UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

ANALYSIS OF FACTORS AFFECTING REHABILITATION OF ABANDONED MINES IN SOUTH AFRICA: CASES ON ASBESTOS PROJECTS

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A research report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Engineering.

19 June 2024

DECLARATION

I declare that this research report is my own unaided work. It is being submitted for the Degree of Master of Science in Engineering to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

I have familiarised myself with the University of the Witwatersrand Student Academic Misconduct Policy (SAMP). I hereby declare that the work I am submitting for assessment is my original work. I affirm that I have not plagiarised, misrepresented, or colluded with any other person or source. I have properly acknowledged, cited, and referenced all the sources that I have used in my work. I also declare that where I have used artificial intelligence (AI) tools it has only been as a means of guidance. The ideas and arguments presented in my work are my original thoughts and interpretations. I acknowledge that any academic misconduct, such as plagiarism or collusion will result in serious consequences. According to the SAMP, these consequences may include a reduced grade, a fail mark, or disciplinary action. The Faculty of Engineering and the University of the Witwatersrand have my consent to investigate any potential academic misconduct in my work. This investigation may include the use of similarity and AI detection software to check the originality of my work. I undertake to abide by the decision of any such investigation.

Signature: ______________________________ Date: 19 June 2024

ACKNOWLEDGEMENTS

Words cannot express my gratitude to my supervisor and colleagues for their support. I also could not have undertaken this journey without my employer and fellow employees, who generously provided, time, understanding and patience. Additionally, this endeavour would not have been possible without the generous support from MINTEK and the DMRE, who financed my research.

I am also grateful to my classmates and cohort members, especially my office mates, for their help, data, and information confirmations, including moral support. Thanks, should also go to the librarians, research assistants, and study participants from the university, who impacted and inspired me.

Lastly, I would be remiss in not mentioning my darling soul and life partner in life and friends. Their belief in me has kept my spirits and motivation high during this process. I would also like to thank my late Yorkie Leah for all the entertainment and emotional support.

ABSTRACT

Asbestos was once mined in South Africa using traditional methods. Unfortunately, the exploitation of asbestos severely impacted both workers and the surrounding communities. In 2008, the government stopped asbestos mining and designated the abandoned mines as Derelict and Ownerless (D&O) Mines. This was done to mitigate the serious health and safety risks associated with asbestos mining. The aim of the programme was also to address the negative environmental impacts caused by abandoned mines on local areas and social environments.

Since 2009, the MINTEK's D&O programme has rehabilitated 38 mines. However, the rehabilitation of these mines has been affected by various factors that have impacted the Derelict and Ownerless mining projects. This study aims to identify and understand the factors that affect abandoned mine projects in South Africa. The study also aims to provide a comprehensive analysis of the identified impacts and provide recommendations to ensure the successful implementation of the D&O projects.

The study used a mixed-method approach to collect both quantitative and qualitative data. The methodology involved data collection from various sources such as recorded reports, financial statements, spreadsheets, engineer reports, project progress reports, construction programs, and document analysis. The study focused on 32 asbestos mining projects in four provinces, namely Northern Cape, Limpopo, KwaZulu Natal, and Mpumalanga, which were used as case studies.

The rehabilitation of abandoned asbestos mines is a challenging task that requires collaboration, innovation, and concerted efforts. The factors affecting the implementation of the rehabilitation projects include slow decision-making by the contractors before and during construction, internal challenges faced by the contractors, time delays in material and stock deliveries, community resistance, specific project team experience, influence of external stakeholders and others. These can be categorized into six areas, namely, technical, economic, management, psychological, political and legislative. The study has revealed that all factors identified in the research have a direct impact on rehabilitation projects and contribute to failures in meeting targets in terms of costs and time. In conclusion, the analysis of technical, economic, psychological, and political factors in the rehabilitation of abandoned mines in South Africa also highlighted the interconnected nature of these considerations. As such, resolving these factors collectively will enhance the success and sustainability of mine rehabilitation projects.

The recommendations from the study include improvements in contract management, ensuring project monitoring and evaluation that encompasses progress monitoring, data management and reporting, and the establishment of performance matrices. The other areas of intervention include policy and legal reforms to define the requirements and objectives of rehabilitation projects. Stakeholder engagement and capacity building are also key elements that have a major influence on the successful implementation of rehabilitation projects. By prioritizing factors and addressing these bottlenecks, the risks associated with asbestos rehabilitation can be mitigated to foster resilient and empowered communities that actively participate and benefit from the restoration processes.

Key Words: Abandoned mines, rehabilitation projects, project management, time and cost impacts.

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LIST OF ABBREVIATIONS

ASHA	Asbestos Safety and Health Act
CGS	Council for Geosciences
D&O	Derelict and ownerless
DB	Design and Build
DDG	Deputy Director General
DEA	Department of Environmental Affairs
DMRE	Department of Minerals Resources and Energy
DOL	Department of Labour
EPWP	Expanded Public Works Program
FPC	Fixed Price Contract
MPRDA	Mineral and Petroleum Resources Development Act
PFMA	Procurement Financial Management Act
PMG	Parliamentary Monitoring Group
ROC	Rehabilitation Oversight Committee
RPC	Renewable Price Contract
RPI	Rehabilitation Priority index
SOE	State Owned Enterprise
UPC	Unit Price Contract
WTC	World trade Centre

1. CHAPTER ONE: INTRODUCTION

1.1. Introduction

This chapter introduces the topic that this research report is based on. It then gives a brief background about asbestos mining in South Africa, its mine rehabilitation projects, and processes. This chapter also highlights the problem that this research seeks to address and gives the aims and objectives of the study. Finally, the chapter concludes with how the research report is structured.

1.2. Background

Asbestos was historically mined in South Africa using artisanal mining methods which were unsafe and caused serious health and safety impacts on workers and communities (Virta, 2002). Community health and safety were not important when the mining of asbestos began in South Africa, and communities and workers were exposed to many health and safety risks (Brier and lia dwi jayanti, 2020).

Before 2002, there were no regulations mandating the rehabilitation and restoration of mined areas. As a result, after closure and/or during operations, asbestos mining caused severe environmental degradation, posed a threat to communities in mining areas, and left a legacy of refuse and contamination (Istikomah, 2014).

As a result of the health and environmental impacts of asbestos mining, the Minister of the Department of Environmental Affairs announced the "Regulations for the Prohibition of the Use, Manufacturing, Import, and Export of Asbestos, and Asbestos Containing Materials" on 28 March 2008 (Kazan-Allen, 2008). After these new regulations, the government designated several abandoned asbestos mines as Derelict and Ownerless Mines (D&O) (Ciccone, 2000). Derelict and Ownerless mines are mining operations that are ownerless after extensive legal investigation and procedures by the State (Mhlongo, 2023). This is because no official owner or liability could be established for rehabilitation or restoration after mining closure. It became the responsibility of the Department of Minerals Resource and Energy (DMRE) to rehabilitate and restore the environmental harm caused by asbestos mining.

The year 2009 saw the formulation of a national D&O Mines Management Strategy (Department of Mineral Resources, 2009). A rehabilitation strategy was developed and published by the Parliamentary Monitoring Group (DMR, 2019) and a rehabilitation plan was developed and published to formalise the rehabilitation of mines (McKenna and Williams, 2006).

As part of implementing the D&O strategy, the DMRE established a contract with MINTEK, a State-Owned Enterprise (SOE) (DMRE, 2021). The role of MINTEK was to investigate, prioritise, manage, and administrate the rehabilitation of D&O mines in the Republic of South Africa (RSA) (DMRE, 2021). The rehabilitation of derelict and ownerless asbestos mines was therefore prioritized by the DMRE, with the support of MINTEK and contract management teams.

A Rehabilitation Priority Index Method (Claassens, Bezuidenhout and Jansen Van Rensburg, 2009) was developed and utilised to select mines to be rehabilitated, and this framework looked at asbestos contamination risks and impacts on communities and areas. In addition, pre-determined factors and evaluations for asbestos sites were taken into account when ranking and prioritising rehabilitation projects (Van Rensburg, Claassens, Bezuidenhout and Jansen Van Rensburg, 2009). The rehabilitation management programme was initiated in 2009 and 38 mines have been restored since the inception of the MINTEK D&O program with 32 completed in 2020 (DMRE, 2021).

1.3. Problem Statement

Asbestos mines are located in rural communities and isolated areas (Mhlongo, 2023). As mentioned above, the government, through the DMRE, funded these asbestos rehabilitation projects all over South Africa. As these projects are government-funded, they need to be conducted under the Public Financial Management Act (PFMA) (Republic of South Africa, 2017). Over the past 15 years of rehabilitation of D&O mines, there have been concerns about the delivery of the D&O project commitments.

The D&O programme has limited budgets to execute rehabilitation as prioritised and in keeping with the specific timeframes and costs per year to ensure compliance with the agreed plans. The programme as assessed by the Council for Geosciences (CGS) determined that the government required fifty billion Rands to rehabilitate these Derelict and Ownerless mines. Asbestos mines are estimated to be 245 out of the

5976 D&O mines in South Africa. The value of the liability for rehabilitation for former asbestos mining sites was estimated at R2 billion as of 31 March 2016 (Coetzee, Sebake, Board, Africa, Heath, Gold and Croukamp, 2008).

In terms of the agreement between MINTEK and the DMRE, four projects are scoped and planned for every financial year (DMRE, 2021). While this is the case, the implementation and finalisation of these projects remain a challenge because of the project costs and project timeframes that are adhered to as agreed upon in the tender award conditions.

More so, the successful rehabilitation of abandoned mines particularly asbestos projects, faces numerous challenges. These challenges range from inadequate regulatory frameworks and funding constraints to technological limitations and complex stakeholder dynamics. According to Cornelissen addressing these challenges requires a nuanced understanding of the specific factors influencing the rehabilitation process (Cornelissen, Watson, Adam and Malefetse, 2019a). While the challenges associated with abandoned mines, in general, have received attention in the country in South Africa (Liebenberg, Claassens and van Rensburg, 2012), there is still a research gap specifically on the comprehensive analysis of factors influencing the rehabilitation of asbestos mines in South Africa (Kwata, Moja, Masindi, Mashalane, Mtyelwa and Malatji, 2017).

1.4. Research Aims and Objectives

The study aims to provide a comprehensive analysis of the factors affecting the rehabilitation of abandoned asbestos mines in South Africa. By investigating financials, timelines, economics, impacts, technological, construction and funding aspects, the research seeks to contribute valuable insights and recommendations for the development of effective and sustainable rehabilitation project strategies. The ultimate goal is to mitigate the adverse impacts of abandoned asbestos mines, promote environmental restoration, protect public health, and foster the localised economic well-being of affected regions.

The objectives of the study are to:

- Review 32 D&O asbestos mine rehabilitation projects between 2009 and 2020 and determine which were not completed within set timeframes and budgets.

- To evaluate the factors that affected the delivery of the projects.
- To propose policy and management recommendations based on the research findings to enhance the rehabilitation of abandoned asbestos mines in South Africa.

The research questions underpinning the study are as follows: What are the critical factors influencing the rehabilitation of abandoned mines in South Africa, particularly in the context of asbestos projects, and how can these factors be addressed to enhance the success and sustainability of rehabilitation initiatives?

The overarching objectives are supported by the following research questions:

- What is the assessment of the completion status, timeframes, and budgets of D&O asbestos mine rehabilitation projects conducted between 2009 and 2020?
- Which projects were not completed within the established timeframes and budgets?
- What factors affected the delivery of the D&O projects?
- What are the identified gaps or inconsistencies in the current policy and project management framework for abandoned mine rehabilitation, specifically addressing asbestos projects?

