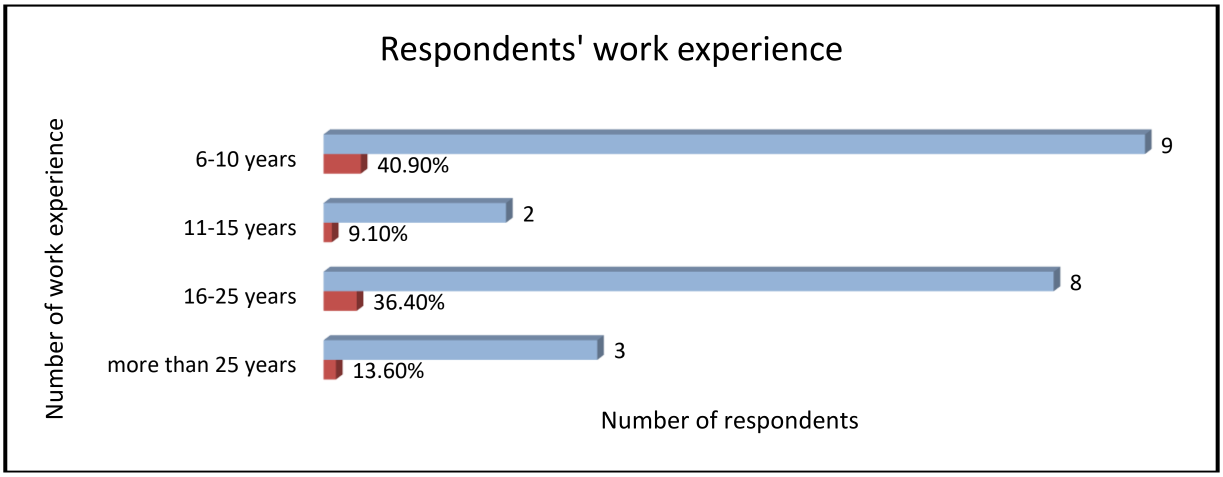

Figure 5-2: Work experience of respondents

Figure 5-2 shows the results of the work experience of the respondents. The majority of respondents 9 (40.9%) and 8 (36.4%) have worked in the construction sector for 6-10 years and 16 to 25 years respectively. This level of work experience is considered adequate to enable the respondents to provide reliable responses. The years of experience of respondents in rank order are 11-15 years (9.1%), and more than 25 years (13.6%).

5.3 Ranking of risk categories affecting delivery of megaprojects

Table 5-3 shows the MIS values of the six risk categories. The MIS values were used to rank the risk categories affecting the successful delivery of megaprojects concerning time, cost, and quality. The higher the MIS value, the more critical the risk category in megaprojects.

Table 5-3: Ranking of risk categories

Risk categories	Respondents' perception of risk category impact in megaprojects					Mean item Score	
Item	Strongly agree	agree	neutral	disagree	Strongly disagree	MIS	Rank
Execution risk	12	10	0	0	0	4.54	1
Technical risk	10	10	1	1	0	4.32	2
Economic risk	9	7	6	0	0	4.14	3
Environmental risk	4	10	6	2	0	3.73	6
Social risk	8	8	4	2	0	4.00	4
Political risk	8	6	5	3	0	3.86	5

The results obtained from the responses show execution risk (MIS=4.54, R=1), technical risk (MIS=4.32, R=2), economic risk (MIS=4.14, R=3), environmental risk (MIS=3.73, R=6), social risk (MIS=4.00, R=4), and political risk (MIS=3.86, R=5). The higher values of MIS for execution risk, technical risk, and economic risk indicate that they are significant risks that affect the delivery of megaprojects concerning time, cost, and quality. On the other hand, social risk, political risk, and environmental risk have a medium impact on the successful delivery of megaprojects.

5.3.1 Risk factors and their impact on time, cost, and quality

Table 5-4 shows the MIS values of the 22 megaproject risk factors that were gathered from the literature review. The MIS values were calculated based on the impact of each risk factor on the project objectives of time, cost, and quality.

Table 5-4: Risk factors and their MIS values for time, cost, and quality

No.	Risk factors	Mean Item Score (MIS) values per project constraints		
		Time (T)	Cost (C)	Quality (Q)
1.	Unforeseen ground conditions	4.10	4.30	2.45
2.	Inaccurate quantity take-off	2.60	3.80	1.55
3.	Unavailability of labour, materials, and equipment	4.30	4.05	3.65
4.	Shortage of skilled labour	3.85	3.20	4.00
5.	Client's late contract award	3.70	2.85	2.10
6.	Supply of faulty materials	3.65	3.20	3.75
7.	Client’s slow decision- making	4.35	3.95	2.45
8.	Late issue of instructions	4.15	3.85	2.30
9.	Poor planning and scheduling	3.85	4.15	3.90
10.	Inappropriate equipment and material quality	3.75	3.95	4.30
11.	Delayed supply of material and equipment	4.50	3.45	2.45
12.	Deviations between specification and implementation	3.55	3.70	3.85
13.	Incomplete drawings	4.35	4.15	3.75
14.	Delay in obtaining preliminary drawings	4.30	3.80	3.10
15.	Design errors	4.35	4.30	3.75
16.	Project complexity	3.80	3.75	3.30
17.	Financial condition of the main contractor	4.45	4.35	3.65

18.	Increase in material cost	2.60	3.90	2.40
19.	Incorrect cost estimate	3.20	4.35	3.10
20.	Adverse weather condition	3.70	3.40	2.75
21.	Labour strikes	4.15	3.65	2.10
22.	Lack of political support	3.80	2.85	2.40

Out of the 22 risk factors presented in the table above, the top ten ranked risk factors affecting the objectives of time, cost, and quality in megaprojects will be considered in the following sections. The choice of selecting the top ten ranked risk factors was adopted from Zou *et al*. (2007), who investigated the key risks in construction projects.

5.3.2 Ranking of risk factors impacting time performance in megaprojects

Table 5-5 shows the results obtained from the responses to megaproject risk factors and their impact on time constraints. A total of ten risk factors are listed and ranked based on their MIS values. The risk factors with the highest MIS value are considered significant risks affecting the time constraints in megaprojects. For this study, only the top ten ranked risk factors affecting time constraints were considered significant.

Table 5-5: Risk factors affecting time constraints

No.	Risk factors	MIS value	Rank
1.	Delayed supply of material and equipment	4.50	1
2.	Financial condition of the main contractor	4.45	2
3.	Client's slow decision-making	4.35	3
4.	Incomplete drawings	4.35	3
5.	Design errors	4.35	3
6.	Unavailability of labour, materials, and equipment	4.30	4

7.	Delay in obtaining preliminary drawings	4.30	4
8.	Labour strikes	4.15	5
9.	Late issue of instructions	4.15	5
10.	Unforeseen ground conditions	4.10	6

The risk factors affecting the time constraint of megaprojects, in descending order, are delayed supply of material and equipment, the financial condition of the main contractor, client's slow decision-making, incomplete drawings, design errors, unavailability of labour, materials and equipment, delay in obtaining preliminary drawings, labour strikes, late issue of instructions, and unforeseen ground conditions.

5.3.3 Ranking of risk factors impacting cost performance in megaprojects

Table 5-6 shows the results obtained from the responses to megaproject risk factors and their impact on cost constraints. A total of ten risk factors are listed and ranked based on their MIS values. The risk factors with the highest MIS value are considered the significant risk affecting the cost constraints in megaprojects. For this study, only the top ten ranked risk factors affecting cost constraints were considered significant.

Table 5-6: Risk factors affecting cost constraints

No.	Risk factors	MIS value	Rank
1.	Financial condition of the main contractor	4.35	1
2.	Incorrect cost estimate	4.35	1
3.	Design errors	4.30	2
4.	Unforeseen ground condition	4.30	2
5.	Incomplete drawings	4.15	3
6.	Poor planning and scheduling	4.15	3
7.	Unavailability of labour, materials, and equipment	4.05	4

8.	Client’s slow decision-making	3.95	5
9.	Inappropriate equipment and material quality	3.95	5
10.	Increase in material cost	3.90	6

The critical risk factors affecting the cost constraints of megaprojects, in descending order, are the financial condition of the main contractor, incorrect cost estimate, design errors, unforeseen ground conditions, incomplete drawings, poor planning and scheduling, unavailability of labour, materials and equipment, client’s slow decision-making, inappropriate equipment and material quality, and increase in material cost.

5.3.4 Ranking of risk factors impacting quality performance in megaprojects

Table 5-7 shows the results obtained from the responses to megaproject risk factors and their impact on quality constraints. A total of ten risk factors are listed and ranked based on their MIS values. The risk factors with the highest MIS value are considered the significant risks affecting the quality constraints in megaprojects. For this study, only the top ten ranked risk factors affecting the quality constraints were considered significant.

Table 5-7: Risk factors affecting quality constraints

No.	Risk factors	MIS value	Rank
1.	Inappropriate equipment and material quality	4.30	1
2.	Shortage of skilled labour	4.00	2
3.	Poor planning and scheduling	3.90	3
4.	Deviations between specification and implementation	3.85	4
5.	Incomplete drawings	3.75	5
6.	Supply of faulty materials	3.75	5
7.	Design errors	3.75	5

8.	Financial condition of the main contractor	3.65	6
9.	Unavailability of labour, materials, and equipment	3.65	6
10.	Project complexity	3.30	7

The risk factors affecting the quality of megaprojects, in descending order, are inappropriate equipment and material quality, shortage of skilled labour, poor planning and scheduling, deviations between specification and implementation, incomplete drawings, supply of faulty materials, design errors, the financial condition of the main contractor, unavailability of labour, materials and equipment, as well as project complexity.

5.3.5 Risk and its impact on project management constraints

After listing and ranking the top ten risk factors for all the project constraints, the next step is to identify the impact these risks have on the objectives of time, cost, and quality. All the risk factors listed in Table 5-5, Table 5-6, and Table 5-7 are presented in Table 5-8 below.

Table 5-8: Risk versus their impact on time, cost, and quality

No.	Risk factor	Impact of risk on time, cost, and quality		
		Time	Cost	Quality
1.	Delayed supply of material and equipment	✓		
2.	Financial condition of the main contractor	✓	✓	✓
3.	Client's slow decision-making	✓	✓	
4.	Incomplete drawings	✓	✓	✓
5.	Design errors	✓	✓	✓
6.	Unavailability of labour, materials, and equipment	✓	✓	✓
7.	Delay in obtaining preliminary drawings	✓		

8.	Labour strikes	✓		
9.	Late issue of instructions	✓		
10.	Shortage of skilled labour			✓
11.	Incorrect cost estimate		✓	
12.	Unforeseen ground condition	✓	✓	
13.	Poor planning and scheduling		✓	✓
14.	Inappropriate equipment and material quality		✓	✓
15.	Deviations between specification and implementation			✓
16.	Increase in material cost		✓	
17.	Supply of faulty materials			✓
18.	Project complexity			✓

Out of the 22 risks presented in the questionnaire,18 risks were considered as having a significant impact on time, cost, and quality. The results from the table above reveal that the financial condition of the main contractor, design errors, incomplete drawings, and unavailability of labour, materials, and equipment affect all the project management constraints. The financial condition of the main contractor and the unavailability of labour, materials, and equipment relates to the contractor. On the other hand, design errors and incomplete drawings relate to the consultant.

5.4 Risk identification tools

This section aims to analyse the results of the primary data related to risk identification techniques to find out the common tools used by construction professionals to identify risks in projects. A total of ten techniques selected from the literature review were analysed. The risk identification tools are used in all types of construction projects, not necessarily megaprojects. Figure 5-3 shows the proportion of the respondents and the various tools they use in their organization.

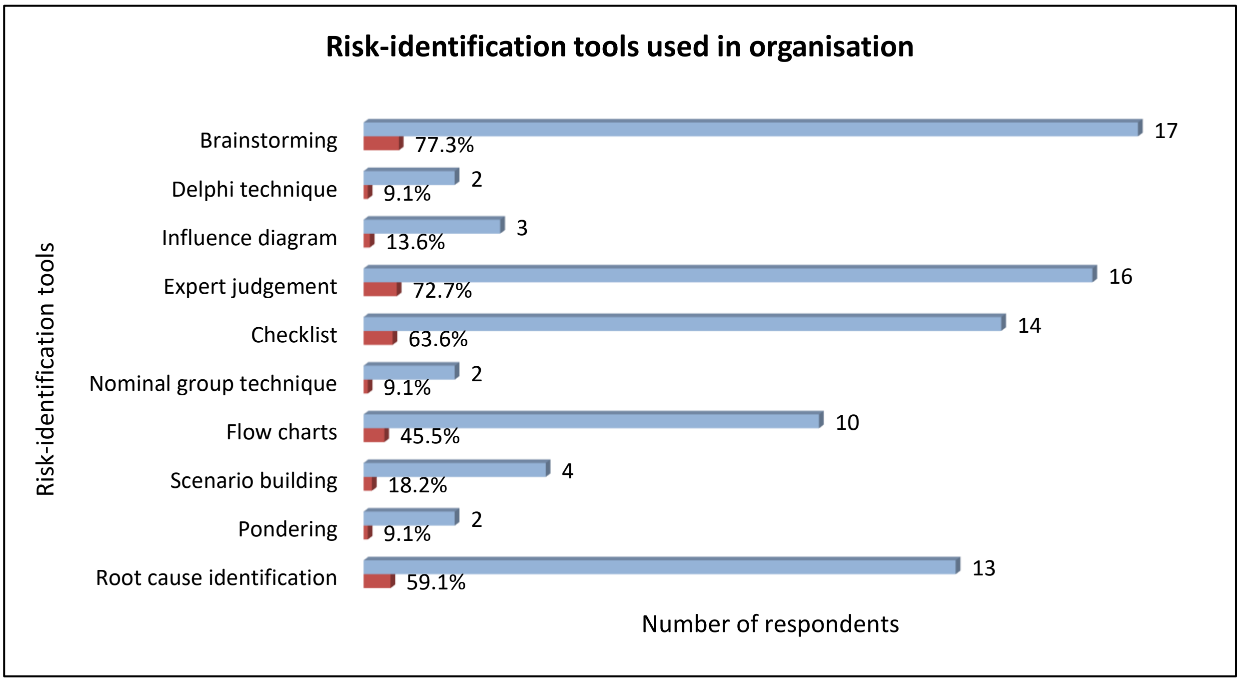

Figure 5-3: Risk identification tool responses

The above results reveal that the majority of respondents 17 (77.3%) use brainstorming as a tool to identify risks in their projects. Furthermore, 2 (9.1%) of the respondents indicated that they use the Delphi, nominal group, and pondering techniques, respectively, followed by 3 (13.6%) who use influence diagrams. This is followed by 16 (72.7%) who use expert judgement, followed by 14 (63.6%) who use the checklist. Moreover, 10 (45.5%), 4 (18.2%), and 13 (59.1%) indicated that they use flow charts, scenario building, and root cause identification, respectively. From these results, it is evident that brainstorming, expert judgement, checklist, root-cause identification, and flow charts are the most popular risk identification tools used in practice. Conversely, the Delphi technique, nominal group technique, and pondering technique do not seem to be commonly used tools.

5.5 Chapter summary

This chapter presented the results of the data that was collected using a questionnaire that was completed by the construction professionals working for clients, consultants, and contractors involved in megaprojects. The objective of this chapter was to determine the critical risks affecting megaprojects concerning time, cost, and quality. The outcomes revealed that the risk categories affecting megaprojects concerning time, cost, and quality are execution risks, technical risks, and economic risks.

The results revealed that the critical risk factors affecting the time constraints in megaprojects are delayed supply of material and equipment, the financial condition of the main contractor, client's slow decision-making, incomplete drawings, design errors, unavailability of labour, materials and equipment, delay in obtaining preliminary drawings, labour strikes, late issue of instructions, and unforeseen ground conditions. On the other hand, the critical risk factors affecting the cost constraints are the financial condition of the main contractor, incorrect cost estimate, design errors, unforeseen ground conditions, incomplete drawings, poor planning and scheduling, unavailability of labour, materials and equipment, client's slow decision-making, inappropriate equipment and material quality, and increase in material cost.

Lastly, the risks affecting the quality constraint are inappropriate equipment and material quality, shortage of skilled labour, poor planning and scheduling, deviations between specification and implementation, incomplete drawings, supply of faulty materials, design errors, the financial condition of the main contractor, unavailability of labour, materials and equipment, as well as project complexity.

The results also reveal that the financial condition of the main contractor, design errors, incomplete drawings, and unavailability of labour, materials, and equipment have an impact on all the project management constraints. The financial condition of the main contractor and the unavailability of labour, materials, and equipment relates to the contractor. On the other hand, design errors and incomplete drawings relate to the consultant. Lastly, concerning risk identification tools used in construction projects, the results revealed that brainstorming, expert judgement, checklist, root-cause identification, and flow charts are common risk- identification tools used in construction projects. The following chapter will discuss the findings of the results to address the objectives of the study and attempt to answer the research question.

Chapter 6 Discussion

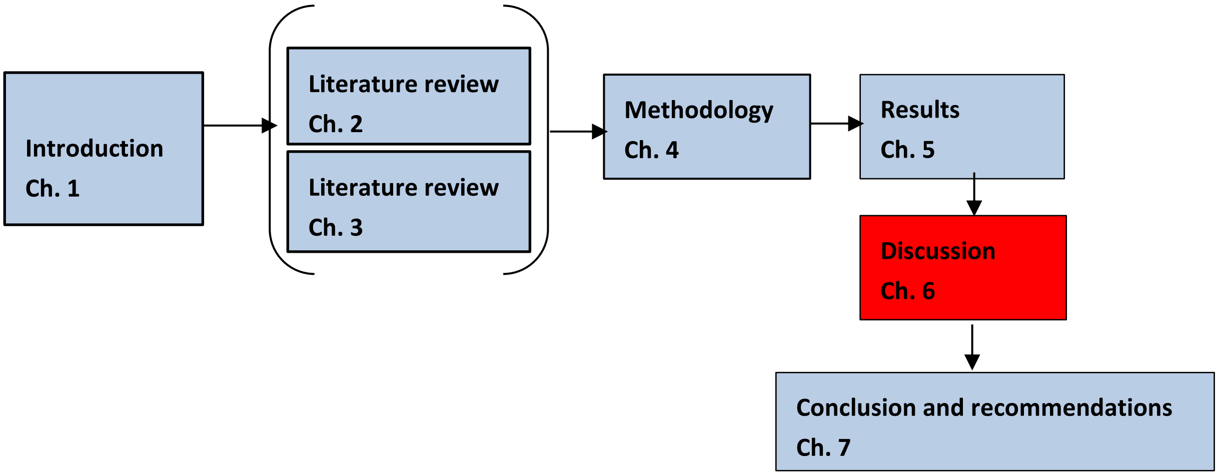

Figure 6-1: Document mapping chapter six

6.1 Introduction

The previous chapter analysed the results of the data that was obtained from construction professionals working for clients, consultants, and contractors. These results were based on the objectives of the study. This chapter discusses the findings relative to the problem statement, research question, as well as objectives and outcomes. At the beginning of this study, the research problem stated in section 1.2 was outlined. The research problem led to the research question as restated in section 6.3, followed by the research objectives and outcomes which were achieved through questionnaires. The findings presented in this chapter relate to risks in megaprojects, risk mitigations, the impact of risks on time, cost, and quality, and risk identification tools.

6.2 Problem statement

The problem statement is restated as follows:

South African construction megaprojects are failing to meet their objectives concerning time, cost, and quality due to various risks associated with these projects. Risks are problematic because they lead to time and schedule overruns combined with inferior quality. If risks are not managed effectively, megaprojects will continue to fail concerning time, cost, and quality. Therefore, mitigations are needed to minimize these risks that affect the successful delivery of megaprojects.

6.3 Research question

The research question is restated as follows:

What are the risks that are resulting in the megaprojects failing to achieve their project objectives concerning time, cost, and quality, and are there mitigations to minimize these risks?

6.4 Research objectives and outcomes

This research study aimed to investigate the risks that are affecting the successful delivery of megaprojects concerning time, cost, and quality. This was achieved through the following objectives:

- To identify the risks to which construction megaprojects are exposed and categorize them into different groups.
- To examine the impact of risks on time, cost, and quality in construction megaprojects.
- To assess the tools commonly used for identifying risks in construction projects.

The primary outcomes emanating from this research study are as follows:

- Outcome 1: To identify the risks that affect the successful delivery of megaprojects concerning time, cost, and quality.
- Outcome 2: To identify the risks that affect all the project constraints of time, cost, and quality.
- Outcome 3: To identify the tools commonly used for identifying risks in construction projects.

6.5 Risk categorization

This section discusses risk categories that are affecting the successful delivery of megaprojects concerning time, cost, and quality. Megaprojects, due to their complex nature, are associated with various types of risk, namely, social, technical, economic, environmental, and political (STEEP). These risks are a challenge to the management of projects (Boateng *et al*., 2015). Categorizing risks into groups is the most appropriate method to identify and respond to risks (PMBOK, 2017).

The risks that were gathered from the literature study and presented in the survey questionnaire that was sent to construction professionals are execution risk, technical risk, economical risk, environmental risk, social risk, and political risk. The results presented in section 5.3 revealed that execution risk (MIS= 4.56, R=1), technical risk (MIS= 4.25, R=2), and economical risk (MIS= 4.19, R=3) were considered critical risks in megaprojects. This is because of their high MIS values when compared to environmental risk, social risk, and political risks. However, environmental risk (MIS= 3.56, R=4), social risk (MIS= 3.94, R=5) and political risk (MIS= 3.88, R=6) were considered as medium risks. All these risks can affect the successful delivery of a megaproject. Therefore, based on the MIS values, the critical risk that affects the delivery of megaprojects concerning time, cost, and quality are execution, technical and economic risks. These three significant risk categories are discussed below.

6.5.1 Execution risk

Execution risk is the significant risk category affecting the successful delivery of megaprojects concerning time, cost, and quality. These findings are supported by Irimia-Dieguez *et al*. (2014), who noted that execution risks are usually the most significant in the whole life of the megaproject. The Execution risk category includes the risks that often affect the execution phase of a project. A few examples of these risks include inappropriate equipment and material quality, poor equipment performance, unforeseen site conditions, incorrect take-off calculation, delayed supply of material and equipment, and unavailability of materials, equipment and labour (Chattapadhyay *et al*., 2021).

6.5.2 Technical risk

Technical risk was the second-ranked significant risk category that affects the successful delivery of megaprojects concerning time, cost, and quality. These findings agree with Makombo (2011), who concluded that technical risks are faced on projects by many companies. Examples of technical risks include design problems on foundations, design changes at the very last stage, and poor communication (Makombo, 2011). Megaprojects, due to their complex nature, involve the use of sophisticated technology and construction techniques. The complexity of megaprojects poses a huge challenge to project managers.

6.5.3 Economic risk

Economic risk was the third-ranked significant risk category that affects the successful delivery of a megaproject. Banerjee (2020), stated that environmental risk and economical risk are the major risks that impact megaprojects. Economic risk is concerned with monetary investment in the megaproject (Banerjee, 2020).

A few examples of risk factors that fall under this category include inflation, changes in market conditions, changes in taxes, Incorrect cost estimate, and financial difficulties/failure of subcontractors (Chattapadhyay *et al*., 2021). Boateng *et al*. (2015) state that factors such as inflation, cash flow issues, and material and energy price hikes can cause time and cost overruns in megaprojects. Economic risk is influenced by external factors.

6.6 Risk factors in megaprojects

This section presents the discussion on the risk factors affecting the megaprojects delivery concerning time, cost, and quality.

6.6.1 Risks affecting time constraints

6.6.1.1 Delayed supply of material and equipment

Delayed supply of material and equipment was considered the critical risk factor that delays the completion of a megaproject. The findings are supported by Enshassi *et al*. (2009) who stated that material ordered and delivered late to the site affects the time performance of projects. For instance, if steel is not delivered to the site on time, the delay can stop the entire project (Garemo *et al*., 2015). This is generally due to poor planning by the contractor, such as not appointing a supplier in time, or not checking availability before ordering the material. Construction materials should be delivered to the site on time, in adequate quantities, and of appropriate quality, and should be used for the purpose for which they were ordered (Aiyetan & Das, 2022).