1.5. Significance of the Study

The significance of the study lies in its potential to contribute valuable insights and knowledge to various stakeholders involved in the rehabilitation of D&O asbestos mines in the specified timeframe. Key aspects of the study's significance include:

1.5.1. Informed Decision-Making:

- The study will provide decision-makers, including government bodies, environmental agencies, and project managers, with a comprehensive understanding of the factors influencing the completion of asbestos mine rehabilitation projects. This information can inform future decisions and strategies for more effective project planning and execution.

1.5.2. Efficiency Improvement:

- By identifying asbestos mine rehabilitation projects that experienced delays and budget overruns, the study can highlight areas where operational efficiency can be improved. This insight is crucial for optimising resource allocation and ensuring that future projects adhere to set timeframes and budgets.

1.5.3. Policy Enhancement:

- The findings of the study can contribute to the enhancement of policies related to mine rehabilitation. Recognising challenges faced in completing projects within established parameters can lead to policy adjustments aimed at addressing specific issues, fostering a more conducive regulatory environment.

1.5.4. Resource Allocation Optimization:

- Understanding which D&O asbestos mine rehabilitation projects faced challenges in terms of time and budget can aid in optimising resource allocation. This knowledge is essential for ensuring that financial resources are efficiently distributed, maximising the impact of rehabilitation efforts.

1.5.5. Industry Best Practices:

- The study can identify best practices and lessons learned from completed and successful asbestos mine rehabilitation projects. This information can serve as a guide for future projects, offering insights into strategies that contribute to timely and cost-effective completion.

1.5.6. Community and Environmental Impact:

- Assessing the completion status of asbestos rehabilitation projects is crucial for understanding the direct and indirect impacts of outcomes on local communities and the environment. This knowledge can inform strategies to minimise negative effects and enhance positive outcomes for affected stakeholders.

1.5.7. Research Gap Addressing:

- The study addresses a specific research gap by focusing on the completion status of D&O asbestos mine rehabilitation projects within a specific timeframe and cost. This targeted approach contributes to the existing body of knowledge on mine rehabilitation, particularly in the context of asbestos projects.

1.5.8. Sustainable Development Goals (SDG):

- By improving the efficiency of asbestos mine rehabilitation projects, this study contributes to several sustainable development goals (SDG), more specifically SDG 3 (i.e., Health and wellbeing), SDG 14 (i.e., Life below water) and SDG 15 (i.e., Life on land).

In summary, the significance of this study extends beyond the immediate scope of D&O asbestos mine rehabilitation, providing actionable insights for stakeholders and contributing to the broader discourse on effective mine rehabilitation practices based on deeper factorial research.

1.6. Outline of this Report

An outline of the study is provided below with brief explanations on what each chapter entailed.

- **Chapter 1**: Introduction: This chapter discusses the research context which includes background information on asbestos mining and the D&O project. It also addresses the problem statement that identifies challenges related to the delivery of rehabilitation projects in terms of timelines and costs. Moreover, the chapter explains the aims of the study, the research objectives, and the significance of the research.
- **Chapter 2**: Literature Review: This chapter provides an overview of asbestos, including its properties and occurrence. It discusses the various uses and applications of asbestos worldwide, as well as the mining activities associated with it. The chapter also explores the impact and effects of asbestos mining and

the challenges involved. In addition, it takes a closer look at the South African asbestos mining landscape, including rehabilitation efforts.

- **Chapter 3**: Research Methodology: This chapter outlines the research design, approach, and procedures used to collect, process, and analyse data for this study. The chapter has multiple objectives, including identifying and describing the research design, factors researched, data collection instruments, results analysis, measures of reliability and validity, ethical considerations, limitations, and challenges faced during the research. The focus of this chapter is to provide a comprehensive overview of the research methodology used in this study.
- **Chapter 4**: Results and Analysis: This chapter presents an analysis of 32 rehabilitation projects and identifies the factors that affected their delivery based on recorded data and information.
- **Chapter 5**: Conclusion and Recommendations: This chapter is a summary of the report. It starts with a brief reminder of the study's scope and objectives. After that, it concentrates on the most critical findings derived from the results presented in this chapter. Finally, it provides recommendations based on those findings.

2. CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

This chapter aims to provide a comprehensive review of the literature related to the topic of this research. The chapter covers a wide range of areas, including the properties and applications of asbestos, its global mining and production, and its impact on the health of communities. Additionally, the chapter provides an overview of legislation and restrictions that have been introduced concerning asbestos mining. Finally, it gives a detailed description of the South African landscape regarding asbestos occurrence.

2.2. Asbestos as a Mineral

According to the International Agency for Research on Cancer (IARC), the term ‘asbestos’ is a generic commercial name for a group of naturally occurring silicate fibres of the serpentine and amphibole series (Khan, Yoo, Wu, Lee, Kim, Park and Ro, 2022). Asbestos minerals may be broadly divided into two groups, namely: amphibole and serpentine. The description of the two categories of the mineral is given below.

2.2.1. Amphibole asbestos

Amphibole asbestos, which has a chain-like crystalline structure as seen in Figure one below comprised of mainly crocidolite (or blue asbestos) as well as amosite, tremolite, anthophyllite and actinolite (Khan, Yoo, Wu, Lee, Kim, Park and Ro, 2022) Because of their chemical structure and straight, needle-like fibres, amphiboles are very dusty (Kwata, Moja, Masindi, Mashalane, Mtyelwa and Malatji, 2017), as well as highly bio-persistent. In some countries, and for some special applications, amphiboles continue to be used for the following reasons:

- Crocidolite is the strongest of the asbestos fibres. It has high tensile strength and acid resistance. Long-fibre crocidolite is woven into fabrics used for boiler lagging, acid-resistant packing, and gaskets. Historically the principal use of the shorter crocidolite fibres was in the manufacture of asbestos-cement products, although this is no longer the case (Peña-Castro, Montero-Acosta and Saba, 2023).

- Amosite is highly resistant to heat and quite flexible but may be susceptible to strong acids and alkalis. It has less tensile strength than chrysotile or crocidolite and has only fair spin ability. Amosite asbestos has the longest fibre lengths. Its resistance to acids and seawater is greater than that of chrysotile, and it fuses at a much higher temperature than crocidolite. It is, however, somewhat more brittle. It is used in blanket form for felted insulation for high-temperature applications. In compacted form, it is applied as a covering for marine turbines, jet engines and similar applications (Khan et al., 2022).

Figure 1: Amphibole Asbestos

Source: (Kim, Kim, Kim and Hong, 2016)

2.2.2. Serpentine asbestos

Serpentine asbestos has a leafy or layered structure and is represented by chrysotile also known as white asbestos, which is the most common serpentine fibre (Herbst, Ed and Cur, 2014). It is silky in texture, with curly fibres, and as such serpentine asbestos is unlikely to remain suspended in the air (Figure 2).

Chrysotile currently accounts for more than 98% of world asbestos consumption. Its fibres are characterised by high tensile strength, resistance to alkalis, high flexibility, and good spin ability. Chrysotile's tensile strength and resistance to heat make it suitable for spinning and weaving and as a counteraction to heat and fires. It is mainly used for asbestos textiles, friction linings and facings, asbestos cement, and insulation products (Bernstein, Dunnigan, Hesterberg, Brown, Velasco, Barrera, Hoskins and Gibbs, 2013).

Figure 2: Chrysolite asbestos - a Serpentine subgroup

(Bernstein, Dunnigan, Hesterberg, Brown, Velasco, Barrera, Hoskins and Gibbs, 2013)

2.3. Occurrence of Asbestos

Asbestos minerals exist as bundles of flexible fibres, which are easily separable and have splaying ends (Schapira, Bolhar, Master and Wilson, 2023). The most commonly occurring type of asbestos is chrysotile, which is found in the form of fibres as veins in serpentine rock formations. The asbestiform minerals belonging to the amphibole group are found in many places in the earth's crust, either in large natural deposits or as minor contaminants in other minerals such as talc. Their chemical composition indicates the region and conditions in which they were formed (Khan et al., 2022). The geological region is the area and location where the asbestos is found, and the conditions are the natural and geographical conditions that helped form the mineral deposit of asbestos. Asbestos minerals are normally found near banded ironstone deposits and rock formations. Asbestos minerals are also found in many areas where the original rock mass has undergone metamorphism (Cornelissen, Watson, Adam and Malefetse, 2019a).

Asbestos is most commonly found in three rock types: serpentinites, altered ultramafic rocks, and some mafic rocks. Other rock types known to host asbestos include metamorphosed dolostones, metamorphosed iron formations, carbonatites, and alkalic intrusions. Faulting and fracturing of these rocks with increased temperatures, pressures, and the presence of water also contribute to the formation of asbestos minerals. The amount of asbestos or asbestiform minerals in various rocks can range in size from commercial-grade ore bodies to thin impure veinlets or low-grade occurrences (Schapira, Bolhar, Master and Wilson, 2023).

Asbestos is not a volatile substance, but its fibres can be released into the air through the natural weathering processes of asbestos-bearing rocks. However, the primary cause of airborne asbestos fibres is human-made activities such as mining (i.e., extraction activities), processing, and stockpiling of asbestos waste. During mining operations, asbestos and waste material are placed in dumps after extraction and the ore material is stockpiled for processing while material not suited for commercial use is left on surface areas as hazardous waste.

Asbestos can also enter the aquatic environment through both natural and human-made sources and has been found in surface water samples and ground samples due to the water-borne depositing after transportation from asbestos-contaminated sources (Liebenberg, Claassens and van Rensburg, 2012). Additionally, asbestos can be present in soil and sediments due to natural weathering processes or the erosion of man-made waste dumps and materials (Abratt, Vorobiof and White, 2004a). However, humans also contribute to its presence through various activities such as the disintegration of asbestos-containing roofing material, corrosion of asbestos-cement pipes, and industrial wastewater runoff.

Asbestos fibres are microscopic and cannot be seen by the naked eye. During asbestos mining processes, tiny asbestos fibres are released into the environment, contaminating the air and soil (Peña-Castro, Montero-Acosta and Saba, 2023). Asbestos fibres can travel long distances in the air before settling on the ground, thus contaminating areas far away from the source (Kwata, Moja, Masindi, Mashalane, Mtyelwa and Malatji, 2017). The fibres settle on top of the soil instead of absorbing into it, making it easier to disturb and redistribute into the air (Hart, 1988).

2.4. Properties and Applications of Asbestos

Humans have known about the qualities of asbestos and have exploited asbestos in small quantities for hundreds of years (Dauphin and Bernardin, 2019). Asbestos is a very versatile mineral and was seen as a ‘miracle fibre’ due to its unique and useful characteristics, which include chemical, electrical, and thermal neutrality, fibrous strength, fire resistance, and sound absorption (Hart, 1988),

The thermal resistance and properties have benefitted many industries and practices that required temperature insulation like furnaces, smelting industries, glass manufacture and metal extraction and processing industries. The fibrous nature allows the mineral to be woven into cloth and mixed with cement products.

The high temperature and wear resistance as well as insulating properties of asbestos, have also seen its implementation in many industrial and commercial applications, such as construction (e.g., roofs, water reservoirs, and pipes production), shipyards, railways, and textile industries (Cornelissen, Watson, Adam and Malefetse, 2019a), with over 3000 uses registered for the mineral during its peak production period in the 1970s (Frank, 2020).

Asbestos has been used in the manufacturing of various products. These products can be found in either friable or non-friable form. All products are also known as asbestos-containing material (Thives, Ghisi, Thives Júnior and Vieira, 2022). Typically, fragile asbestos products have a high concentration of asbestos in their dry state. It is simple to manually break or crush fragile asbestos into small pieces or dust. Fragile asbestos is typically employed as an interlayer material in industrial areas like heat pipes due to its loose texture.