6.6.1.2 Financial condition of the main contractor

The financial condition of the main contractor (MIS=4.45) was ranked the second most significant risk factor affecting the time constraints of megaprojects. For this study, the financial condition of the main contractor refers to the financial failure of the main contractor. These findings agree with Kartam and Kartam (2001) and Oyegoke and Al Kiyumi (2017) who reported that the financial failure of the contractor was the most significant risk causing a delay in mega construction projects. In South African construction projects, not necessarily megaprojects, Renault *et al*. (2016a) found that the financial failure of the contractor was the second most significant risk in projects. If a contractor fails financially and does not have the cash flow to complete a project, the successful delivery will be delayed. This will also be more costly for the client.

6.6.1.3 Client's slow decision-making

Another significant risk factor affecting the time constraints of megaprojects was the client's slow decision-making. These findings are supported by Tshidavhu and Khatleli (2020). In their study, they found that the client's slow decision-making was the number one ranked risk factor that caused schedule overrun in the Kusile and Medupi energy megaprojects in South Africa. Similarly, Baloyi and Bekker (2011) noted that the client's slow decision-making was the second most significant risk that affected the time delays in the construction of the 2010 FIFA World Cup stadia in South Africa. Internationally, these findings are supported by Oyegoke and Al Kiyumi (2017). They found that the delay in decision-making by the client was the third-ranked cause of megaproject delays in the Sultanate of Oman.

For the construction work to progress according to the planning schedule, clients must make decisions on time. Most clients that are responsible for the commissioning of megaprojects in South Africa are from the public sector. This influences the decision-making process due to government bureaucracy which results in project delays. Slow decision-making has a major impact on the time related to the project which can result in standing time costs.

6.6.1.4 Incomplete drawings

The findings revealed that Incomplete drawings (MIS=4.35) were the third most significant risk factor causing time delays in megaprojects. These findings are supported by Baloyi and Bekker (2011) who ranked incomplete drawings as the number one cause of time delays in the execution of the 2010 FIFA World Cup stadia. In their study, Tshidavhu and Khatleli (2020), found that incomplete drawings were the eighth significant cause of schedule overruns in energy megaprojects in South Africa.

6.6.1.5 Design errors

Design errors are another critical risk factor that delays the completion of a megaproject. These findings agree with Kartam and Kartam (2001) who reported that defective design is one of the most significant risks that delay a project. The design team must spend more time redoing the work and correcting the errors during the review of designs. This will have an impact on the completion of a project.

6.6.1.6 Unavailability of labour, materials, and equipment

This risk factor was ranked the fourth significant factor affecting the time constraint of megaprojects. If the contractor does not have the required resources to effectively execute the project, the successful delivery of a megaproject may be hindered. Megaprojects require resources such as labour, materials and equipment. Without these resources, the execution of megaprojects may be hindered.

6.6.1.7 Delay in obtaining preliminary drawings

The findings revealed that delay in obtaining preliminary drawings (MIS= 4.30) was the fourth significant risk factor causing time delays in megaprojects. This type of risk factor falls under the technical risk category and is related to the consultant. When drawings are issued late to the contractor, work may be delayed, and consequently, the completion of the project may be hindered. This risk may be mitigated by providing the drawing on time.

6.6.1.8 Labour strikes

Labour strikes were the fifth ranking factor affecting the time constraints of megaprojects. Labour strikes can delay the completion of megaprojects. These findings are supported by Tshidavhu and Khatleli (2020), who found that labour strikes were the seventh-ranking cause of schedule delays during the construction of the Kusile and Medupi energy sector megaproject. In 2012, there was a five-month labour strike during the construction of Medupi (PWC, 2014). Moreover, Baloyi and Bekker (2011) found that labour strikes were the sixth ranking cause of time overruns during the construction of the 2010 FIFA World Cup stadia.

6.6.1.9 Late issue of instructions

Late issue of instructions is another critical risk factor that affects the time constraints of megaprojects. These findings are supported by Baloyi and Bekker (2011). In their study, they found the late issue of instructions to be the second-ranked significant factor that caused time delays in the construction of the 2010 FIFA World Cup stadia. These findings also agree with the findings of Tshidavhu and Khatleli (2020), who noted that the late issue of instructions was the significant factor that caused time delays in the Kusile and Medupi energy megaproject construction. Whenever the client, consultant, or contractor issues instructions late, there will be a delay in the progress of the work.

6.6.1.10 Unforeseen ground condition

The unforeseen ground condition was ranked the sixth significant risk factor affecting the time constraints of megaprojects. This type of risk may delay the completion of megaprojects. This is often the case when no adequate geotechnical investigation has been conducted on-site. These findings agree with those of Lessing *et al*. (2017). If there is an unrecognized soil structure on site that was not considered during the pre-tender stage, it may lead to delays, should there be a need for its removal. This may affect the planned schedule of the work.

6.6.2 Mitigations for the identified risks

Table 6-1 below provides possible mitigations of the identified critical risk factors that have an impact on the time constraints of megaprojects. These mitigations were gathered from the construction professionals who participated in the survey questionnaire.

Table 6-1: Mitigations for risks affecting time constraints

Risk	Mitigations
Delayed supply of material and equipment	• Ensure sufficient planning and coordinating of materials. • Order and deliver material on time. The planner must indicate on the programme the delivery date and construction date. This must be coordinated and managed through a proper construction programme. • Compile resource plans with reliable suppliers. • Have an alternative material supplier company to supply material on site. • Order materials timeously. The contractor must have performance agreements with suppliers. Pay the suppliers as soon as possible, and if possible and if risks can be managed do so upfront. Implement and maintain a project Risk Register. Identify risks. Speak to material suppliers regularly to build relationships and use reputable suppliers. • Include the dates on which materials are required on site in the schedule. Manage the approved schedule actively. If the risk materialises, include it in the risk register and manage the risk through contractual correspondence in terms of notifications of delay and delay claims. • Initiate procurement ahead of time, allowing for a reasonable buffer for any unforeseen delays.
Financial condition of the main contractor	• Front-end loading of contracts to assist with the financial failure of the contractor.

	• Competent contractors must be used • Ensure the financial status of a company is identified during the tender stage; ensure the appropriate retention and performance guarantees are received up front, and control the cash flow accordingly. • Ensure proof of financial standing at the tender stage/ before the appointment. • Ensure that tender technical requirements and financial standing of the contractors invited to tender, meet the project requirements. • As soon as a contractor starts to fail in their performance apply contractual clauses to force them to perform. • Employ others to remedy non-performance by contractors in terms of the agreement in place. • Do not pay the contractor in advance in an attempt to "boost" their finances. Make arrangements to secure project payments to go to project suppliers and sub-contractors. • Monitor and control the contractor's performance and expenditure against the approved schedule and cash flow. Identify risks early, include them in the risk register and manage the risk actively through contractual mechanisms.
Client’s slow decision-making	• Having an informed Client and a Project Manager/Engineer/Employer's Agent that understands their roles and responsibilities within the decision-making process. • Good designs and clear communication with the client can mitigate this. • Advise client/employer early on regarding any issue as soon as it is known (where possible) to allow the client sufficient time to review the issue. • Subject the client to contractual obligations in terms of adherence to contractual periods.

	• Appoint a project manager to facilitate decision making, minimise delays and advise the client of the impact if a decision is not taken or delayed. • At the Viability and Feasibility stages of the project, the client is to be informed of the risks posed by the lack of decision-making. • The project programme to have clear milestone activities indicating when what decisions are to be taken by the client. • Ensure that the client has all the information required before the date on which decisions are to be taken. Do not propose items or options requiring client decisions if these items cannot be applied within the client's approved and confirmed budget. • Put a strong project leader in the client-facing role to identify early on if the client is slow in making decisions. If the risk materialises, include it in the risk register and manage the risk through contractual correspondence in terms of notifications of delay and delay claims. Manage the client relationship actively to understand how the consultants and contractors can support the client's decision-making process. • Provide support to the client with a third-party consultant.
Incomplete drawings	• Review drawings before approving them for construction. The contractor must only use reviewed and approved drawings. • Ensure drawings are well defined at the start of the contract and ensure a HAZOP is conducted. • The drawings must be checked by the project manager and the resident engineer. • Conduct design review using a third-party consultant and contractor.

Delay in obtaining preliminary drawings	• Data can be issued to prevent the contractor from claiming. More time is generally required to complete detailed drawings for mega projects. • Manage issuing of drawings through construction programme. • Include the date on which drawings must be received. Manage the approved schedule actively. If the risk materialises, include it in the risk register and manage the risk through contractual correspondence in terms of change delay notifications and claims. • The drawings' deadlines must be met, and there must be a time frame for drawings to be completed.
Design errors	• Review designs and only issue approved designs for construction. • Perform HAZOP at the start of the contract. • Conduct client design reviews, appoint experienced design engineers and apply penalties for substandard work. • Capacity for clients to review designs in detail.
Late issue of instructions	• Generally mitigated through better design and documentation. • The engineer or contract administrator must adhere to contractual procedures. • Ensure the programme is well administered to avoid delays and apply pressure on the decision-makers. • It is important that the issue of instruction be done quickly, and sent to the contractor during the site inspection time. • The project programme must be used to determine the effect of late instructions before the instructions are issued. • Consult with the contractor on the effect of issuing a late instruction before doing so.

	• Avoid issuing late instructions for tasks on the critical path of the project - in this regard, make sure that the critical path on the project is "true" with no "false" links and constraints.
Unavailability of labour, materials, and equipment	• Appoint a reputable contractor with a good track record. These risks should have been noted and accounted for in the Tender. The problem is when you appoint the cheapest Contractor that has not taken these risks into account. You may end up having to terminate the contract at the end of the day. Diligent tender evaluation based on price, BBE and functionality assessment is key. • Before entering a contract, the contractor is to ensure and review the tender to ascertain whether the contract can still be completed under the initial specification and obligation. • Design must cater for and accommodate available resources. • Ensure the Contractor has sufficient staff and provide a contingency plan upfront accordingly. Regarding materials, ensure alternative suppliers are available. • Plan for resources during the design phase. • Source alternative materials, contractors and equipment if these are in short supply. Find an additional budget that could be required to pay for alternative materials, contractors and equipment. Omit some components of the project as long as the intended use of the end product is not compromised unduly. • Consider the labour, materials and equipment with long lead times. Highlight it in the risk register. Manage long lead items on a schedule.
Labour strikes	• Ensure compliance with the labour relations act and appoint a labour representative.

	• There should be fair and transparent community liaison. • Identify risks of delays caused by labour strikes early, include these risks in the risk register, and manage the risks through contractual mechanisms. • Use and comply with labour regulations to avoid strikes.
Unforeseen ground conditions	• Geotechnical report to be done before construction. • These risks could be significantly mitigated if a more detailed geotechnical investigation was conducted during the detailed and preliminary design. A front-end loading approach has increased value on mega projects. • This risk can be avoided if the necessary geotechnical investigations had been done at the planning and/or tender stage. • Appropriate and adequate geotechnical investigations are to be done. • Perform a geotechnical survey before the Contract. • Complete full Geotechnical investigations at the planning stage, to fully inform design aspects. • Proper surveys of ground material. • Identify the best expert consultants and contractors to cut down time on resolving the problem. Appreciate that there will be budget implications and determine where additional funds will be coming from. If the project deadline cannot be extended, "acceleration" costs are also to be determined. If no additional funds are available, the project might have to be placed on hold, or cost-saving measures such as "omissions" and more economical materials and finishes to be identified and implemented as soon as possible.

	• Involve geotechnical specialists in the planning stage to advise on possible risks associated with soil structures and proposed mitigation measures. • Cross-examine findings with a different consultant.

6.6.3 Risks affecting cost constraints

6.6.3.1 Financial condition of the main contractor

The financial condition of the main contractor was considered a significant risk factor affecting the cost constraints of megaprojects. These findings are supported by Memon *et al*. (2010). They concluded that cash flow and financial difficulties faced by contractors, contractor's poor site management and supervision, inadequate contractor experience, shortage of site workers, and incorrect planning and scheduling by contractors are the most significant causes affecting cost in construction projects. The contractor's financial failure falls under the economic risk category which was ranked in section 5.1.3 as the third significant risk affecting the successful delivery of megaprojects.