Asbestos material was used in many applications and products from the Modern Era (1750 A.D to Present). These applications were used worldwide as well as in South Africa. (Abratt, Vorobiof and White, 2004b) Asbestos applications are tabulated in the table below.

Table 1: Asbestos Applications and Periods

Application	**Year**
Asbestos was used for wicks in lamps and candles.	1750 A.D to Present
Embalmed bodies of Egyptian pharaohs were wrapped in asbestos clothes to offset the ravages of time.	2000 – 3000 BCE
Used in Finland to strengthen clay pots	2500 BCE
Anecdotal evidence of Charlemagne's tablecloth made from woven asbestos	800—900 AD
Mediterranean people used chrysotile from Cyprus and tremolite from upper Italy for the fabrication of cremation cloths, mats, and wicks for temple lamps	1000
Marco Polo visited an asbestos mine in China in the latter half of the 13th century. He concluded that asbestos was a stone and lay to rest the myth that asbestos was the hair of a woolly lizard	1300—1400
Asbestos papers and boards were made in Italy	Early 1700
Benjamin Franklin brought a purse made of asbestos to England. The purse is now in the Natural History Museum	1724
United States (US) patent issued for asbestos insulating material used in steam engines	1828
Asbestos helmets and jackets worn by the Parisian Fire Brigade	1853
Moulded lagging material made from water glass and asbestos	1866
First asbestos brake linings were made by Ferodo Ltd., in England	1896
High-pressure asbestos gaskets made by Klinger in Austria.	1900
First asbestos pipes developed in Italy	1913
Standard corrugated sheet introduced in Australia by Hardies	1919
Wartime use included fireproof suits and parachute flares	1939—1945
Post-war construction projects relied heavily on the use of asbestos, reaching an all-time high in 1973	1945—1975
In the film ''The Wizard of Oz,' the Wicked Witch of the West appeared on a broom made of asbestos	1939
The solid fuel boosters of the space shuttle are insulated with asbestos, one of the few remaining current uses	1990s

Source: (Abratt, Vorobiof and White, 2004b)

2.5. Global Mining and Production of Asbestos

The commercial asbestos industry began in the final two decades of the 19th century. By the early 1900s, countries such as South Africa, Russia, Canada, and Southern Rhodesia (now Zimbabwe) had variously-sized asbestos mines. The majority of asbestos product manufacturing occurred in the United States and the United Kingdom (Cornelissen, Watson, Adam and Malefetse, 2019a). The major manufacturers of asbestos-based products often controlled the mines in the countries of origin. Chrysotile, amosite, and crocidolite were the most commercially valuable types of asbestos, with chrysotile accounting for over 90% of the fibres used during the 20th century (Cornelissen et al., 2019a).

During the Second World War, asbestos became highly valuable due to its strategic application in military and war equipment, and its various products which were deemed essential due to its resistance to heat and temperature in the industry. As a result, the industry expanded gradually until it reached its peak around the 1970s in terms of production and consumption (Li, Dong, Yu and Liu, 2014). At its peak, the worldwide production of asbestos was estimated to be 5.09 million metric tons in 1975, with 25 countries producing asbestos fibre for trade and export to 85 countries that were manufacturing asbestos products (Frank, 2020).

Asbestos production and consumption peaked globally, after which it saw a decline in the 1970s due to its discovered adverse health impacts. Asbestos was widely considered a carcinogen, leading to its removal from workplaces and private homes. Starting in the late 1970s, numerous legal actions were taken by affected communities and individuals impacted by respiratory illnesses caused by asbestos, resulting in major US asbestos companies filing for bankruptcy. Legal cases were also initiated against UK-based companies, with many claims being settled against them (Ndlovu, Naude and Murray, 2013). Consequently, many mines closed, with asbestos being banned in several countries.

In South Africa, asbestos was banned for any use or manufacture in 2008. South Africa also had many court cases and claims for compensation against the asbestos mining companies at the time. Asbestos is still mined in Russia, China, Brazil, and Kazakhstan (Allen, Baez, Stern and and Frank George, 2017). There are still great challenges around asbestos

mining locations regarding health and impacts in the remaining countries. As a result, there is a global move to alternative technologies to replace the use of asbestos and this has impacted the profitability of countries that are still mining the mineral (Nayak, 2016).

2.5.1. China

China has been a major producer of asbestos for decades and was the largest producer in the 1950s. Today, it remains the second-largest producer (Dauphin and Bernardin, 2019). This makes China a major player in the global market for asbestos production and consumption. China represents 30.5% of the total world asbestos consumption and was the first world consumer of asbestos (Dauphin and Bernardin, 2019). During the 1960s and 1970s, 62 to 90 million tonnes of asbestos were produced and used commercially due to the strength of the asbestos fibres (Lévesque, Bélanger, Poder, Filotas and Dupras, 2020).

A total of 310,000 tonnes were used for industrial and urban purposes in 2001, increasing to 450,000 tonnes in 2009 (Maphuti, 2019). Some asbestos materials were used for cement, sealing, gasket, insulation, and textiles (Kazan-Allen, 2009). As the case in other countries, health and safety risks associated with asbestos mining remain a concern. The health effects of exposure to chrysotile asbestos in China included lung cancer and gastrointestinal illness (Wang, Yano, Lin, Yu, Lan, Tse, Qiu and Christiani, 2013).

2.5.2. Canada

Asbestos mining in Canada began in 1899 and this led to negative health effects. In 1971, dust control legislation was introduced for mines and stricter standards were put in place to address the public health concerns (Peña-Castro, Montero-Acosta and Saba, 2023). The exposure of fibres per cubic centimetres and the contamination level were addressed in the standards. As a result, the allowable level of asbestos dust fibre exposure for miners was lowered from 5 fibres per cubic centimetre in 1971 to 1 fibres per cubic centimetre today (Becklake, Bagatin and Neder, 2007). Canada produced 240,000 metric tons of asbestos in 2003, making it one of the world's top producers (Luus, 2007).

Asbestos mining is typically carried out using two methods: underground digging and open casting (Kwata, Moja, Masindi, Mashalane, Mtyelwa and Malatji, 2017). The process of milling and transporting asbestos material to the plant involved sorting it into various grades. Long fibres were used for commercial purposes, while short fibres were discarded, leading to current exposure to fibres that cause asbestos-related diseases (Maphuti, 2019). This exposure is worsened by un-rehabilitated asbestos dumps. The current risk of exposure to asbestos poses a serious problem for miners and residents living near mines in the country. Residents are unknowingly inhaling dust contaminated with asbestos, which can cause abnormal lung functioning and lead to lung cancer due to a rare asbestos-related disease called mesothelioma (Burden, 1998).

According to Ndlovu et al (2013), the mine workers have experienced several diseases caused by exposure to asbestos. Asbestos fibre exposure can occur through ingestion, skin contact, and inhalation (Pira, Donato, Maida and Discalzi, 2018). Even at lower concentrations of dust, asbestos fibres can cause significant health effects. Most previous mine workers were exposed to asbestos at levels 10-100 times the legal limit of 1 fibre/cm3 in Canada at the time of the operational mines (Ndlovu, Naude and Murray, 2013). The last operations closed in 2011.

2.5.3. Russia

Russia is the largest producer of chrysotile asbestos in the world, gathering around 500,000 metric tonnes of asbestos annually from its mines. This accounts for roughly 20% of the world's supply (Pira, Donato, Maida and Discalzi, 2018). The city of Asbestos, located about 1440 kilometres northeast of Moscow, is responsible for Russia's high production numbers. The city was once known as the "dying city" due to its high rates of mesothelioma and related diseases. Chrysotile was mined in Russia through both underground and open-cast methods, and the milling process was used to separate the asbestos fibre grades based on their strength, tensile strength, and size. In Asbestos, asbestos shrouds were wrapped around the dead before their bodies were placed on funeral pyres to prevent their ashes from being mixed with those of the fire (Kwata, Moja, Masindi, Mashalane, Mtyelwa and Malatji, 2017).

Chrysotile was the primary form of asbestos mined, using both underground and open-cast mining techniques (Ray and Burr, 2014). Asbestos is commonly used for manufacturing a range of products, including asbestos-cement sheets, asbestos-cement pipes, brake linings, clutch linings, asbestos yarn and ropes, gaskets, and seals (Maphuti, 2019).

2.5.4. India

Asbestos mining in India started in 1973 and ended in 2002. While this is the case, abandoned asbestos mines in India still cause asbestos-related diseases among residents of Roro Village (Ray and Burr, 2014). Most people in this village are suffering from lung cancer, asbestosis, and other asbestos-related diseases, probably due to the presence of un-rehabilitated asbestos mine dumps in the area (Ray and Burr, 2014).

2.5.5. Brazil

In many countries, large quantities of asbestos remain in schools, homes, commercial buildings, and various industrial applications as a legacy of past construction practices. It has been reported that more than 6 million tons of asbestos have been used only in Brazil. Brazil is still mining and exporting asbestos despite a Federal Ban 2017 (Clemens, 2024). Unfortunately, estimates suggest that the rate of mesothelioma and related deaths will continue to rise in Brazil's future. In the 1980s, a pulmonologist at the University of São Paulo Medical School treated about 20 mesothelioma cases per year, and that number was slowly increasing. The majority of patients were current or former asbestos plant workers (Algranti, Ramos-Bonilla, Terracini, Santana, Comba, Pasetto, Mazzeo, Cavariani, Trotta and Marsili, 2019).

2.6. Impacts of Asbestos Mining

Asbestos mining has significant impacts in different areas. This section focuses on the health, environmental and social impacts of asbestos mining.

2.6.1. Health impact of asbestos

Asbestos is known to have negative health impacts, which were first recognised in 1899. However, it was only regulated in the UK in 1985 (Alapján, 2016), in Canada in 2020 (Burden, 1998), and in South Africa in 1987 (Cornelissen, Watson, Adam and Malefetse, 2019b). The delay in regulation was largely due to the industry suppressing results linking asbestos exposure to lung disease, such as the US Saranac studies of 1940 and the South African survey of asbestos and mesothelioma in 1962. Workers in the mines and consumers of asbestos products were not made aware of the dangers of asbestos.

Asbestos is a substance that can cause serious health problems when its fibres are inhaled. It is a known carcinogen for humans and can lead to diseases such as cancer of the lungs, larynx, and ovaries, as well as asbestosis and malignant mesothelioma (Maulida, Kim and Jung, 2022). Exposure to asbestos fibres usually occurs through inhalation or ingestion, while dermal contact is not considered a significant source of risk, although it may lead to secondary inhalation or ingestion.

The size of the asbestos fibre determines how deeply it can penetrate the lungs, with smaller fibres tending to penetrate deeper (Niklinski, Niklinska, Chyczewska, Laudanski, Naumnik, Chyczewski and Pluygers, 2004). Asbestos products have been widely used in the past, and therefore many individuals working in old buildings or doing renovations and repairs are still at risk of occupational exposure. The general population can be exposed to asbestos both indoors and outdoors. Ingestion of asbestos fibres can occur through the erosion of asbestos cement piped water, natural erosion into water sources, and the erosion of waste dumps.

2.6.2. Environmental impacts of asbestos mining

Communities and humans have the right to a healthy and safe environment, and mining operations have adversely impacted on many, and large areas of land affected by waste contamination, and made the areas unsafe and uninhabitable for human life. These areas that have been affected and contaminated by mining operations. Asbestos contamination affects large areas and poses great risks health-wise (Bennett, 2016).