6.6.3.2 Incorrect cost estimate

An incorrect cost estimate is another first-ranked critical risk factor affecting the cost performance of megaprojects. These findings are supported by Baloyi and Bekker (2011) who ranked incorrect cost estimates as the second most important factor that caused cost overruns in the construction of the 2010 FIFA World Cup stadia. If a contractor made a calculation error and cannot recover their cost on a project, it could impact their cash flow. Moreover, if the contractor does not have the cash flow to complete a project, successful delivery will be delayed. Incorrect cost estimate falls within the economic risk category, which was ranked as the third critical risk category under section 4.2.

6.6.3.3 Design errors

Design errors constitute the second-ranked risk factor that affects the cost constraints of megaprojects. Design errors result in rework, and this causes time and cost overruns in construction projects (Han *et al*., 2013). There are expenses involved when work needs to be redone on site. It is necessary to have experienced designers to avoid design errors and to recheck the drawings.

6.6.3.4 Unforeseen ground condition

Unforeseen ground condition is another second-ranked critical risk factor that affects the cost constraints of megaprojects. These findings are supported by Tshidavhu and Khatleli (2020) who concluded that unforeseen ground conditions were one of the factors that caused schedule and cost overruns in the Kusile and Medupi energy megaproject. Infrastructure projects are often impacted by unforeseen ground conditions such as water pressure, sudden changes in material, etc. These risks have high impacts on projects and may be caused by a lack of input into the design stage.

6.6.3.5 Incomplete drawings

Incomplete drawings pose another risk factor affecting the cost constraints of megaprojects. This type of risk falls under the design category. Additional time and cost will be spent to complete the drawings that should have been completed initially. The designers will charge additional costs for the task of completing the drawings. This means the client will be responsible for the payment of this task.

6.6.3.6 Poor planning and scheduling

Poor planning and scheduling is the third-ranked critical risk factor affecting the cost constraints of megaprojects. When the construction work is poorly planned and scheduled, it will have a direct impact on the schedule of the project. Consequently, the cost of the project will be affected. There will be cost overruns as a result of poor planning and scheduling.

6.6.3.7 Unavailability of labour, materials and equipment

Unavailability of labour, materials and equipment is the fourth-ranked significant risk affecting the cost constraints of megaprojects. Lack of resources poses a risk to the contractor concerning time and cost. However, a contractor will not tender for work he cannot complete under the obligation of the contract, therefore, this risk emanates between the time of tender and awarding of the contract. Before entering a contract, the contractor is to ensure and review the tender to ascertain whether the contract can still be completed under the initial specification and obligation. Megaprojects require the use of expensive equipment. This equipment must often be hired or imported from other countries.

6.6.3.8 Client's slow decision-making

The client's slow decision-making was the fifth-ranked critical risk affecting the cost constraints of megaprojects. The slow decision-making by the client has an impact on the schedule of the project. In most cases when the schedule is affected the cost is also affected. Therefore, when the client fails to make decisions on time, cost overruns will result.

6.6.3.9 Inappropriate equipment and material quality

Inappropriate equipment and material quality was another fifth-ranked critical risk affecting the cost constraints of megaprojects. All construction projects require equipment and materials, these are the resources needed by the contractor to execute the project. Materials are normally procured by the contractor. If the contractor procures inappropriate material of inferior quality, this will affect the cost of the project. The use of inappropriate equipment and quality affects the quality of the project. This could result in rework, which can result in additional costs.

6.6.3.10 Increase in material cost

An increase in material cost was another risk factor that affects the cost performance of megaprojects. These findings agree with Baloyi and Bekker (2011) who found the increase in material cost as the most significant contributor to cost overruns for global and South African stadia megaprojects. Similarly, Tshidavhu and Khatleli (2020), concluded that an increase in material cost was the largest contributor to cost overruns in the construction of the Medupi and Kusile energy megaprojects in South Africa. An increase in material cost tends to occur when projects are built during periods of strong economic growth and tight employment markets, which creates scarcity and drives price increases (Siemiatycki, 2015). In other words, this risk is caused by external factors.

6.6.4 Mitigations for the identified risks

Table 6-2 below provides possible mitigations for the identified critical risk factors that have an impact on the cost constraints of megaprojects. These mitigations were gathered from the construction professionals who participated in the survey questionnaire.

Table 6-2: Mitigations for risks affecting cost constraints

Risk	Mitigations

Financial condition of the main contractor	• Front-end loading of contracts to assist with the financial failure of the contractor. • Competent contractors must be used • Ensure the financial status of a company is identified during the tender stage; ensure the appropriate retention and performance guarantees are received up front, and control the cash flow accordingly. • Ensure proof of financial standing at the tender stage/ before the appointment. • Ensure that tender technical requirements and financial standing of the contractors invited to tender, meet the project requirements. • As soon as a contractor starts to fail in their performance apply contractual clauses to force them to perform. • Employ others to remedy non-performance by contractors in terms of the agreement in place. • Do not pay the contractor in advance in an attempt to "boost" their finances. Make arrangements to secure project payments to go to project suppliers and sub-contractors. • Monitor and control the contractor's performance and expenditure against the approved schedule and cash flow. Identify risks early, include them in the risk register and manage the risk actively through contractual mechanisms.
Design errors	• Review designs and only issue approved designs for construction. • Perform HAZOP at the start of the contract. • Conduct client design reviews, appoint experienced design engineers and apply penalties for substandard work. • Capacity for clients to review designs in detail.
Unforeseen ground condition	• Geotechnical report to be done before construction. • These risks could be significantly mitigated if a more detailed geotechnical investigation was conducted

	during the detailed and preliminary design. A front-end loading approach has increased value on mega projects. • This risk can be avoided if the necessary geotechnical investigations had been done at the planning and/or tender stage. • Appropriate and adequate geotechnical investigations are to be done. • Perform a geotechnical survey before the Contract. • Complete full Geotechnical investigations at the planning stage, to fully inform design aspects. • Proper surveys of ground material. • Identify the best expert consultants and contractors to cut down time on resolving the problem. Appreciate that there will be budget implications and determine where additional funds will be coming from. If the project deadline cannot be extended, "acceleration" costs are also to be determined. If no additional funds are available, the project might have to be placed on hold, or cost-saving measures such as "omissions" and more economical materials and finishes to be identified and implemented as soon as possible. • Involve geotechnical specialists in the planning stage to advise on possible risks associated with soil structures and proposed mitigation measures. • Cross-examine findings with a different consultant.
Incomplete drawings	• Review drawings before approving them for construction. The contractor must only use reviewed and approved drawings. • Ensure drawings are well defined at the start of the contract and ensure a HAZOP is conducted. • The drawings must be checked by the project manager and the resident engineer. • Conduct design review using a third-party consultant and contractor.

Poor planning and scheduling	• Functionality assessments as part of tender evaluation and award. • The lack of experienced staff is an issue which leads to poor coordination. Finding good staff is key to a good project. • Implement proper project management. • A well-defined and on-track programme is critical. • It is important to always properly plan the amount of work to be done on-site. • Avoid employing unscrupulous contractors who under-price their competition in tenders. Their low rates are often based on them employing "cheap", inexperienced and unprofessional site contract staff who cannot plan, coordinate and implement site management and coordination. • Ensure that the project manager is competent and experienced. Ensure that the project organogram is in place and that all role-players understand and accept the responsibilities and accountabilities associated with their role. • Create systems to audit and supervise the project planning.
Unavailability of labour, materials, and equipment	• Appoint a reputable contractor with a good track record. These risks should have been noted and accounted for in the Tender. The problem is when you appoint the cheapest Contractor that has not taken these risks into account. You may end up having to terminate the contract at the end of the day. Diligent tender evaluation based on price, BBE and functionality assessment is key. • Before entering a contract, the contractor is to ensure and review the tender to ascertain whether the contract can still be completed under the initial specification and obligation. • Design must cater for and accommodate available resources.

	• Ensure the Contractor has sufficient staff and provide a contingency plan upfront accordingly. Regarding materials, ensure alternative suppliers are available. • Plan for resources during the design phase. • Source alternative materials, contractors and equipment if these are in short supply. Find an additional budget that could be required to pay for alternative materials, contractors and equipment. Omit some components of the project as long as the intended use of the end product is not compromised unduly. • Consider the labour, materials and equipment with long lead times. Highlight it in the risk register. Manage long lead items on a schedule.
Client's slow decision-making	• Having an informed Client and a Project Manager/Engineer/Employer's Agent that understands their roles and responsibilities within the decision-making process. • Good designs and clear communication with the client can mitigate this. • Advise client/employer early on regarding any issue as soon as it is known (where possible) to allow the client sufficient time to review the issue. • Subject the client to contractual obligations in terms of adherence to contractual periods. • Appoint a project manager to facilitate decision making, minimise delays and advise the client of the impact if a decision is not taken or delayed. • At the Viability and Feasibility stages of the project, the client is to be informed of the risks posed by the lack of decision-making. • The project programme to have clear milestone activities indicating when what decisions are to be taken by the client. • Ensure that the client has all the information required before the date on which decisions are to be taken. Do

	not propose items or options requiring client decisions if these items cannot be applied within the client's approved and confirmed budget. • Put a strong project leader in the client-facing role to identify early on if the client is slow in making decisions. If the risk materialises, include it in the risk register and manage the risk through contractual correspondence in terms of notifications of delay and delay claims. Manage the client relationship actively to understand how the consultants and contractors can support the client's decision-making process. • Provide support to the client with a third-party consultant.
Inappropriate equipment and material quality	• Due diligence should be undertaken on the appointed contractor who should clarify the equipment to be used on the site. Should this not be the case and inappropriate equipment is introduced, action should be taken by the consultant. • Review of construction methods. • Inspect material at all times to ensure compliance with specifications. • Ensure the scope is well defined at the tender stage and that a good QCP is administered. • Specify the quality required. Appoint a Quality Control officer to ensure compliance. Penalise contractors for running out of specific materials. • Make sure the equipment and materials are properly specified for the project and that the specifications issued are fit for purpose and that the contractor complies. Do not pay for work done using sub-standard equipment and poor materials. • Consider the quality of available materials and equipment during the planning stage. Consider the possibility of the risk materialising and include the risk in the risk register. Identify the timeline within which

	materials and equipment unavailability will not impact the critical path. Manage the risk in the risk register. • Define clearly the source of materials and select adequate construction methods.
Incorrect cost estimate	• Allow panels to review and agree on cost estimates. • Utilise experienced staff to conduct estimates. Market forces are sometimes unpredictable - Accept the risk if all tenders come in above the estimate. Project implementation could be delayed due to insufficient funds. • If a contractor made a calculation error and cannot recover their cost on a project, it could impact their cash flow. If a contractor does not have the cash flow to complete a project, the successful delivery will be delayed. It will also cost the client more money. Monitor and control the contractor's performance and expenditure against an approved schedule and cash flow. Identify risks early, include them in the risk register and manage the risk actively through contractual mechanisms.
Increase in material cost	• Ensure a CPA is implemented and budgeted for at the tender stage. • Change material. • Include contingencies in the contract. • Tendered rates should address this. Hence, appointing the proper contractor/s will address this matter. Where possible purchase material upfront and keep material stored "on-site" or in bonded storage". • Define in Contract a range in price change that allows for revision of prices.

6.6.5 Risks affecting quality constraints

6.6.5.1 Inappropriate equipment and material quality

The most significant risk factor that affects the quality constraints of megaprojects is inappropriate equipment and material quality. These findings are supported by Chattapadhyay *et al*. (2021). They noted that when considering the quality aspect of megaprojects, “inappropriate equipment and material quality was the key risk factor that needs attention to ensure megaprojects achieve their objectives” (Chattapadhyay *et al*., 2021).

6.6.5.2 Shortage of skilled labour

Another critical risk factor affecting the quality constraints of megaprojects is the shortage of skilled labour. The shortage of skilled labourers, which could affect planning, design, and scheduling may be a result of the rushed implementation of megaprojects in South Africa (Tshidavhu & Khatleli, 2020). Moreover, the availability of competent personnel in the construction and engineering field is a challenge (Aiyetan & Das, 2022).

Megaprojects require a considerable number of skilled labourers. Low-skilled labour will slow the progress of the work, as they do not have adequate experience in the work they are undertaking. Consequently, low-skilled labourers may make mistakes which can result in the work being redone. On the other hand, work will progress faster if skilled labourers are employed. The use of low-skilled labour could have a negative impact on the quality of the delivered project, as these workers may not have adequate training and skills required to execute the work. The higher the number of skilled labourers available for a megaproject, the better the results achieved (Olaniran *et al*., 2015).

6.6.5.3 Poor planning and scheduling

Poor planning and scheduling are ranked the third critical risk factor affecting the quality aspect of megaprojects. Chattapadhyay *et al*. (2021) noted that poor site coordination was among the key risk factors affecting the quality of worldwide megaprojects. In construction projects, not necessarily megaprojects, Oke *et al*. (2017) concluded that poor planning and scheduling, inadequate knowledge, training and skills of construction workmen are some of the major factors affecting the performance quality of construction projects. If construction work is poorly planned, the execution will also be poor, thus resulting in inferior quality of the work.

6.6.5.4 Deviations between specification and implementation

Deviations between specifications and implementation pose another critical risk affecting the quality of megaprojects. These findings are in line with Zou *et al*. (2007). They highlighted that in construction projects, not necessarily megaprojects, the failure to adhere to specifications or standards is one of the risks affecting the quality of projects. This is a risk to the client and the employer should ensure that specifications are correct when awarding the contract.

6.6.5.5 Incomplete drawings

Incomplete drawings were ranked as the fifth critical risk affecting the quality aspect of megaprojects. Construction work that is executed using incomplete drawings may not meet the requirements of the client. The contractor will only carry out the work as designed in the drawing. This type of risk falls under the technical and design category and is internal to the project.

6.6.5.6 Supply of faulty materials

The supply of faulty materials is another fifth-ranked risk affecting the quality performance of megaprojects. These findings agree with Renault *et al.* (2016a), who concluded that the supply of faulty materials was the most critical risk factor in construction projects. The supply and the use of faulty materials may have a negative impact on the quality of the delivered project. The contract will cover the risk to the client for cost overruns and poor-quality workmanship, but the risk of late completion must be mitigated through stage prototype demonstration/approval and penalty clauses that cover the client's risk.

6.6.5.7 Design errors

Design errors are among the significant risk factors affecting the quality of megaprojects. This is evident in the recently completed Medupi power station. The station has suffered poor performance in some of its units because of design faults. This has resulted in Eskom as the client paying additional expenses to remedy the defects. When there is an error in design it will eventually result in poor output since projects are executed based on the designs.

6.6.5.8 Financial condition of the main contractor

The financial condition of the main contractor has a significant impact on the quality of megaprojects. The main contractor is responsible for the procurement of materials and equipment and paying the labourers. When considering the complex nature of megaprojects, the contractor’s financial stability is of utmost importance to be able to execute and deliver the project. If the contractor experiences financial challenges, a compromise may be made concerning the use of cheap labour and materials. This could have an impact on the quality of a project.

6.6.5.9 Unavailability of labour, materials and equipment

The unavailability of labour, materials and equipment has an impact on the quality of megaprojects. Megaprojects require numerous, skilled labourers, as well as material and equipment. If the contractor lacks at least one of these resources, a project may not be delivered satisfactorily to the client.

6.6.5.10 Project complexity

Project complexity was ranked the seventh risk factor affecting the quality of megaprojects. Complexity is one of the characteristics of megaprojects. When a megaproject becomes complex it can cause delays, and consequently lead to inferior quality. This is evident in the Medupi power station project. Although the project has been completed, some defects result in the poor functioning of some of its units.

6.6.6 Mitigations for the identified risks

Table 6-3 below provides possible mitigations of the identified critical risk factors that have an impact on the quality constraints of megaprojects. These mitigations were gathered from the construction professionals who participated in the survey questionnaire.

Table 6-3: Mitigations for risk factors affecting quality constraints

Risk	Mitigations
Inappropriate equipment and material quality	• Due diligence should be undertaken on the appointed contractor who should clarify the equipment to be used on the site. Should this not be the case and inappropriate equipment is introduced, action should be taken by the consultant. • Review of construction methods. • Inspect material at all times to ensure compliance with specifications.

	• Ensure the scope is well defined at the tender stage and that a good QCP is administered. • Specify the quality required. Appoint a Quality Control officer to ensure compliance. Penalise contractors for running out of specific materials. • Make sure the equipment and materials are properly specified for the project and that the specifications issued are fit for purpose and that the contractor complies. Do not pay for work done using sub-standard equipment and poor materials. • Consider the quality of available materials and equipment during the planning stage. Consider the possibility of the risk materialising and include the risk in the risk register. Identify the timeline within which materials and equipment unavailability will not impact the critical path. Manage the risk in the risk register. • Define clearly the source of materials and select adequate construction methods.
Shortage of skilled labour	• Training of relevant personnel within your organisation. • Ensure a good quality scoring is provided at the tender stage to identify skilled stakeholders. • The client needs to specify key personnel in the evaluation criteria in the tender document. Only tenderers that meet these criteria should be appointed to do the job.

	• Train more artisans as a country. • Bring in additional skilled labour from other geographical areas - for some projects the costs to transport and house skilled labour is less than the risk of not completing the work or less than completing the work late or completing the work with unacceptable quality standards. • Identify the skilled labour required to successfully deliver the projects. Ensure that consultants and contractors alike understand the skilled labour requirements. Request proof that the consultants and contractors will have access to the skilled labour at the time of awarding the project. Incentivise consultants and contractors for on-time and quality delivery and penalise them for late delivery and poor-quality work.
Poor planning and scheduling	• Functionality assessments as part of tender evaluation and award. • The lack of experienced staff is an issue which leads to poor coordination. Finding good staff is key to a good project. • Implement proper project management. • A well-defined and on-track programme is critical. • It is important to always properly plan the amount of work to be done on-site. • Avoid employing unscrupulous contractors who under-price their competition in tenders. Their low rates are often based on them employing "cheap", inexperienced and

	unprofessional site contract staff who cannot plan, coordinate and implement site management and coordination. • Ensure that the project manager is competent and experienced. Ensure that the project organogram is in place and that all role-players understand and accept the responsibilities and accountabilities associated with their role. • Create systems to audit and supervise the project planning.
Supply of faulty materials	• Importation of inferior products has been an issue over time, however, the introduction of the DTI local content requirements has had some influence on this area. Local municipalities, however, tend to battle with this issue due to the lack of skilled staff available to assess the products. • Ensure quality management systems are adhered to. • Inspection of all materials to ensure compliance with specifications before materials are used. • Ensure the suppliers have a local back-up and are of a good and recognized quality, particular examples include instrumentation and the calibration thereof. • Prepare a quality-control plan, appoint a material management specialist and establish a material testing laboratory to ensure compliance. • Testing of materials.

	• Where materials are specified by the client/consultants with no contractor's alternatives to be considered, 100% of the risk remains with the client/consultant. • Critical equipment and materials must be identified in terms of availability and suitability for the project. Suppliers of risk materials and equipment should be consulted to determine upfront that the material/equipment is suitable for the project application. Determine upfront service agreements and support with material/equipment suppliers. Employ experienced and skilled labour resources to apply and install materials and equipment. In some cases, material and equipment suppliers advise that contractors must be trained, skilled and certified to work with their materials and equipment. Make sure that the project work plan allows for the proper procurement, delivery, site storage, site handling, hoisting, and installation of all risk materials and equipment. • The contract will cover the risk to the client for cost overruns and poor-quality workmanship, but the risk of late completion must be mitigated through stage prototypes demonstration/approval and penalty clauses that cover the client's risk. • Conduct procurement activities ahead of time.
Deviations between specification and implementation	• Employer to ensure that specifications are correct when awarding the contract.

	• Poor documentation results in most of the issues on site. Limited time is spent on the compilation of the tender documents which results in delays, cost overruns and poor quality. Contractors are forced to adhere to the contract documents due to low tendering and hence become more claim conscience. • Control deviations through a change management process. • Implement a good QCP at the start of the contract. • Have a quality-control plan in place and penalty clauses for out-of-spec work. • Quality-control procedures: Approve all materials before use. Build sample panels confirming approved materials and workmanship and have a procedure in place to verify that the materials being used match the approved samples. Have regular quality conformance inspections from the design team. Register non-compliance items and record dates for resolving non-compliance items. Stop or reverse payments if non-conformance items are not being made good. • Specifications are to be clear and allow for inevitable on-site changes. • Understand the scope of work well during the tender time. Clearly define the scope of works offered. If the risk of scope creep materialises include it in the risk register and manage the risk through contractual correspondence in

	terms of change notifications and contractual claims.
Incomplete drawings	• Review drawings before approving them for construction. The contractor must only use reviewed and approved drawings. • Ensure drawings are well defined at the start of the contract and ensure a HAZOP is conducted. • The drawings must be checked by the project manager and the resident engineer. • Conduct design review using a third-party consultant and contractor.
Design errors	• Review designs and only issue approved designs for construction. • Perform HAZOP at the start of the contract. • Conduct client design reviews, appoint experienced design engineers and apply penalties for substandard work. • Capacity for clients to review designs in detail.
Financial condition of the main contractor	• Front-end loading of contracts to assist with the financial failure of the contractor. • Competent contractors must be used • Ensure the financial status of a company is identified during the tender stage; ensure the appropriate retention and performance guarantees are received up front, and control the cash flow accordingly. • Ensure proof of financial standing at the tender stage/ before the appointment.

	• Ensure that tender technical requirements and financial standing of the contractors invited to tender, meet the project requirements. • As soon as a contractor starts to fail in their performance apply contractual clauses to force them to perform. • Employ others to remedy non-performance by contractors in terms of the agreement in place. • Do not pay the contractor in advance in an attempt to "boost" their finances. Make arrangements to secure project payments to go to project suppliers and sub-contractors. • Monitor and control the contractor's performance and expenditure against the approved schedule and cash flow. Identify risks early, include them in the risk register and manage the risk actively through contractual mechanisms.
Unavailability of labour, materials, and equipment	• Appoint a reputable contractor with a good track record. These risks should have been noted and accounted for in the Tender. The problem is when you appoint the cheapest Contractor that has not taken these risks into account. You may end up having to terminate the contract at the end of the day. Diligent tender evaluation based on price, BBE and functionality assessment is key. • Before entering a contract, the contractor is to ensure and review the tender to ascertain whether the contract

	can still be completed under the initial specification and obligation. • Design must cater for and accommodate available resources. • Ensure the Contractor has sufficient staff and provide a contingency plan upfront accordingly. Regarding materials, ensure alternative suppliers are available. • Plan for resources during the design phase. • Source alternative materials, contractors and equipment if these are in short supply. Find an additional budget that could be required to pay for alternative materials, contractors and equipment. Omit some components of the project as long as the intended use of the end product is not compromised unduly. • Consider the labour, materials and equipment with long lead times. Highlight it in the risk register. Manage long lead items on a schedule.
Project complexity	• Appoint an experienced team for complex and specialist work, allowing sufficient time to complete projects. • Front-end loading should be used to mitigate this risk. • Construction tasks should be broken down into sub-projects. • Project complexity should be clear at the tender stage, considered in the project budget, and noted as such by the client. • Ensure a process where only contractors with the required

	experience, skills and resources are allowed to tender or pass the technical qualifications. • Set up and maintain a proper risk register with monitoring and process to address risks. • Ensure that the project manager is competent and experienced to manage a complex project. • identify complex areas and plan satellite/ technical meetings to mitigate shortfalls. • Ensure adequate integration of all specialities.