2.6.3. Social impact of asbestos

The impact of asbestos mining on society is vast and long-lasting, particularly in the communities that have been affected by it. Asbestos miners in South Africa faced similar issues to those experienced in other mining regions, such as low wages, occupational diseases, difficult management, and shift work. The individuals who worked in asbestos mining, including men, women and children, were recruited from poor communities and generally did not receive support from company doctors, trade unions or regulatory agencies (Ndlovu, Naude and Murray, 2013)

After the asbestos mines in many communities shut down, the towns that had developed around them were left without any alternate sources of income. Apart from the evident ills and social consequences of mining, the towns are often heavily polluted with asbestos fibre, making future development difficult and causing continued exposure (Mhlongo, 2023). One such example is the town of Penge in the Limpopo Province of South Africa.

A study of the area recommended that the rehabilitated asbestos dumps be closed for livestock grazing as this would remove the only source of livelihood for the community. It was also recommended that the entire village be relocated as the town is so polluted that it is unfit for human habitation (Tanner, Beukes and Möhr-Swart, 2007a). However, neither of these recommendations were taken into account. There are also cases where communities have successfully taken on large asbestos corporations and even won their legal cases for compensation. However, the benefits of these victories were often short-lived due to the shortfall of decent and adequate sustainable income after compensation (Davis and Franks, 2014). There is currently no method of sustainable income after the closing of the asbestos mines occurred.

2.7. The South African Landscape

2.7.1. The geology and history of asbestos mining in South Africa

The mineral deposits of asbestos in South Africa are illustrated in Figure 3. The primary provinces where asbestos deposits occur are Free State, Limpopo, Gauteng, KwaZulu Natal, Mpumalanga, Northern Cape, and North West. The map below also indicates the type of asbestos mineral discovered in each province (Nelson, 2013).

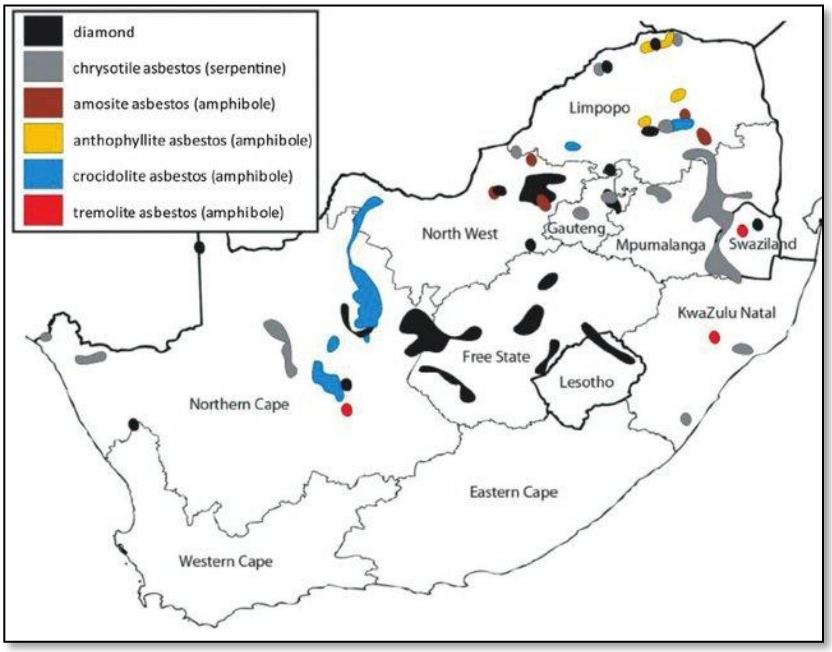

Figure 3: *Map of South Africa showing the geographical distribution of diamond and asbestos deposits*

Source: (Nelson, 2013)

The Limpopo province is a region of South Africa that boasts diverse natural features such as bush veld, majestic mountains, primaeval indigenous forests, unspoilt wilderness, and patchwork of farmland. The geology of the region is characterised by the Transvaal and Chuenespoort group, which contains carbonate rock formation with iron and magnesium embedded in the rocks that form part of the dolomite series in succession near the top, followed by a carbonate rock formation (Kwata, Moja, Masindi, Mashalane, Mtyelwa and Malatji, 2017). Most rocks in the province belong to the Malmani Subgroup and Penge formation, and the most common rocks found in the province are shale, dolomite, chert, quartzite, conglomerate, breccia, and diamictite (Kwata, Moja, Masindi, Mashalane, Mtyelwa and Malatji, 2017). Penge is a town located about 80 km northwest of Burgersfort, in the Greater Tubatse Local Municipality and Greater Sekhukhune District Municipality.

The asbestos mines were situated to the south of the Pietersburg asbestos fields, spanning an 80 km arc from Malipsdrift in the northwest to the confluence of the Olifants and Steelpoort Rivers in the southeast. The Penge asbestos mine and village are located at the south-eastern edge of the Pietersburg asbestos field (Phillips, Swanepoel and Rees, 2016).

The geology of Mpumalanga province is made up of the Tjakastad and Komatipoort Group and Transvaal Super Group. The common types of rocks found in the province are sandstones, shale, murchison, and intrusive granite. Komatiites often have unique and striking textures with skeletal crystals branching out like fern leaves, known as spinifex textures. This information is derived from Ward and Wilson's research in 1998 (Waldman, 2007).

The composition and textures of rocks can be determined by studying Komatiites lavas, which were formed from quickly cooling, hot, and possibly water-filled magma. The Barberton Greenstone Belt (BGB) is situated in the eastern region of Mpumalanga Province and contains numerous asbestos mines (Schapira, Bolhar, Master and Wilson, 2023).

The geology of the Northern Cape Province is marked by steep to moderately steep mountains, along with valleys at varying elevations. From a geological standpoint, the study area is a part of the Asbestos Hills Subgroup of the Transvaal Supergroup, located in the Griqualand West basin. This subgroup contains a significant amount of iron, which is present in the form of Superior type-banded iron formations (Maphuti, 2019).

2.7.2. Mpumalanga Province

There are several asbestos mines located in various regions of South Africa. These include Nelspruit, Kaapsehoop, Malelane, Senekal, Tjakastad, and Nkomazi Game Reserve. Additionally, there are mines situated between Badplaas and Carolina at Msauli and Rietfontein. In 1905, chrysotile asbestos was discovered in Kaapsehoop, and the processing of asbestos fibre involved milling. The mine started as an open pit and then later transitioned to underground mining. Msauli mining started in 1942 and closed in September 2001 (Kwata, Moja, Masindi, Mashalane, Mtyelwa and Malatji, 2017).

The Kaapsehoop ultramafic complex was found in four deposits located in the western addition of the Jamestown Schist Belt. These deposits were industrialised in four mines, namely New Amianthus or Kaapsehoop Asbestos Mine, Munnik-Myburgh, Stella, and Sunnyside. The Ribbon Line in the New Amianthus Mine is a remarkable zone of 2.13 mm fibres, with 165 seams and fibre lengths varying from 1.6-12 mm.

These mines have some of the longest fibre lengths recorded in the world, ranging from 50-152 mm in some places. Additionally, a cross-fibre measuring 218 mm was found and was highly sought after for museum specimens (Kwata, Moja, Masindi, Mashalane, Mtyelwa and Malatji, 2017).

In the intrusion layer, four mines were industrialised namely New Amianthus or Kaapsehoop Asbestos Mine, Munnik-Myburgh, Stella, and Sunnyside. The New Amianthus Mine has a spectacular 2.13 mm fibre zone called the Ribbon Line. This zone displayed 165 seams with fibre lengths ranging from 1.6-12 mm, which are among the longest recorded in the world. In some places, fibre lengths reached up to 50-152 mm. There were also cross-fibres measuring 218 mm that was found in some areas and was highly sought after as museum specimens (Hart, 1988).

All the mines in the Kaapsehoop region have stopped operating after producing over 222,348 tons of high-quality fibre (Hart, 1988). In the Barberton vicinity, two massive chrysotile asbestos deposits were found between the South African and Swaziland border gates, located in the Msauli-Havelock Ultramafic Complexes.

Asbestos and gold were first discovered on the Havelock Concession in 1887, which was named after Sir Arthur Havelock, who was the Governor of Natal at that time. However, it was only in 1918 that Izaak Holtzhausen rediscovered the existence of asbestos, exposed in the deposit. The major fibre was managed in 1939, followed by exploration and milling (Hart, 1988).

The mine initially operated as an open pit, but later switched to underground mining. Located in mountainous terrain, it was decided to connect the mine to the railhead at Barberton (Maphuti, 2019). To accomplish this, the Bleichert Company of Leipzig, Germany constructed an aerial ropeway spanning 20.36 km across the mountains. The aerial ropeway began operations in mid-1937 and was completed in 1939. It was designed to transport bulk materials weighing up to 13.5 tons per hour in both directions and was used to transport all the asbestos but not mine workers.

The ropeway was in operation successfully until the Havelock Mine stopped production in 2001. The mine produced over 2 million tons of chrysotile fibre and was once the second-largest asbestos deposit in the Southern Hemisphere, after the Shabani Mine in Zimbabwe. At the time, it was also the main contributor to the economy of Swaziland, as noted by Hart in 1988.

Asbestos was discovered in the serpentine ultramafic rocks of the Msauli Complex, which is believed to be an extension of the Havelock Complex. The African Chrysotile Asbestos Mine owns this border area. In 1942, C.J. Yissel and J.F. Cronje extracted 148 tons of fibre from the Msauli asbestos mine. The mine was located in the Diepgezet valley (Maphuti, 2019), and there was no bridge across the Komati River at that time. Therefore, an aerial ropeway was constructed across the river to transport the fibre by road to the railhead at Breyton, which is around 130 km away (Hart, 1988).

The asbestos fibre was milled and blended before being transported over the mountains to the Barberton area, covering a distance of about 40 km. The mine had four quarries and changed hands multiple times over the years. In 2001, the mine stopped operating after producing approximately 2.5 million tons of fibre. It was owned by Gencor and operated underground as a mining enterprise. Currently, the mine has been abandoned, and the mill and asbestos mine dumps have been demolished and rehabilitated. The village has been left as a ghost town (Hart, 1988).

The Stolzburg complex is a site located in the Barberton greenstone belt, where several other chrysotile asbestos deposits have also been discovered. It is home to three mines - Sterkspruit, Stolzburg, and Doyershoek - situated in Nkomazi Game Reserve near Badplaas. From 1942 to 1959, Stolzburg mine was the largest of the three, producing 38,877 tons of asbestos fibre (Brier and lia dwi jayanti, 2020). The Sterkspruit Mine, on the other hand, produced 10,769 tons of quality asbestos fibre from 1951 to 1963. Although mining continued in both these mines for some years, they were eventually closed, abandoned, and rehabilitated. Unfortunately, the production levels for the later years are not known. Finally, the Doyershoek mine operated from 1943 to 1946 and then again from 1950 to 1955, producing 4,190 tons of asbestos fibre in total (Hart, 1988).

Between 1928 and 1970, Kalkloof Mine operated to the north of Badplaas in the Kalkloof layered ultramafic complex. This mine produced over 45,000 tons of asbestos fibre. Although there were some minor chrysotile mining operations in the Barberton greenstone belt, there is no known data on their production.

Kwata have described the geological setting and the primary source of chrysotile asbestos deposit in the Kalkloof mine (Maphuti, 2019). All the deposits are found with layered ultramafic complexes, with the main host rocks being serpentinized dunites, harzburgites, and orthopyroxenites (Kwata and Moja, 2017).

Chrysotile asbestos, a mineral from the serpentine group, was mined in Mpumalanga Province. The asbestos was extracted through milling and transportation of the fibres across the Barberton Mountains. Since there was no bridge, the fibres were blown into the river during transportation. The mine is now abandoned, and the mill and mine dumps have been demolished and rehabilitated, leaving the village as a ghost town. The Barberton greenstone belt (Brier and lia dwi jayanti, 2020) also has other chrysotile asbestos deposits, including the Stolzburg Complex, which comprises three mines: Sterkspruit, Stolzburg, and Doyershoek, located in the southwest near Badplaas (Hart, 1988).

The Stolzburg mine was the largest of the three asbestos mines, which operated from 1942 to 1959 and produced 38,877 tons of asbestos fibre. The Sterkspruit mine produced 10,769 tons of quality asbestos fibres from 1951 to 1963. Mining continued for a few years after that, but the mine was eventually closed, abandoned, and rehabilitated. The production of later years is not known. The Doyershoek mine operated from 1943 to 1946 and again later from 1950 to 1955, producing 4,190 tons of fibre.

2.7.3. Limpopo Province

Asbestos mines are located in Ga-Mafefe, Penge and Burgersfort within the Limpopo Province. The rocks underlying all sites in Limpopo belong to the Chuenespoort Group and consist mainly of carbonate rocks (previously known as the dolomite series). Banded iron formation appears near the top in the North Eastern Transvaal, east of Chuenespoort, followed by more carbonate rocks (Kwata and Moja, 2017). Minor-scale asbestos mining started in Penge in 1914. By 1949, approximately 23 very dusty asbestos mills were present in the Penge area (Matsabatsa, 2009). Asbestos mine dumps were formed by waste rock and materials from the mills during the mining period. Site buildings and residential quarters were constructed for mine workers.

In 1962, the Pneumoconiosis Research Unit (PRU) surveyed the Penge Area in the Limpopo Province and concluded that everyone who lived in the area was at risk of asbestos contamination, even those with no industrial asbestos exposure (Kwata, Moja, Masindi, Mashalane, Mtyelwa and Malatji, 2017). Griqualand Exploration and Finance Company Ltd (GEFCO) started rehabilitating asbestos mine dumps in 1986 until the mine's closure in 1992. After the mine's closure, approximately 250 houses and other buildings previously belonging to the mine were used for residential purposes by local people and former mine employees (Matsabatsa, 2009).

2.7.4. Northern Cape Province

The Asbestos Mountains are a range of hills located in the Northern Cape province stretching south-southwest from Kuruman to Prieska. The range is situated about 150 km west of Kimberley and rises from the Ghaap Plateau. The mountains were named after the asbestos that was mined there in the 20th century. The asbestos found in the area is known as crocidolite, which is a variety of amphibole. It is found in veins in slate rocks and is associated with jaspers and quartzites rich in magnetite and brown iron ore. Geologically, the Asbestos Mountains belong to the Griquatown series.

The asbestos rocks are found between strata of rocks. With a little beating, the rocks become Prussian blue; others are golden, white, brown, and green (Matsabatsa, 2009). Asbestos has been known to people since the days of imperial Rome. It was used in women's gowns for its fire-resistant properties. The serious mining of crocidolite in these mountains began in 1893 when open-cast quarrying produced 100 tons of material (Hart, 1988).

By 1918, underground mining had started, and scattered mines were found from Prieska to Kuruman along the length of the range. Mills were constructed in both of these towns. Between 1950 and 1960, production had risen to 100,000 tons. Each mine was doing its own milling, and the tailings dumps had grown in size (Maphuti, 2019)

The geological processes that produced the Green Mountains in Vermont in the US are the same as those that produced the Asbestos Mountains. These processes produced an abundance of serpentine, which is the source of chrysotile asbestos (Maphuti, 2019). During the mining process, asbestos would regularly go airborne and spread to nearby towns. A field study conducted from 1960 to 1962 in the Northern Cape cities of Prieska, Kuruman, and Koegas confirmed that people living in proximity to these mines and mills faced risks of contracting asbestosis, a non-cancerous asbestos-related disease (Maphuti, 2019).

A high number of cases of mesothelioma of the pleura had been discovered among people who have lived in the Northern Cape, and there was evidence that this condition was associated with exposure to non-industrial asbestos dust inhalation. Asbestos has heavily contaminated many parts of South Africa, most notably the Northern Cape Province. Even with the last asbestos mine closed, the province still struggles with exposure risks from the region's 82 remaining asbestos mine dumps (Phillips, Swanepoel and Rees, 2016).

2.7.5. Gauteng Province

Asbestos mines are located in Muldersdrift, on the way to Krugersdorp, and in the West Rand. Honingklip is a farm located about 10km north of Krugersdorp in the Mogale Municipality, Gauteng Province, South Africa. Asbestos was mined in the Muldersdrift ultramafic complex, which contains chrysotile asbestos mineralisation associated with serpentine dunites. The area where the mining took place has not been rehabilitated and developments are expanding. Gelden asbestos mine was located in the Honingklip mine farm and operated in the early 1930s (Cornelissen, Watson, Adam and Malefetse, 2019b).

The white asbestos mineral (chrysotile) was mined in the serpentine rocks of the Archaean system. Mining operations in this area were short-lived, and mining ceased before 1930. This former asbestos mining area has now been developed into an estate called Artificial Dam (Maphuti, 2019). West Rand asbestos mine is situated in the West Rand area, and asbestos mine dumps are close to local communities. The combustion gases from the mine are affecting the local communities (Maphuti, 2019).

2.7.6. North-West Province

The Pomfret asbestos mine, which was previously rehabilitated, is now open to the public. Unfortunately, chrysotile asbestos fibres have been exposed right next to the road that the community frequently uses. On the site, an open inclined shaft was observed, which poses a significant danger. According to Freemantle et al (2022a), a young boy lost his life while swimming inside it when it rained. Additionally, there is a tall, nine-story old infrastructure on the site, along with several other old structures that contain asbestos material posing health and safety risks in the community (Freemantle, Chetty, Olifant and Masikhwa, 2022a).

2.7.7. Kwa-Zulu Natal Province

Asbestos mines can be found in the Kwa-Zulu Natal Province in Fort Yolland Village. The mine site is situated near a village about 5 km away. Although the site is frequented by people and livestock, most materials from the mine are covered by grass and the surrounding area is highly vegetated, which helps prevent ground erosion (Maphuti, 2019). The mine is also located close to a sugarcane field and can be seen from a major road that is within 200 meters.

The site has several open holes, but the deep ones may have been closed off with rocks in the past as an attempt to stabilize the slope. The opencast hole on top of the hill measures around 50 x 60 meters and has evidence of erosion material, but grass has started to grow and cover the exposed rock.

Another asbestos mine, called Ntulwane, is also situated close to a sugarcane field. (Maphuti, 2019). Sithilo asbestos mine is located a few kilometres from local communities, but there is a deep accessible pathway where people and animals pass by daily. Visible asbestos ore can be seen scattered on the hill.

Other asbestos mines in the area include Lilani and Madegela. Lilani is situated next to a hot spring, and the excavations from the asbestos mines in the area were more like prospecting holes, which were closed (Maphuti, 2019). On top of the mountain, overlooking Lillani village, there are closed diggings covered by thick overgrowth. The area attracts tourists due to the hot springs.

There are some waste rock dumps in the fenced-off grazing camp near the mine adit, but there is no evidence of new fibres entering the environment. The people in the area remember that small operations of asbestos/mica prospecting in the area ceased around 1989 (Maphuti, 2019).

2.8. Asbestos exposure and impacts

According to studies by Moja and Kwata (Maphuti, 2019) different environmental samples were analysed to test for asbestos mineral presence in dust filters, plant and soil specimens, and other samples collected from areas affected by old abandoned asbestos mines in South Africa. The results of the analyses showed that asbestos minerals were present in all samples. Samples were collected from areas around the asbestos dumps that impacted communities and the environment. Samples were taken from January 2016 until July 2016 (Maphuti, 2019). Statistical and risk assessment tools were used to interpret the results of the collected data and soil samples. About 60% of the asbestos mineral was identified from asbestos waste material at the surface and 67% on dirt roads or yards daily used by inhabitants.

A review of published reports and articles on asbestos-affected victims and the impact of asbestos exposure on human health, specifically cardiovascular health was done (Ray and Burr, 2014). The retrieved data from the PubMed database was used with meta-analysis to analyse the collected data. The results showed that asbestos exposure could increase the risk of cardiovascular-related disease mortality amongst mine workers compared to those from mining and cement production. Samples were collected from mines where crocidolite was present, and these samples showed oxidant activity and cell toxicity.

The Campopiano study methodology involved collecting samples from house roofs using air samplers to gather airborne specimens (Obmiński, 2022). The presence of asbestos in house roofing was a great risk to communities. The airborne samples were then analysed using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS) techniques. All samples were coated with carbonate before analysis began. The analysis revealed the presence of amosite in both the roof and airborne samples. The analysis revealed the presence of amosite in both the roof and airborne samples. Additionally, cement roof and asbestos cement were detected, which a great concern for the local residents living around the abandoned asbestos dumps in South Africa.

Felix and Randeree conducted a study on the secondary effects of asbestos contamination in South Africa (Maphuti, 2019). The study aimed to determine the impacts on communities and the effects of such exposure. The occurrence of respiratory diseases in Mafefe, a community with a population of just over 11,000 people was documented. The study found that asbestos exposure resulted in Asbestos Related Deaths (Phillips, Swanepoel and Rees, 2016) with rates of 34%. Moreover, the environmental and occupational disease rates were as high as 49%.

2.9. Establishment of the Derelict and Ownerless Mines (D&O) project

Between 1910 and 2001, South African mines exported millions of kilograms of asbestos annually. However, due to the mineral being restricted, along with all imports and applications, the state closed down these activities in 2008. Currently, in South Africa, there are roughly 6,000 abandoned and unclaimed mining sites, out of which 265 are old asbestos mines. To address this issue, the DMRE initiated the D&O rehabilitation plan in 2000 (DMR, 2019), which focuses on rehabilitating and prioritising high-risk asbestos mines in various national regions including, the Northern Cape, Limpopo, Mpumalanga, and others. The Minerals and Petroleum Resource Development Act defines rehabilitation as restoring the environment to its natural condition before mining operations (Tanner, Beukes and Möhr-Swart, 2007b) . The Occupational Health and the Amended Asbestos Health and Safety Act apply to asbestos rehabilitation projects, and all projects and operations must comply with Asbestos Inspection Authority standards (Department of Labour, 2020).

After asbestos mining was prohibited, respiratory illnesses related to the mining became widespread, affecting social, environmental, economic, and communal spheres. To address the health, safety, and environmental risks associated with abandoned asbestos mines, the State asked the Council of Geosciences (CGS) to locate, identify, and prioritise asbestos mines based on the risks they pose to local communities (DMR, 2019). On April 1, 2015, a catalogue of 5,906 abandoned mines was released. The Acting Deputy Director General, Mosa Mabuza, stated that "policy and promotion were essential in perpetuating the context in which the problem of abandoned and unclaimed mines existed" (Auditor General South Africa, 2009).