6.7 Impact of risk on time, cost, and quality

Table 6-4: Impact of risk on time, cost, and quality

No.	Risk factor	Impact of risk on time, cost, and quality		
		Time	Cost	Quality
1.	Delayed supply of material and equipment	✓		
2.	Financial condition of the main contractor	✓	✓	✓
3.	Client's slow decision-making	✓	✓	
4.	Incomplete drawings	✓	✓	✓
5.	Design errors	✓	✓	✓
6.	Unavailability of labour, materials, and equipment	✓	✓	✓
7.	Delay in obtaining preliminary drawings	✓		

8.	Labour strikes	✓		
9.	Late issue of instructions	✓		
10.	Shortage of skilled labour			✓
11.	Incorrect cost estimate		✓	
12.	Unforeseen ground condition	✓	✓	
13.	Poor planning and scheduling		✓	✓
14.	Inappropriate equipment and material quality		✓	✓
15.	Deviations between specification and implementation			✓
16.	Increase in material cost		✓	
17.	Supply of faulty materials			✓
18.	Project complexity			✓

Table 6-4 shows the risk factors that are affecting the successful delivery of megaprojects concerning time, cost, and quality. Of the 22 risks presented in the questionnaire,18 risks were considered as having a significant impact on time, cost, and quality. The results from the table above reveal that the financial condition of the main contractor, design errors, incomplete drawings, and unavailability of labour, materials, and equipment affect all the project management constraints. The financial condition of the main contractor and the unavailability of labour, materials, and equipment relates to the contractor. On the other hand, design errors and incomplete drawings relate to the consultant.

6.8 Risk identification tools

This section presents the findings related to the third objective of the study, namely, to determine the commonly used risk-identification tools in construction projects. A total of ten risk identification tools formed part of the questionnaire that was administered to the construction professionals. The findings revealed that five tools are commonly used to identify risk in the South African construction industry.

Based on the results presented in the previous chapter, brainstorming, expert judgement, checklist, root-cause-identification, and flow charts are the most common tools used to identify risk in projects. These findings are supported by the international study by Goh and Abdul-Rahman (2013). They found that brainstorming and checklist were the most common tools in the construction industry in Malaysia. In the South African context, these findings agree with Renault *et al*. (2016). They found out that checklists and brainstorming were among the top three tools frequently practised. Similarly, these findings are supported by Chihuri and Pretorius (2010). They emphasized that brainstorming allows participants to use different sources of information such as former experience and expert judgement (Chihuri & Pretorius, 2011). Furthermore, the use of a checklist allows an opportunity to adhere to a structured approach and ensures that no items are omitted (Chihuri & Pretorius, 2011).

6.9 Chapter Summary

This chapter presented findings gathered from a questionnaire completed by construction professionals working on megaprojects. These findings were related to the objectives of the study: risk in construction megaprojects; the impact of risk on project management constraints; and the tools used for identifying risk in construction projects. The objective of this chapter was to discuss the findings relative to the problem statement, research objectives, and research question.

The findings of this research relative to the problem statement and the research question showed that there are critical risks that have a greater impact on the time, cost, and quality of megaprojects. These critical risks fall into the categories of execution risks, technical risks, and economic risks. The findings related to megaproject risk factors are supported by the literature consulted in this study.

Concerning the impact of risk on the objectives of time, cost, and quality, the findings revealed that the financial condition of the main contractor, design errors, incomplete drawings, and unavailability of labour, materials, and equipment affect all the project management constraints. The financial condition of the main contractor and the unavailability of labour, materials, and equipment relates to the contractor. On the other hand, design errors and incomplete drawings relate to the consultant. Lastly, regarding the findings relative to the tools used for identifying risks in construction projects, the study found that brainstorming, expert judgement, checklist, root-cause identification, and flow charts are the commonly used tools. The following chapter will present conclusions and recommendations for future research.

Chapter 7 Conclusions and recommendations

7.1 Introduction

In the previous chapter, discussions were presented to address the objectives of this study. This chapter aims to conclude the research study and provide recommendations. This research study aimed at investigating the risks that are affecting the successful delivery of megaprojects concerning time, cost, and quality. This was done to address the research problem restated as follows:

South African construction megaprojects are failing to meet their objectives concerning time, cost, and quality due to various risks associated with these projects. Risks are problematic because they lead to time and schedule overruns combined with inferior quality. If risks are not managed effectively, megaprojects will continue to fail concerning time, cost, and quality. Therefore, mitigations are needed to minimize the risks that affect the successful delivery of megaprojects.

Furthermore, this research study was undertaken to answer the research question presented under section 1.3 and restated as follows:

What are the risks that are resulting in the megaprojects failing to achieve their project objectives concerning time, cost, and quality, and are there mitigations to minimize these risks?

This chapter will formally present conclusions relative to the research problem, research question, and the outcomes of the objectives of this study. Furthermore, this chapter will present the contribution of the research, the limitations of the study, and the recommendations for future research.

7.2 Conclusions

This section presents the conclusions of this research study. The conclusions presented in this section are divided into two sections. Firstly, conclusions gathered from the literature review and the findings of this research are listed. Secondly, the answer to the research and the outcomes of the objectives of this study are presented.

7.2.1 Conclusions from the literature study

The following are the conclusions drawn from the literature studies and the research conducted:

- Construction megaprojects differ from ordinary projects in that these projects require large sums of money, involve numerous contractors, and can take more than three years to be completed.
- The development of megaprojects requires the involvement of highly skilled personnel. This is because of the complex nature of these projects. For the design team, management team, and construction team, highly skilled personnel is required.
- Megaprojects are suffering from cost and schedule overruns, due to risks. These projects are delivered late and exceed the estimated project cost. This is a challenge for megaprojects worldwide, including in South Africa.
- Risk affects the triple constraints of the project, which are time, cost, and quality. However, time and cost constraints are largely affected by risks in megaprojects.
- There are various risks affecting the successful delivery of megaprojects such as execution risks, technical risks, economic risks, environmental risks, political risks, cultural risks, and social risks.
- Megaprojects that are funded by private organizations have fewer political risks since there are fewer stakeholders involved. On the other hand, a public-funded megaproject will have more political risks, due to the involvement of many stakeholders.
- This study found that the critical risk categories affecting the time, cost, and quality of South African construction megaprojects are execution risk, technical risk, and economic risks.
- In South Africa, a few notable public-sector megaprojects that have been developed in the past decade and a half, have all suffered massive cost and time overruns, with the transport and energy sector projects mainly affected by these overruns.
- With regards to risk management in construction projects, the commonly used tools worldwide for identifying risks in construction projects are brainstorming, checklists, flow charts, interviews/expert opinion, and the Delphi Technique.

7.2.2 Conclusions from the findings of the study

Table 7-1 presents the conclusions from the findings of this study. The table shows the objectives and the outcomes that were achieved for this study.

Table 7-1: Conclusions based on the outcomes of the objectives

<table>
<tr><th>Objectives</th><th>Outcomes</th></tr>
<tr><td>Objective 1: To identify the risks to which construction megaprojects are exposed and categorize them into different groups.</td><td>Outcome of objective 1: The study will identify the risks that affect the successful delivery of megaprojects concerning time, cost, and quality.

The risk factors that affect the time constraint of megaprojects are:
Delayed supply of material and equipment
Financial condition of the main contractor
Client’s slow decision-making
Incomplete drawings
Design errors
Unavailability of labour, materials and equipment
Delay in obtaining preliminary drawings
Labour strikes
Late issue of instructions
Unforeseen ground conditions
The risks that have an impact on the cost constraint of megaprojects are:
Financial condition of the main contractor
Incorrect cost estimate
Design errors
Unforeseen ground conditions
Incomplete drawings
Poor planning and scheduling
Unavailability of labour, materials and equipment
Client’s slow decision-making
Inappropriate equipment and material quality
Increase in material cost</td></tr>
</table>

	The risks that have an impact on the quality constraint of megaprojects are: • Inappropriate equipment and material quality • Shortage of skilled labour • Poor planning and scheduling • Deviations between specification and implementation • Incomplete drawings • Supply of faulty materials • Design errors • Financial condition of the main contractor • Unavailability of labour, materials and equipment • Project complexity The study further revealed that there are mitigations for the risks affecting time, cost, and quality, as shown in Table 6-1, Table 6-2, and Table 6-3. Based on the findings concerning the critical risks in megaprojects, it can be concluded that the research question presented in Chapter 1 was answered, and the outcome of the first objective was achieved.

Objective 2: To examine the impact of risk on time, cost, and quality in construction megaprojects.	**Outcome 2:** The study will identify the risks that affect all the project constraints of time, cost, and quality. Out of the 22 risks presented in the questionnaire,18 risks were considered as having a significant impact on time, cost, and quality. The results from Tables 5-8 reveal that the financial condition of the main contractor, design errors, incomplete drawings, and unavailability of labour, materials, and equipment affect all three project management constraints.
Objective 3: To investigate the tools commonly used for identifying risks in construction projects.	**Outcome 3:** The study will identify the tools commonly used for identifying risks in construction projects. Out of the 10 risk-identification tools that were gathered from the literature and presented in the questionnaire, this research study found that 5 tools are commonly used, namely, brainstorming, expert judgement, checklist, root-cause identification, and flow charts. These 5 are the common tools used for identifying risks in construction projects.

7.3 Contribution of research

With many of the worldwide construction megaprojects failing to achieve their objectives concerning time, cost, and quality, this study will help solve the problems encountered by megaprojects. This study will be beneficial to the governments and private construction firms as it will provide mitigations to the prevalent risks and thus aid in decision-making processes in dealing with risks in their current and future megaprojects.

7.4 Limitations and constraints of the study

Since this research study focused on risks in construction megaprojects, the findings cannot be generalized to small and medium-sized civil engineering and construction projects. Therefore, this study the findings of this study are limited to construction megaprojects.

The limitation of this research study was data collection. During the data collection process, some participants, particularly contractors, did not complete the survey questionnaire due to their busy schedules. Another restraint is based on the research approach for the study. This study used a quantitative approach to identify the critical risks. A mixed-method approach could have provided more detailed information on the mitigations for the risks.

7.5 Recommendations for future research

The following recommendations are proposed for further studies:

- The participants should be requested to state the risk factors that are not provided in the questionnaire, this will enable the participants to provide the risks they perceive to be affecting the successful delivery of megaprojects.
- The study should use a mixed-method approach to explore the critical risks related to megaprojects and their mitigations.
- The frequency of occurrence of the identified critical risks should be investigated together with the impact of risk on time, cost, and quality. This will help to determine how frequently the risks are likely to be experienced during the project.
- The study should investigate the factors contributing to the successful delivery of megaprojects.
- More research should be conducted on risk factors impacting the quality performance of megaprojects. Based on the consulted literature, there are few studies conducted on risks affecting the quality of megaprojects.

7.6 Chapter Summary

This chapter presented the conclusion to the study, contribution, and limitations of the research, as well as the recommendations for future research. This chapter concluded the research by highlighting that there are critical risks affecting megaproject delivery. These risks result in massive cost and schedule overruns, combined with inferior quality. Moreover, there are mitigations for these risks. This chapter showed that the research question has been answered, and the objectives of the study were met.

References

Aarthipriya, V., Chitra, G. & Poomozhi, J.S. 2020. Risk and its impacts on time and cost in construction projects. *Journal of Project Management*, 5 (4): 245–254.

Abdulmoneim, A., Al Samadony, A. & Nosair, I. 2021. Identification and Ranking the Most Significant Risks of the Mega Construction Projects in Saudi Arabia. *Saudi Journal of Civil Engineering,* 5 (2): 35–49.

Aiyetan, A. & Das, D. 2022. Factors and Strategies for Improving Construction Management on Sites in Mega-Projects in South Africa : *Infrastructures*, 19 (7): 1–26.

Alattyih, W., Haider, H., Boussabaine, H., Altoryman, A. & Otobo, O. 2014. *Identification and assessment of risk factors affecting construction projects in the Gulf region: Kuwait and Bahrain.* The School of Mechanical, Aerospace and Civil Engineering, PhD thesis, University of Manchester.

Andrić, J.M., Wang, J., Zou, P.X.W., Zhang, J. & Zhong, R. 2019. Fuzzy Logic–Based Method for Risk Assessment of Belt and Road Infrastructure Projects. *Journal of Construction Engineering and Management*, 145 (12): 1–12.

Atkinson, R. 1999. Project management: Cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria. *International Journal of Project Management*, 17 (6): 337–338.

Baloi, D. & Price, A.D.F. 2003. Modelling global risk factors affecting construction cost performance. *International Journal of Project Management,* 21 (4): 261–269.

Baloyi, L. & Bekker, M. 2011. Causes of construction cost and time overruns: The 2010 FIFA World Cup stadia in South Africa. *Acta Structilia : Journal for the Physical and Development Sciences,* 18 (1): 51–67.