Mining has always been the backbone of South Africa's economy, and it became crucial to involve the mining sector in discussions about pertinent issues. Before the 1991 Mining and Environmental Summit in Rio de Janeiro, the mining industry in South Africa did not have a strategic approach to environmental sustainability. The Minerals Act, No. 50 of 1991, marked a paradigm shift in environmental affairs and served as the foundation for the Mineral and Petroleum Resources Development Act (DMRE, 2019b), which was enacted in 2002. The DMRE programme to resolve abandoned and unclaimed mines began in 2000 but was immediately hampered by human resource and funding issues. In 2009, the DMR enacted the National Strategy on

Abandoned and Unclaimed Mines, which established a Rehabilitation Oversight Committee to help overcome the obstacles. The evaluation of 6,000 abandoned and unclaimed properties has already been completed, but this number is not fixed and is subject to change. With the implementation of the law, the DMRE became responsible for the rehabilitation of abandoned and ownerless asbestos mines (Department of Mineral Resources, 2009). To date, around 40 of the 249 asbestos mines on record have been rehabilitated by the government at a cost of around ZAR 800 million (Cornelissen, Watson, Adam and Malefetse, 2019b)

The current process for rehabilitating mines involves identifying the site in consultation with the DMRE. The focus is on areas that are classified as "derelict and ownerless mines." The responsibility of the DMRE is limited to rehabilitating areas within the former Republic of South Africa mining limits and not outside of them. The limits of rehabilitation are set by identifying the point where ambient soil asbestos contamination levels exceed 1.8 % 'free' asbestos fibres. Only those areas that fall below this level of contamination are excluded from the primary contamination source and where the main mining area was.

The level was set by reviewing soil sample results from previous rehabilitation sites and determining the average residual contamination levels outside the rehabilitation area (Tanner, Beukes and Möhr-Swart, 2007a). The waste dumps that have been identified are covered by 300 mm of clean soil that is usually extracted from a nearby source. The slopes are designed to be no steeper than 12 degrees and may include structures such as stone gabions and diversion channels that help control surface water movement and minimise soil erosion. Indigenous plants that are non-edible are planted in the dumps to prevent foraging and grazing by local livestock. The dumps are then monitored for a period of three to five years to ensure their integrity. The rehabilitation project focuses on covering open shafts or holes, main contaminated areas, and mining dumps.

2.9.1. Filling of open shafts or holes

Most asbestos mine open shafts or holes are vertical and inclined shafts. The width of the asbestos open shafts ranges from 10 m to 50 m. It is easy for livestock and wildlife to get trapped in the open vertical shafts and holes (Maphuti, 2019). In the horizontal open shafts or holes, the depth ranges from 10 m to 50 m. It is important to seal the open vertical shafts or holes to reduce physical damage and loss of human life.

2.9.2. Rehabilitation of asbestos mine dumps

Waste rock and tailings are mining waste on land surfaces, which often pose highly stressful conditions for rehabilitation (Li, Dong, Yu and Liu, 2014). The conditions of abandoned mine tailings are highly varied in terms of their physical, chemical, and ecological aspects. Mine tailings are typically inconsistent in physical composition with regards to their depth and low in organic matter and essential plant nutrients, which make it difficult for vegetation to establish (Maphuti, 2019).

It is unlikely that the area impacted by mining activities will be restored to its original condition and land use (McKenna and Williams, 2006). Section 38(1) of the Mineral and Petroleum Resources Development Act (DMRE, 2019b) of 2002 requires the mine area to be rehabilitated to its natural or predetermined state, but this is subject to practical limitations and involves a Public Participation Process to determine the end use. Coaltech (Tanner, Beukes and Möhr-Swart, 2007b) identifies three different perspectives on the objectives of rehabilitation, which are

- Instead of maintaining the previous status quo, the focus is on fulfilling the requests of the affected human settlements.
- The original thought process in the South African context was to restore previous land use capability, particularly when mining occurs on land with high agricultural potential.
- No net loss of biodiversity: there must be no loss of biodiversity and rehabilitation must restore the biodiversity of the site to its natural state.

The objective of rehabilitation usually includes aspects of three approaches in the South African setting. These objectives must be in line with the Integrated Development Plans (IDPs) of the national and regional levels, which may or may not correspond with the desires of the local community (Tanner, Beukes and Möhr-Swart, 2007b).

2.9.3. Rehabilitation outside the mining sites

The responsibility of rehabilitating soil outside of designated mining sites lies with the Department of Environmental Affairs and Tourism (DEAT). So far, the DEAT has started some remediation of asbestos contamination around former mine sites (Environmental Affairs, 2021). Rehabilitation efforts so far have only focused on former mining areas, including the more significant and obvious waste disposal sites. These sites have been estimated at 121 countrywide, a number that is substantially lower than the actual number (Freemantle, Chetty, Olifant and Masikhwa, 2022b).

According to the CGS, secondary contaminated locations containing asbestos waste are more widespread and may be in the thousands due to decades of poorly controlled waste disposal practices, including using waste asbestos in local building materials. Secondary contamination includes waste and contaminated asbestos fibre exposure in locations away from main mining areas caused by spread, or distributed by other means (Virta, 2002).

2.9.4. Local Challenges and Rehabilitation

Several challenges hinder the rehabilitation of D&O mines worldwide. The reasons for the delay in rehabilitating abandoned mines include the absence of clear responsibilities assigned, inadequate criteria and standards for rehabilitating these mines, and the high cost of rehabilitation, which is typically expensive without any clarity on the funds' source (Cornelissen, Watson, Adam and Malefetse, 2019b).

The rehabilitation of D&O asbestos mines in South Africa also faces several challenges. These include issues related to legal clarity, the process and requirements for undertaking government-funded rehabilitation, and various technical concerns. These challenges are discussed in more detail below.

2.9.4.1. Legislative challenges

In South Africa, the Mines Health and Safety Act (Act 29 of 1996) is responsible for regulating health and safety legislation on mines, while the Occupational Health and Safety Act (Act 85 of 1993) is responsible for all other industrial and construction sites and is regulated by the Department of Labour. Rehabilitation of asbestos mines is not a listed activity under the MPRDA but falls under the Occupational Health and Safety Act as a construction project, this challenges the Mine Health and Safety Act and causes regulatory and compliance issues on projects. The need to comply with various legislation complicates the design and implementation of asbestos rehabilitation (Department of Labour, 2020). As a result, project implementers face challenges when trying to comply with legislation that does not always make practical or financial sense, taking into account the financial requirements, especially in the context of mine rehabilitation.

The MPRDA includes provisions for the implementation of a Social and Labour Plan. The purpose and objectives of this plan are to integrate and manage the social, economic, and environmental impacts of mining throughout all phases of a mine, until closure to avoid job losses and mitigate the social and economic impacts on individuals in the event of premature mine closure or at the closure of mines. The implementation of the SLP also aims to prevent the establishment of settlements that cannot be sustained after the closure of mines (Swart, n.d.). Mine rehabilitation is not a mining or beneficiation activity and is strictly a civil construction activity, and there is no economic gain economically (DMRE, 2019a). As such, the requirements towards SLP cannot apply. However, there is usually an expectation from communities to benefit from rehabilitation projects.

Additionally, the processes, roles, and responsibilities involved are not always clear. The absence of specific legislation poses a problem as it creates confusion regarding the roles of various parties involved, the mandate of DMRE, and the relevant state-owned enterprises such as Mintek and CGS including requirements to comply with the laws. The existing legislation also presents expensive compliance requirements (Cornelissen, Watson, Adam and Malefetse, 2019b).

The need for environmental impact assessments is required, and it is a very costly process and can be very time-consuming to prepare and comply with the legislation and environmental laws. Any project according to law that has an impact and affects the environment adversely needs an official environment impact assessment to be submitted and this includes the rehabilitation of mines.

A water-use license is mandatory when water is used for projects from available natural sources to provide for adequate dust suppression and large volumes are required at times. Environmental laws require the need of a license when large volumes of water are needed above the standard uses. Asbestos projects use large volumes of water for the suppression of dust as required by Health and Safety

Standards. This further adds to the costs and affects the implementation of rehabilitation projects (Freemantle, 2019).

More so, all the rehabilitation sites require clean and asbestos-free topsoil for covering contaminated areas, this requires an official mining right and approval from the Minister of Mining to excavate and establish borrow pits at the rehabilitation sites, to obtain material as asbestos coverage material. In many cases, the clean material is not available in the near vicinity of the rehabilitated areas and needs to be obtained from distant locations. Commercial rock and materials are acquired from local commercial sources and are very expensive and subject to local pricing and supplier demands (Freemantle et al., 2022a).

Currently, rehabilitation projects are not officially exempted from standard regulations that prohibit the use of certain materials such as rock, soil and water without proper administration and licenses. This means that projects have to obtain and purchase these materials from commercial sources to avoid breaking the law. Unfortunately, this leads to higher costs compared to when the projects can have exemptions from these requirements. Obtaining a mining license takes time and all excavation and beneficiation of minerals require a license from the Minister of Minerals legally (Cornelissen et al., 2019b).

Mines, both today and in the past, were major contributors to the Gross Domestic Product (GDP) of South Africa. Despite their contribution, abandoned mines remain a costly legacy due to confusion in policies and legislation, posing major risks to the environment and the communities living around these abandoned sites (Kuipa, 2023). The funds utilised for D&O rehabilitations are state-approved funds and is taxpayer funds through the treasury. As the initial polluter has been deemed absent, the state now must fund the projects for rehabilitation and public health purposes. This places great responsibility and accountability on rehabilitation projects. The increased public awareness related to responsibility and visibility adds to extra care components.

Additionally, the formal closure process for a site that is rehabilitated by the State is still not perfectly defined. Like other countries dealing with abandoned mines, South Africa is also undertaking a legal reform process to prevent the abandonment of mines and the associated costs of rehabilitation incurred by the state. Currently, legislation requires a draft closure plan to be submitted before opening a new mine and further development of this plan over the life of the operation (Cornelissen et al., 2019).

Financial provisions for closure must also be lodged, reviewed and adjusted regularly, which is in line with global best practice. However, these requirements can complicate the rehabilitation of abandoned mines. This was discussed in the ‘Linking science, society, business and policy for the sustainable use of abandoned mines in the SADC region's conference held in November 2017 (Anon., 1994).

Ideally, a rehabilitation site should have a viable end-use to justify the expense of rehabilitation, and to achieve this, it is important to note that all sites are site-specific and would be subject to different end-use goals. According to Lowry et al (2019), post-mining landscapes must integrate with the surrounding undisturbed environment geo-morphically and ecologically. Some models help guide rehabilitation strategies by understanding the pre- and post-mining landscape (Lowry, Narayan, Hancock and Evans, 2019). It has been argued that there is no specific guideline to follow when carrying out a rehabilitation project for a mine. Each case is different and influenced by many factors that depend on the specific area where the mine is located (Menegaki and Nair, 2019). The planning involved and further stakeholder engagement for the repurposing of land or infrastructure complicates the rehabilitation process.

2.9.4.2. Process challenges

The rehabilitation of D&O mines is a responsibility of the government, which involves different administrative processes that can complicate the rehabilitation efforts (DMR, 2019). These processes include shared responsibility and requirements of different government departments, budgeting cycles, timeframes, and the need to involve local community participants and stakeholders.

Mintek is responsible for managing the rehabilitation process, as contracted by the DMRE. The rehabilitation process is generally a cyclical process that involves obtaining the contract from DMRE, planning, agreeing on projects, scoping, designing, tendering, and finally, implementation on a three-year cycle (DMRE, 2021).

However, this process has a predictable cyclic nature that results in a systemic lag in the process. This is because project implementers must wait for certainty of funding before starting a new project planning cycle. The State department that sponsors the rehabilitation does not plan for longer than three years, as prescribed in the Medium-Term Expenditure Framework funding cycle. Therefore, the State-Owned Enterprises (SOEs) are not allowed to commit anything until a master contract is signed. This means that most of year 1 of the three-year cycle is usually spent with contracting, design, and approvals, and no actual work is done on-site (National Treasury South African, 2015).

Designs take between 6 to 9 months to complete and the prescribed government procurement process takes up to 3 months after that, further delaying progress. The risk with this approach is that the implementing agent may spend too much on planning for projects far into the future that may never get authorised to proceed to implementation, resulting in fruitless expenditure (PFMA Government of South Africa, 2001).