Banerjee, D. 2020. Mega-Project Risk Prediction in Construction Management Mega-Project Risk Prediction in Construction Management. Journal of critical reviews, 7 (5): 2674–2687.

Banerjee, D., Jagadeesh, P. & Ramamohan Rao, P. 2017. Risk Analysis and Decision Support in Transportation Megaprojects. International Journal of Civil Engineering and Technology, 8 (7): 836–845.

Barber, R.B. 2005. Understanding internally generated risks in projects. *International Journal of Project Management*, 23 (8): 1–9.

Barnes, M. 1983. How to allocate risks in construction contracts. *Project Management,* 1(1): 24–28.

Barradas, S. 2016. Ingula pumped-storage scheme project, South Africa. *Creamer Media's Engineering News.* Available at: https://www.engineeringnews.co.za/print-version/ingula-pumped-storage-scheme-project-south-africa-2016-02-19 (Accessed: 20 June 2022).

Boateng, P., Chen, Z. & Ogunlana, S.O. 2015. An Analytical Network Process model for risks prioritisation in megaprojects. *International Journal of Project Management*, 33 (8): 1795–1811.

Brooks, N. 2015. *Delivering European Megaprojects - A Guide for Policy Makers and Practitioners*. University of Leeds.

BusinessTech. 2022. A look at South Africa's new mega bridge – under construction in the Eastern Cape. *Business Tech*. Available at: https://businesstech.co.za/news/trending/596458/a-look-at-south-africas-new-mega-bridge-under-construction-in-the-eastern-cape/ (Accessed: 17 June 2022).

Caldas, C. & Gupta, A. 2017. Critical factors impacting the performance of mega-projects. *Engineering, Construction and Architectural Management*, 24 (6): 920–934.

Calitz, E. & Fourie, J. 2007. Infrastructure in South Africa : Who is to finance and who is to pay ? *Development Southern Africa,* 27 (2): 177–191.

Chattapadhyay, D.B., Putta, J. & Rama Mohan Rao, P. 2021. Risk identification, assessments, and prediction for mega construction projects: A risk prediction paradigm based on cross analytical-machine learning model. *Buildings,* 11(4): 1–28.

Chihuri, S. & Pretorius, L. 2010. Managing risk for success in a South African engineering and construction project environment. *South African Journal of Industrial Engineering*, 21 (2): 63–77.

Cooper, D.R. & Schindler, P.S. 2014. *Business Research Methods*. 12th ed. New York: McGraw-Hill.

Crafford, G.J. 2007. *Clients ' Views on Construction and Design Team Competencies*. PhD thesis, Nelson Mandela Metropolitan University.

Creamer, T. 2019. Technical defects at Medupi and Kusile resulting in serious underperformance. *Creamer Media's Engineering News.Available at:* https://www.engineeringnews.co.za/article/technical-defects-at-medupi-and-kusile-resulting-serious-underperformance-2019-02-01-1/rep_id:4136 (Accessed: 13 June 2022).

Creswell, J. 2014. *Research Design : Qualitative, Quantitative, and Mixed Methods Approaches*. 4th ed. California: SAGE.

Damayanti, R.W., Hartono, B. & Wijaya, A.R. 2021. Project Managers' Perspectives on the Complexity of Construction Megaproject in Indonesia: A Multicase Study. *IEEE Engineering Management Review,* 49 (2): 153–171.

El-Sayegh, S.M. 2008. Risk assessment and allocation in the UAE construction industry. *International Journal of Project Management*, 26 (4): 431–438.

Enshassi, A. & Abu Mosa, J. 2008. Risk Management in Building Projects: Owners' Perspective. *The Islamic University Journal (Series of Natural Studies and Engineering)*, 16 (1): 95–123.

Enshassi, A., Al-Najjar, J. & Kumaraswamy, M. 2009. Delays and cost overruns in the construction projects in the Gaza Strip. *Journal of Financial Management of Property and Construction,* 14 (2): 126–151.

Esty, B.C. 2004. Why Study Large Projects? An Introduction to Research on Project Finance. *European Financial Management,* 10 (2): 213–224.

Ezzat Othman, A.A. 2013. Challenges of mega construction projects in developing countries. Organization, Technology & Management in Construction: *An International Journal*, 5 (1): 730–746.

Fahri, J., Biesenthal, C., Pollack, J. & Sankaran, S. 2015. Understanding megaproject success beyond the project close-out stage. *Construction Economics and Building*, 15 (3): 48.

Flanagan, R. & Norman, G. 1993. *Risk Management and Construction*. Oxford: Wiley-Blackwell.

Flyvbjerg, B. 2014. What you should know about megaprojects and why: An overview. *Project Management Journal*, 45(2): 3–19.

Garemo, N., Matzinger, S. & Palter, R. 2015. *Megaprojects: The good, the bad, and the better*. Available at: https://www.mckinsey.com/business-functions/operations/our-insights/megaprojects-the-good-the-bad-and-the-better.

Gellert, P.K. & Lynch, B.D. 2003. Mega-projects as displacements. International Social Science Journal, 55(175): 1–25.

Goh, C.S. & Abdul-Rahman, H. 2013. The identification and management of major risks in the Malaysian construction industry. *Journal of Construction in Developing Countries*, 18 (1): 19–32.

Gray, D. 2014. *Doing Research in the Real World*. 3rd ed. London: SAGE.

Grimsey, D. & Lewis, M.K. 2005. Are Public Private Partnerships value for money?: Evaluating alternative approaches and comparing academic and practitioner views. *Accounting Forum*, 29 (4): 345–378.

Hallock, B. & Zack, J. 2018. What Have We Learned from Megaprojects? *In 8th International Society of Construction Law Conference*, Chicago, 26-28 September 2018, pp. 2-44.

Iqbal, S., Choudhry, R.M., Holschemacher, K., Ali, A. & Tamošaitienė, J. 2015. Risk management in construction projects. *Technological and Economic Development of Economy*, 21(1): 65.

Irimia-Diéguez, A.I., Sanchez-Cazorla, A. & Alfalla-Luque, R. 2014. Risk Management in Megaprojects. *Procedia - Social and Behavioral Sciences*, 1 (119): 407–416.

Ismail, Z., Mabuza, P., Pillay, K. & Xolo, S. 2014. Infrastructure Development Within a Regulated Environment : Concerns for Regulators. *Journal of Economic and Financial Services,* 7 (4): 569–586. https://doi.org/10.4102/jef.v7i4.385.

Jobling, P.E. & Smith, N.J. 2018. Experience of the role of contracts in megaproject execution. Proceedings of Institution of Civil Engineers: Management, Procurement and Law, 171(1): 18–24. https://doi.org/10.1680/jmapl.17.00006

Jha, K.N. & Iyer, K.C. 2006. Critical factors affecting quality performance in construction projects. *Total Quality Management and Business Excellence*, 17(9): 1157.

Junior, R.R. & de Carvalho, M.M. 2013. Understanding the impact of project risk management on project performance: An empirical study. *Journal of Technology Management and Innovation*, 8: 64–78.

Kardes, I., Ozturk, A., Cavusgil, T. & Cavusgil, E. 2013. Managing global megaprojects: Complexity and risk management. *International Business Review*, 22 (6): 905–917.

Kartam, N.A. & Kartam, S.A. 2001. Risk and its management in the Kuwaiti construction industry: a contractors' perspective. *International Journal of Project Management,* 19 (6): 325–335.

Kessides, C. 1993. *The contributions of infrastructure to economic development. A Review of Experience and Policy Implications.* The World Bank, Washington DC. https://doi.org/10.1596/0-8213-2628-7.

Khumalo, S. 2020. Fixing of Medupi defects to be done by year-end - at R300 million per unit. *fin24*. Available at: https://www.news24.com/fin24/Economy/Eskom/de-ruyter-fixing-of-medupi-defects-to-be-done-by-year-end-at-r300-million-per-unit-20201020 (Accessed: 24 June 2022).

Kishan, P., Bhatt, R. & Bhavsar, J. 2014. A Study of Risk Factors Affecting Building Construction Projects. *International Journal of Engineering Research & Technology*, 3 (12): 831.

Kishk, M. & Ukaga, C. 2008. The impact of effective risk management on project success. In Dainty, A (eds.). *Association of Researchers in Construction Management, ARCOM 2008 - Proceedings of the 24th Annual Conference*, 1-3 September 2008. London: ARCOM. pp. 799–808.

Kothari, C. 2004. *Research Methodology : Methods and Techniques*. 2nd ed. New Delhi: New Age.

Kumar, R. 2011. *Research Methodology : a step-by-step guide for beginners*. 3rd ed. London:

SAGE.

Leedy, P. & Ormrod, J. 2015. *Practical Research: Planning and Design*. 11th ed. New Jersey: Pearson.

Lessing, B., Thurnell, D. & Durdyev, S. 2017. Main Factors Causing Delays in Large Construction. *Journal of Management,* 1 (2): 63–82.

Li Zhai, Yanfei Xin & Chaosheng Cheng. 2009. Understanding the value of project management from a stakeholder's perspective: Case study of mega-project management. *Project Management Journal,* 40 (1): 99–109.

Luque, R.A.-, Dunović, I.B., Gebbia, A., Ana, I., Diéguez, I.-, Mikić, M., Pedro, M.J.G., Sánchez, Á., Silva, J.D.A.E. & Spang, K. 2015. *Risk in the Front End of Megaprojects*. Ivana Burcar Dunović, ed. Leeds: University of Leeds.

Makombo, H.M. 2011. *The Risk Management Framework for Organisation Dealing with Construction Project Management in South Africa*. Master's thesis, University of Pretoria.

van Marrewijk, A., Clegg, S.R., Pitsis, T.S. & Veenswijk, M. 2008a. Managing public-private megaprojects: Paradoxes, complexity, and project design. *International Journal of Project Management*, 26 (6): 591–600.

van Marrewijk, A., Clegg, S.R., Pitsis, T.S. & Veenswijk, M. 2008b. Managing public–private megaprojects: Paradoxes, complexity, and project design. *International Journal of Project Management*, 26 (6): 591–600.

Maylor, H. & Turner, N. 2017. Understand, reduce, respond: project complexity management theory and practice. *International Journal of Operations and Production Management*, 37(8): 1076–1093.

Maylor, H.R., Turner, N.W. & Murray-Webster, R. 2013. How hard can it be?: Actively managing complexity in technology projects: The complexity assessment tool offers a framework for articulating, assessing, and managing sources of complexity in technology projects. *Research Technology Management*, 56(4): 45–51.

Miller, D. & Salkind, N. 2011. *Sampling. In Handbook of Research Design & Social Measurement*.

Thousand Oaks: SAGE: 52–56.

Mobey, A. & Parker, D. 2002. Risk evaluation and its importance to project implementation. *Work Study*, 51(4): 202–208.

Moloi, P.M. & Khatleli, N. 2018. An exploratory study on the legitimacy of energy megaproject in South Africa. In SACQSP *10th International Research Conference,* Johannesburg, Rosebank, 30 September - 01 October 2018, pp. 285–293.

Morano, C.A.R., Martins, C.G. & Ferreira, M.L.R. 2006. Application of techniques for the identification of risk in the E & P. *Engevista*, 8 (2): 120–133.

Moser, C.A. & Kalton, G. 2017. *Survey Methods in Social Investigation*. 2nd ed. Darmouth Publishing Company Ltd.

Moyo, A. & Crafford, G. 2010. The Effects of Hyperinflation on the Zimbabwean Construction Industry. *Acta Structilia*, 17 (2): 1–156.

Mpungose, A. 2017. *The Politics of Megaprojects: Assessing the Socio-Spatial and Environmental Impacts of the Proposed Dig-Out Port in South Durban*. Master's thesis, University of KwaZulu Natal.

Naidoo, B. 2010. New R6,7bn King Shaka airport gets set for takeoff. *Creamer Media's Engineering News*. Available at: https://www.engineeringnews.co.za/print-version/new-r67bn-king-shaka-airport-gets-set-for-takeoff-2010-03-19 (Accessed:20 June 2022).

Naoum, S. 1998. *Dissertations research & Writing for Construction Students*. 2nd ed. Oxford: Butterworth-Heinemann.