The government tender processes follow a model in the Procurement Financial Management Act and this requires the award to the lowest bidder after technical criteria have been met (Government Gazette, 2003). This is a challenge with asbestos rehabilitation locations that are more complex with difficult geographical terrain. The simple and cheaper rehabilitation projects have mostly been completed and the remaining rehabilitation projects are much more complex and larger in terms of construction and financial size going forward. The lowest bidders are often not financially capable to start or finance the project, so they are heavily dependent on cash flows from progress invoicing and payments. They are caught in a proverbial 'Catch-22 situation', they must spend money to make money, but they cannot spend the money upfront to claim it back and make their profit in the project. Additional problems arise when companies submit a low-ball bid and then want to increase the contract price by variation order when they have underestimated key project costs.

Stakeholder engagement is an important process common to many countries' abandoned mines programmes, including South Africa. In addition to this engagement, the rehabilitation of D&O mines provides an opportunity for the employment of local community members, largely as short-term, semi-skilled labourers. This was one of the proposals from the National Asbestos Summit in 1998 (DMRE, 1999), that rehabilitation must be linked to development and is currently the practice.

Contractors rehabilitating sites are required to use local labour and to procure goods and services from local suppliers (PFMA Government of South Africa, 2001). This brings direct financial benefit to communities that have been negatively impacted by mining operations. However, their involvement is not always straightforward and can increase the cost of a project.

It has been found that communities do not always understand the purpose and sponsorship model of rehabilitation projects. Communities then make demands on the project similar to those they would make on a commercial mine. State procurement rules prevent the project implementing agents from complying with these community demands, creating fertile grounds for conflict enacted to secure funding for the rehabilitation of abandoned sites. All wages and salaries are conformant to the Department of Labour policies and regulations for all projects in South Africa (The Republic of South Africa, 2022), rehabilitation is funded by the government from the central fiscal budget. With various and competing demands, budgets are limited with a focus on delivery.

Asbestos mining and its impacts are commonly used as reasons for activism and resistance against rehabilitation projects. Historical issues with health and mining activities that have been discontinued impact the relationships and activities in the areas that need to be rehabilitated through communities feeling that the area and the state still owe them due to failures in compensation and health support from the past (Thives, Ghisi, Thives Júnior and Vieira, 2022).

2.9.4.3. Technical challenges

The goal of rehabilitating asbestos mines is to eradicate the dispersion of asbestos fibers and restore the disturbed area to a stable natural ecological state (McKenna and Williams, 2006). This must be accomplished in abandoned sites that have often deteriorated and where there is limited prior knowledge of the mine locations. Asbestos mining across the country occurred in arid areas where it is harder to establish vegetation and special vegetation methods need to be implemented. The areas to be rehabilitated are challenging due to geology and topography and the designs and implementation for rehabilitation need to consider the technical challenges caused by the surrounding areas and the geological location of the mines to be rehabilitated. This requires customized “out-of-the-box thinking” and adds to the difficulties of rehabilitating the area and the mining area impacts.

In addition to these challenges, the planning horizons are very short. An operating mine has several years of production decline and an opportunity to plan for closure. In the mine rehabilitation project, the team is pushed to produce a closed site within a given year or even according to quarterly targets (Cornelissen, Watson, Adam and Malefetse, 2019a). This could result in planning or production shortcuts and lead to quality compromises.

A planned mine closure has not just time, but also funding, to use to do the rehabilitation. Mines closed by the state do not have this luxury and must use zero-based budgeting to motivate project funding in each case (Freemantle, 2019).

Resources for cleaning up abandoned mines are very limited in most jurisdictions Likewise, one can assume that no topsoil has been stockpiled and there are no recent mine plans to work from, so everything must be sourced or re-created from scratch, increasing costs. The choice of soil, rock, plants, and other materials to use in the closure process is therefore limited to what can be found on-site or sourced locally, leaving little or no room for creative or alternative closure solutions. As already mentioned, the effective transfer of responsibility for monitoring and aftercare is still not resolved, and there is no funding to maintain completed sites. Even if a site is rehabilitated to a good standard, the entity taking control or having effective control of it afterwards may not have the funding to maintain it (Mhlongo, 2023).

Access to rehabilitated sites needs to be controlled to allow vegetation to re-establish. This is difficult where land is communally owned. There are examples of where rehabilitation has had to be redone following access to the site by livestock. In this case, unpalatable and impenetrable species were used to minimise subsequent trampling and grazing of the rehabilitated asbestos dumps. This meets the first aim of rehabilitation to cover and prohibit further contamination of surface asbestos but does not promote the second goal to provide a useful end-use. Some of the vegetative species previously used on rehabilitation sites proved to sanitize the areas for any further useful plant species and this was counter-productive to sustainable end land use. An example was the introduction of ‘MELKBOS’ Euphorbia Mauritanica a succulent plant that allows no undergrowth useful for grazing or animals due to the complete exclusion of natural sun and the toxicity to animals after revegetation installation (Matsabatsa, 2009).

An emerging challenge is the reopening of rehabilitated sites because of illegal material recycling taking place in the country. Cases are on record where members of communities living in proximity to old, previously closed asbestos mines have re-opened the mines to access resources of economic value still contained in the old mining infrastructure like steel and other sellable materials. In the case of asbestos, this does not extend to mining of the ore reserve, as there is no market for it, but rather "mining" for other resources still underground, including steel, copper, and cabling for sale as scrap metal (Cornelissen, 2019). This is a major concern, from an economic, environmental, health and safety perspective, and needs urgent attention. Addressing this may include ensuring that nothing of value, including scrap metal, is left behind following rehabilitation, and more constructive involvement and support from local communities.

2.9.4.4. Challenges affecting rehabilitation as a construction project

Rehabilitation projects are predominantly construction projects and can be impacted by challenges and other issues. Construction projects globally have also had time and cost delays that was caused by a variety of factors. Environmental impacts, such as pollution, can often lead to or trigger conflict with broader social and economic issues, like the distribution of project benefits or the quality of the construction company's ongoing consultation processes, typically causing underlying conflict situations. These underlying issues can affect the quality of the relationship between the company and the community, which can be categorised by confrontations (Davis and Franks, 2014).

The effects of political and electoral cycles cause impacts and conflicts on cost overruns of projects. The sustaining of political economies and opportunistic behaviour results in institutional and regulatory time delays (Franks, Davis, Bebbington, Ali, Kemp and Scurrah, 2014). Some root causes of factors affecting construction projects were found to be a lack of project-specific experience by project teams, external and organisational decisions in the past, community resistance, and pressure on the project team, including scope changes driven by stakeholders (Simushi and Wium, 2020a). Delays and cost overruns in public sector investments can increase the capital-output ratio and reduce investment effectiveness, impacting estimates of delays, cost overruns, and opportunity costs (Morris, 1990).

2.10. International case studies of rehabilitation

2.10.1. The case of Mountain View Mobile Home Estates, Arizona, USA

Mountain View is a small mining town situated in Gila County, Arizona (US Environmental Protection Agency, 2009). The town was established to house miners who were working on the extraction of blue asbestos in the region from 1953 to 1974. However, due to health concerns regarding air pollution caused by asbestos dust, the mine was shut down in 1974. After the closure of the mine, the land was flattened, and the asbestos waste was used for landfilling. The reclaimed land was then divided into 55 plots, on which a residential estate was built to accommodate approximately 130 people (Matsabatsa, 2009).

In 1979, it was discovered that the soils and air of a certain community were contaminated with asbestos, making the area unsuitable for human habitation. The residents were temporarily relocated while the areas were rehabilitated. The mills were demolished, and all the contaminated material was buried. A 1.5-meter topsoil cover was placed over the buried material to prevent asbestos migration. Unfortunately, in 1981, it was found that erosion and human activities had exposed the asbestos again (US Environmental Protection Agency, 2009).

The community was relocated once more in 1983 while a four-week investigation and feasibility study were conducted to determine the best course of action. The possible solutions considered included abandoning the site, rehabilitating it through the removal of asbestos, and capping the asbestos tailings. Investigations concluded that, due to the level of contamination, a permanent solution was required. Based on cost-effectiveness, feasibility, and the most effective way of protecting public health and the environment, it was decided that the estate be abandoned, fenced off and permanent relocation of residents be carried out. The community was permanently relocated in 1985 (US Environmental Protection Agency, 2009).

The government purchased the properties that were affected, and then demolished and buried them. To prevent further erosion, the entire area was covered with filter fabric. Crushed rock was then placed on top of the capping, and the area was fenced off and monitored for 20 years. Monitoring conducted in 1988, 1991, and 2005 indicated that there was no further contamination. The site has not been redeveloped but serves as a reuse and assessment site until the funds are available to repurpose the location (US Environmental Protection Agency, 2009).

2.10.2. Asbestos contamination in Wittenoom, Australia.

Wittenoom was a mining town established in 1937 in northern Australia for asbestos miners (McNulty, 2011). It was the largest town in the north of Australia. The area was mainly used for mining blue asbestos, which yielded about 150,000 tonnes between 1937 and 1966. It was estimated that the asbestos waste ore (tailings) amounted to about 3 trillion tonnes (GHD, 2006).

The air in a certain area was found to have high levels of asbestos fibres. As a result, the Australian Department of Environment and Conservation declared the area contaminated. In the late 1970s, the community was temporarily relocated to rehabilitate the town due to the high number of asbestos-related diseases, including 40 deaths and many reported illnesses (GHD, 2006). A risk assessment conducted showed that the airborne asbestos was blown over an area of about 10 square kilometres. The study identified 29 strategic options aimed at reducing the sources of contamination, managing the exposure pathways, reducing the movement of contamination, and managing user groups to reduce exposure to contamination.

These options were evaluated based on cost, health and safety, social acceptability, and impact on physical and natural processes and ecosystems. The risk assessment recommended that the town be closed, with all buildings except the graveyard demolished. The graveyard can only be accessed through a dedicated road, and all other areas were fenced off (McNulty, 2011). In around 1970, the government decided to relocate the community permanently through a phased approach. According to a study conducted in 2006, only eight residents remained in the affected area (McNulty, 2011).

2.11. Chapter Summary

This chapter provided a detailed literature review on asbestos, including its properties, occurrence, global mining and production, impacts on health, and the rehabilitation of abandoned mines. Asbestos is a hazardous mineral with various applications, primarily valued for its thermal resistance, strength, and insulating properties. The global mining and production of asbestos peaked in the 1970s but declined after the discovery of its harmful health effects, leading to bans in many countries. The impacts of asbestos mining on health, society, and the environment are significant, with exposure leading to respiratory illnesses and various diseases.

The South African landscape is particularly affected by numerous abandoned including asbestos mines requiring rehabilitation under the Derelict and Ownerless Mines project. The rehabilitation of abandoned mines faces many challenges and these include legislative, process, and technical issues, such as legal uncertainties, short planning horizons, and access control to rehabilitated sites. International case studies highlight similar challenges in rehabilitating abandoned mines, with conflicts arising from environmental impacts, community resistance, and political influences. There are also issues in global construction projects, such as delays and cost overruns, that affect the implementation of rehabilitation projects.

3. CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Introduction

In this chapter, the research methodology that was used to answer the research questions of this study is discussed. According to Quinlan (n.d), the research methodology outlines the processes and procedures that are employed by the researcher to conduct the study. It describes the theoretical and philosophical assumptions that are used in a research study (Quinlan, n.d.).