Netemeyer, R., Bearden, W.. & Sharma, S. 2003. *Scaling procedures : issues and applications*. London, United Kingdom: SAGE.

Oke, A., Aigbavboa, C. & Dlamini, E. 2017. Factors Affecting Quality of Construction Projects in Swazilland. In *The Ninth International Conference on Construction in the 21st Century (CITC-9),* United Arab Emirates, Dubai, 5-7 March 2017, pp. 1-6.

Olaniran, O., Love, P., Edwards, D., Olatunji, O. & Matthews, J. 2015. Cost Overruns in

Hydrocarbon Megaprojects: A Critical Review and Implications for Research. *Project Management Journal*, 46 (6): 126–138.

Othman, A. & Harinarain, N. 2009. Managing risks associated with the JBCC (principal building agreement) from the South African contractor's perspective. *Acta Structilia*, 16 (1): 83–119.

Oyegoke, A.S. & Al Kiyumi, N. 2017. The causes, impacts and mitigations of delay in megaprojects in the Sultanate of Oman. *Journal of Financial Management of Property and Construction*, 22 (3): 286–302.

Parrock, P. 2015. *Mega Project Analysis : A Case Study Of The Gauteng Freeway Improvement Project*. Master's thesis, University of Stellenbosch.

PMI. 2013. *A Guide to the Project Management Body of Knowledge: PMBOK Guide*. 5th ed. Newtown Square, PA: Project Management Institute.

PMI. 2017. *A Guide To The Project Management Body of Knowledge*: *PMBOK Guide*. 6th ed. Newtown Square, PA: Project Management Institute.

PWC. 2014. *Trends, challenges and future outlook: Capital projects and Infrastructure in East Africa, Southern Africa and West Africa.* Available at:https://www.pwc.co.za/en/assets/pdf/capital-projects-and-infrastructure.pdf.

Renault, Berenger Y., Agumba, J.N. & Ansary, N. 2016. An Appraisal of Critical Risk Factors in Construction Projects in South Africa: Perspective of Contractors. In *Transforming the Future of Infrastructure through Smarter Information - Proceedings of the International Conference on Smart Infrastructure and Construction,* Livingstone, Zambia, 31 August-2 September 2016, pp.130-138.

Renault, Berenger Y, Agumba, J.N. & Ansary, N. 2016. Evaluating the Use of Risk-identification Techniques in the South African Construction Industry. In *Proceedings of the 9th Annual Quantity Surveying Conference*, Port Elizabeth, 19-21 October 2016, pp. 125–137.

Rostami, A. & Oduoza, C.F. 2017. Key risks in construction projects in Italy: Contractors' perspective. *Engineering, Construction and Architectural Management*, 24 (3): 451–462.

Sanchez-Cazorla, A., Alfalla-Luque, R. & Irimia-Dieguez, A.I. 2016. Risk Identification in

Megaprojects as a Crucial Phase of Risk Management: A Literature Review. *Project Management Journal*, 47 (6): 75–93.

SANRAL. 2019. *Hello Eastern Cape*. Available at: https://stop-over.co.za/publications/hello/2019/eastern-cape/03/page-2.html

Saunders, M., Lewis, P. & Thornhill, A. 2009. *Research methods for business students*. 5th ed. Edinburgh Gate: Pearson Education.

Serpella, A.F., Ferrada, X., Howard, R. & Rubio, L. 2014. Risk Management in Construction Projects: A Knowledge-based Approach. *Procedia - Social and Behavioral Sciences*, 119: 653–662. https://doi.org/10.1016/j.sbspro.2014.03.073

Shunmugam, S. & Rwelamila, P. 2014. *An Evaluation of The Status of Risk Management In South African Construction Projects- The Case of South Africa.* Growing Project Management in Africa: *Proceedings of the Project Management South Africa (PMSA) Conference 2014*, 29 September-01 October 2014, pp.1-11.

Siemiatycki, M. 2015. Cost overruns on infrastructure projects: Patterns, causes, and cures. *Institute on Municipal Finance and Governance*, 1 (11): 1–14.

Smit, P. 2011. De Hoop dam achieves concrete placement. *Creamer Media's Engineering News.* Available at: recordhttps://www.engineeringnews.co.za/article/de-hoop-dam-achieves-concrete-placement-record-2011-02-15/rep_id:4136 (Accessed: 15 July 2022).

Sodurlund, J., Sankaran, S. & Biesenthal, C. 2017. The Past and Present of Megaprojects. *Project Management Journal*, 48(6):1-12. https://doi.org/10.1177%2F875697281704800602.

Sutherland, C., Sim, V. & Scott, D. 2015. Contested discourses of a mixed-use megaproject: Cornubia, Durban. *Habitat International*, 45: 185–195.

Tamošaitienė, J., Khosravi, M., Cristofaro, M., Chan, D.W.M. & Sarvari, H. 2021. Identification and Prioritization of Critical Risk Factors of Commercial and Recreational Complex Building Projects: A Delphi Study Using the TOPSIS Method. *Applied Sciences*, 11(17): 7906.

Tang, W., Qiang, M., Duffield, C.F., Young, D.M. & Lu, Y. 2007. Risk Management in the Chinese

Construction Industry. *Journal of Construction Engineering and Management*, 133 (12): 944–956.

Tshidavhu, F. & Khatleli, N. 2020. An assessment of the causes of schedule and cost overruns in South African megaprojects: A case of the critical energy sector projects of Medupi and Kusile. *Acta Structilia*, 27(1): 119–143. https://doi.org/10.18820/24150487/as27i1.5

Vadivel, T.S. 2016. Analyzing the Factors Affecting Quality in Construction. *IJERT*, 4 (33): 60-65.

Walsh, Alan and Walker, P. 2020. Looking beyond time and cost influences in mega projects. Available at: http://usir.salford.ac.uk/id/eprint/56726/3/Looking_beyond_Time__Cost_Considerations_for_Megaprojects_Revised%201622020.pdf

Walsh, A., Walker, P. & Ellis, M. 2021. The Underestimation of Cultural Risk in the Execution of Megaprojects. *International Journal of Civil and Environmental Engineering*, 15 (1): 33–40.

Wang, S.Q., Dulaimi, M.F. & Aguria, M.Y. 2004. Risk management framework for construction projects in developing countries. *Construction Management and Economics*, 22 (3): 237–252.

Watermeyer, R. & Phillips, S. 2020. *Public infrastructure delivery and construction sector dynamism in the South African economy*. Johannesburg.

Xie, L., Han, T. & Skitmore, M. 2019. Governance of Relationship Risks in Megaprojects: A Social Network Analysis. *Advances in Civil Engineering*, 2019: 1–13. https://doi.org/10.1155/2019/1426139

Zhi, H. 1995. Risk management for overseas construction projects. *International Journal of Project Management*, 13 (4): 231–237.

Zikmund, W., Babin, B., Carr, J. & Griffin, M. 2009. *Business Research Methods*. 8th ed. South-Western College.

Zou, P.X.W., Zhang, G. & Wang, J. 2007. Understanding the key risks in construction projects in China. *International Journal of Project Management*, 25 (6): 601–614.

Appendices

Appendix A: Questionnaire

RISK IDENTIFICATION AND ITS IMPACT ON PROJECT MANAGEMENT CONSTRAINTS IN CIVIL ENGINEERING AND CONSTRUCTION COMPANIES

I'm Macaleni, a master's in civil engineering student at the Cape Peninsula University of Technology. I am conducting a research study that aims to investigate the critical risks that are affecting the successful delivery of megaprojects concerning time, cost, and quality. The results that I will obtain from this research will help provide possible solutions to the risks that affect the successful delivery of megaprojects.

o Gauteng Freeway Improvement Project
o Gautrain Rapid Rail Link Project
o Eskom's Ingula pumped storage scheme
o FIFA World Cup 2010 Stadiums
o Transnet's new Multi-Product Pipeline
o Eskom's Kusile and Medupi coal power plants
o Airports Company South Africa's King Shaka International Airport

For this research study, a megaproject is defined as a large-scale project which is constructed for three years or more at a minimum cost of R 700 000 000.

SECTION 1: SOCIO-DEMOGRAPHIC VARIABLES

1.1 Please indicate your gender
o Male
o Female

1.2 Please indicate your age range
o 21 years-30 years
o 31 years-40 years
o 41 years-50 years
o > 50 years

1.3 Please specify your position in the company
o Project Manager
o Project Engineer
o Construction Manager
o Contracts Manager
o Other, please specify:

1.4 Please indicate your total years of experience in the construction industry
- o 6-10 years
- o 11-15 years
- o 16-25 years
- o > 25 years

1.5 Please indicate the involvement of your company in projects

- o Client
- o Consultant
- o Contractor

SECTION 2: RISK FACTORS AND THEIR IMPACT ON PROJECT MANAGEMENT CONSTRAINTS

From my research, I came up with a list of potential risk categories. Do you agree that these risk categories affect the successful delivery of mega projects concerning time, cost, and quality? Please tick **(✓)**

2.1 Do you agree that ***Execution risks** affect megaprojects concerning time, cost, and quality?

Strongly agree	Agree	Neutral	Disagree	Strongly disagree

2.2 Do you agree that * **technical and design risks** affect megaprojects concerning time, cost, and quality?

Strongly agree	Agree	Neutral	Disagree	Strongly disagree

2.3 Do you agree that ***Economic and Financial risks** affect megaprojects concerning time, cost, and quality?

Strongly agree	Agree	Neutral	Disagree	Strongly disagree

2.4 Do you agree that ***Social risks** affect megaprojects concerning time, cost, and quality?

Strongly agree	Agree	Neutral	Disagree	Strongly disagree

2.5 Do you agree that ***Environmental risks** affect megaprojects concerning time, cost, and quality?

Strongly agree	Agree	Neutral	Disagree	Strongly disagree

2.6 Do you agree that ***Political and Legal risks** affect megaprojects concerning time, cost, and quality?

Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Section 3: impact of risk on project management constraints

From my research, I came up with a list of possible risk factors associated with megaprojects. These risks are presented under various categories. Please rate the impact of each risk on project objectives of time, cost, and quality. For ratings 3, 4, and 5, please state a possible solution for this risk. If you select EXTREMELY LOW IMPACT (1) and LOW IMPACT (2), you do not have to provide a solution for the risk.

Please use the following rating scale:

1-extremely low impact

2-low impact

3-moderate impact

4-high impact

5-extremely high impact

Risk categories and their factors	Rate (1,2,3,4 or 5) impact of risk on															If you rated 3,4 or 5, please state what you think could be a possible solution
3.1 Execution Risks	**Time**					**Cost**					**Quality**					
3.1.1 Unforeseen ground condition	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
3.1.2 Inaccurate quantity take- off	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
3.1.3 Unavailability of labour, materials, and equipment	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
3.1.4 Shortage of skilled labour	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
3.1.5 Client's late contract award	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
3.1.6 Supply of faulty materials	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
3.1.7 Client’s slow decision- making	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
3.1.8 Late issue of instructions	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
3.1.9 Poor planning and scheduling	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
3.1.10 Inappropriate equipment and material quality	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	

3.1.11 Delayed supply of material and equipment	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
3.1.12 Deviations between specification and implementation	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	

3.2 Technical and Design Risks																
3.2.1 Incomplete drawings	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
3.2.2 Delay in obtaining preliminary drawings	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
3.2.3 Design errors	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
3.2.4 Project complexity	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	

3.3 Economic Risks																
3.3.1 Financial condition of the main contractor	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
3.3.2 Increase in material cost	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
3.3.3 Incorrect cost estimate	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
3.4 Environmental Risks																
3.4.1 Adverse weather condition	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	

3.5 Social Risks																
3.5.1 Labour strikes	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	

3.6 Political and Legal Risks																
3.6.1 Lack of political support	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	

SECTION 4: RISK IDENTIFICATION TOOLS

NB: Please complete this section if it applies to your organization
Based on your experience, indicate the technique that you apply to identify risks in your projects.

Risk identification tool	(✓)
1. Brainstorming	
2. Delphi Technique	
3. Influence Diagram	
4. Expert Judgement	
5. Checklist	
6. Nominal group technique	
7. Flow charts	
8. Scenario building	
9. Pondering	
10. Root cause identification	
11. Cause effect diagram	