This chapter provides an in-depth discussion of how the data was collected and analysed to address the research questions outlined in the introduction chapter. The research methodology chapter plays a significant role in this study by providing a detailed plan for investigating the factors that affect asbestos rehabilitation projects in South Africa. It outlines the approach, methods, and procedures used to obtain and analyse data, ensuring that the study is reliable and valid.

3.2. Research Philosophy

The term research philosophy refers to a set of beliefs and assumptions about developing knowledge in a specific field. It includes assumptions about human knowledge, the realities one encounters in research, and how one's values influence the research process. These assumptions shape how one understands research questions, methods, and findings. Developing a clear and consistent set of assumptions will establish a credible research philosophy, which will guide the methodological choice, research strategy, data collection techniques, and analysis procedures (Fleming and Zegwaard, 2018).

3.3. Research Methodology

A mixed-methods research design has been adopted to understand the factors affecting asbestos rehabilitation projects. This approach integrated both quantitative and comparative data methodologies to provide a comprehensive understanding of the multifaceted aspects relating to the research study (Creswell, 2007). The methodology included collecting data through recorded reports, financial statements and spreadsheets, engineer reports, project progress reports, construction programs, and document analysis, including reports and project notes. Purposeful sampling was used to select study units, and data analysis involved content analysis as described by (Creswell, 2007).

This approach was advantageous as it allowed the researcher to explore complex relationships between various research questions. The mixed research approach is an interdisciplinary methodology that employs both comparative and quantitative data collection and analysis methods for a better understanding of a subject or phenomenon. Essentially, it is based on the notion that multiple research methods are employed to gain a comprehensive understanding of a particular subject or phenomenon (Creswell, Piano and Published, 2007).

This approach enabled the researcher to gain a more comprehensive understanding of the subject matter. It has been gaining popularity due to its associated benefits. The comparative part of research involves gathering data through content analysis, while quantitative research relies on numerical data to answer questions and test hypotheses. By combining these two approaches through the mixed methods approach, it can provide a more comprehensive understanding of the subject matter (Creswell, Piano and Published, 2007).

3.4. Sampling Strategy

Developing an effective sampling strategy was a crucial step in research methodology. The strategy the researcher chose depended on several factors, including the size and accessibility of the document set. There are different types of sampling strategies that can be used, such as random sampling, purposeful sampling, snowballing, convenient and others. Purposeful sampling and document analysis involved intentionally selecting specific documents that are relevant to the research objectives and provide valuable information for the analysis. Unlike random sampling, purposeful sampling focuses on sources selecting documents that have a high potential to contribute to the research questions or provide in-depth insights into the phenomenon and data under investigation (Taherdoost, 2018).

Methods of sampling that were used in this report were purposed document selection and data collection from reports, spreadsheets and project documents relevant to information required to analyse and assimilate. Purposeful sampling allowed the researcher to deliberately select documents that best served the research questions and provided valuable insights into the topic of interest. This technique ensured that the sample represented the desired range of content, periods, or other relevant criteria, which enhanced the depth and accuracy of the document analysis sources (Taherdoost, 2018). The process of purposeful sampling in document analysis involved the following steps: (Palinkas, Horwitz, Green, Wisdom, Duan, Hoagwood, Angeles and Northwest, 1968).

a. Research Focus: Clarify research objectives, questions, or areas of interest that guide document analysis and identify relevant document types.
b. Document Identification: Identify potential sources where desired documents can be found, including academic journals, official reports, historical archives, organizational records, reports, and online databases.
c. Sampling Criteria: To ensure that the analysis is accurate, it was essential to establish specific criteria or characteristics that the documents must have included in the study. These criteria were related to the document's relevance, quality, authorship, geographical location, or any other factors that aligned with the research focus. Additionally, it was important to identify sampling criteria, which will guide the selection of documents. For instance, the criteria included technical data, relevant information, reports, certificates and others.
d. Compiling a Sampling Frame: A database of potential documents that meet defined criteria by searching documents, records and expert data was created.
e. Selected Samples: To ensure an accurate representation of the different datasets, project records dates, and target data groups, it was crucial to review the sampling frames and deliberately select a sample of documents. It was essential to aim for diversity and variety within the sample to obtain a broad perspective on the roles, impacts, and factors involved. Sample Size: When conducting document analysis research, it was important to determine the appropriate sample sizes based on several factors such as the research questions, available resources, and feasibility. The sample size varied depending on the scale and objectives of the study, ranging from just a few dozen to several hundred documents. To determine the sample size for document analysis research, the researcher needed to consider the research

objectives, available resources, and the desired level of precision or confidence in the findings.

3.5. Data Collection

The rehabilitation programme was rolled out in 2009. Since the start of the Mintek D&O programme, 38 mines have been rehabilitated and 32 completed up to 2020 (DMRE, 2021). Of these mines, 32 projects are the focus of this report as case studies.

a. Firstly, a desktop study was conducted, employing purposeful sampling to select and analyse relevant documents, including project meeting minutes, project reports, and policy documents. This step provided contextual information and enriched the overall data set.

b. Secondly, since Mintek is the custodian of the data, the researcher requested permission to utilise the data from Mintek databases, files, and project records.

c. Thirdly, the data for the study was extracted from the 32 Asbestos Rehabilitation Project Documentations and Project Files.

Table 2 below lists all the sources where the data was collected and the description of all documentation.

Table 2: Control Documentation Used for Report

Control Documentation	**Description**
Control Spreadsheets	Control spreadsheets are the data and information sheets that were used to manage and control the progress of the project from start to completion.
Site Diaries	Site diaries are the live documentation on all sites that are completed by the Residential and Project Engineers (Field Data). They represent the facts and verified information of site management regarding technical and scoping details, and daily issues.
Payment Certificates	Payment certificates were issued once a month by the employer's agent on all the thirty-two construction project sites after measurement, and quantity surveying confirmed the actual work

	done on site and certified for payment to the contractor by the employer (Financial Data).
Site Instructions	All site instructions are recorded in a document called a site instruction. The Site Engineer issues the document officially after approval by the employer's Agent and Employer.
Site Meeting Minutes	The employer’s agent and contractors conducted site meetings onsite to discuss and evaluate challenges and these records were factored into the time and cost events on all projects.
Project Progress Meeting Minutes	Project Meeting minutes included all issues and reports brought to the table. These meetings were held with all the contractors and project stakeholders involved and included the Departments of State, i.e., DMRE, and local suppliers.
Electronic Mails	All emails and electronic communications were saved and recorded to ensure consistency.
Contractor Claims	Contractor claims are recorded and managed according to the General Conditions of Contract, all claims follow a specific procedure that ensures consistency, and that fairness and ruling of claims are maintained.
General Conditions of Contract	From 2013 onwards, the projects were all managed under the General Conditions of Contract 2010. All the guidelines and specifications had to be followed closely to ensure that all management and control of the projects were according to prescribed rules.
Project Timelines and Construction Programs	At the award of the projects to the successful bidder, the bidder would submit timelines and construction programs, which were checked and verified by the Employers Agent, to see if they were realistic, and could be completed within the available budgets.
Variation orders	Any incident or occurrence that extends the project time or cost, needs to be processed as a variation order to be investigated by the Employer's Agent, and the case would then be presented as a claim.
Natural Delays (Force Majeure)	Conditions of the Contract allow for the claiming and processing of elements that are out of the control of the contractor and the

	employer. After investigation and proof of conditions, an extension of time and costs can be awarded.

3.6. Data Analysis

Data analysis is a widely used technique for making sense of the data that has been collected. It involves themes, and searching for patterns, trends, or anomalies in the data. Once a pattern is identified, it is interpreted in the context of a social theory or the situation under investigation. This process helps to give meaning and significance to the collected data (Creswell, Piano and Published, 2007).

This is a research project that required a systematic approach to gather, analyse, and interpret information. The data was analysed using thematic content analysis, which is the most common method for comparative research, as it allows for the identification of patterns. Thematic analysis is a method that involves finding and examining recurring themes or patterns within documents. Its focus is to capture the underlying meaning, interpretations, and nuances in the text (Fleming and Zegwaard, 2018).

One can use either an inductive approach, where themes emerge directly from the data, or a deductive approach, where predefined themes are used (Quinlan, n.d.). For instance, in a study on attitudes towards project completion, thematic analysis could entail identifying themes such as time delays, costs, impacts, causes and outcomes in the documents. To do this, the researcher read the documents multiple times until they understood the general idea of all of them. They generated initial codes manually across the entire data set, based on themes from the information they had read, as well as anything interesting, unexpected, or surprising. Then, they searched for sub-themes and grouped them into themes related to the research questions.

Content analysis involves categorising and quantifying the content within the documents systematically. This can include counting the frequency of specific words, themes, or concepts, as well as analysing the distribution of content across different categories. For example, in a study on information bias, content analysis could involve categorising data sources based on their content towards a particular topic (positive, negative, neutral).

During the data analysis process, a structured coding framework was used. This framework was applied by the researcher to help systematically analyse documents and was aligned with the research questions. During this process, the researcher captures important themes, concepts, and variables in the documents (Creswell, Piano and Published, 2007). The coding framework served as a useful tool to organise and analyse data, promoting consistency and coherence throughout the analytical process. The data analysis process included the following steps:

- Reading and Note-Taking: The selected documents were and notes were taken highlighting important passages, themes, or quotes that are relevant to the research question. Note-taking ensured that key information was captured for further analysis.
- Highlighting and Marking: Highlighting or marking techniques were used to identify specific sections or passages within the documents that corresponded to the predefined factors or codes in the coding framework. This helped in organising the data and facilitated the analysis process.
- Document Scanning or Digitisation: The notes were then scanned and digitised to create electronic copies. This allowed for easier storage, organisation, and retrieval of the documents during the analysis phases.
- Triangulation with Other Data Sources: Triangulating of document analysis and findings with data from other sources was done by the researcher, and cross-referencing, reports, or records were captured. This helped in validating and enriching the analysis by comparing and contrasting findings across different data sets.
- Researcher Reflexivity: The researcher's reflections, thoughts, and interpretations throughout the data collection process were recorded. Reflexivity involves acknowledging and critically reflecting on the researcher's biases, assumptions, and perspectives that may influence the analysis and findings and not letting them affect the interpretation and results (Creswell, 2007).

3.7. Validity and Reliability

In research analysis, it is crucial to ensure the accuracy and consistency of the findings. This was achieved by using techniques such as inter-coder reliability (if multiple coders are involved), number checking (to ensure accuracy in data and information), or triangulation (using multiple sources of data or methods). Validity and reliability were essential considerations in this research that helped to establish the credibility and dependability of the findings (Creswell, Piano and Published, 2007).

Research validity is the degree to which this study or research design accurately measured or assessed the concepts or variables it intended to examine. It was an essential aspect of scientific research because it ensured the credibility and reliability of the findings. Validity established how accurate, meaningful, and applicable the conclusions drawn from the research were (Creswell, Piano and Published, 2007).

Validity in research refers to how well the study measured or reflected the concept it meant to assess. There were different types of validity that the researcher considered to ensure that the findings were reliable and accurate. When selecting documents for a research study, it was important to ensure that they accurately represented the topic and themes of interest. This is known as content validity. To enhance the validity of the findings, a diverse range of data sources, periods, and perspectives were considered. This led to a more comprehensive understanding of the topic and increased the overall validity of the research (Lammers and Babbie, 2005). The other forms of research validity that were considered were:

- Construct Validity: It was important to ensure that the coding framework or categories used in this analysis were aligned with the research question and the concepts being studied, as suggested by Rosenthal (Westen and Rosenthal, 2003). To ensure accuracy, a review of the coding framework was conducted to confirm that it adequately captured the relevant dimensions or themes related to the representation of factors.
- Internal Validity: It was important to take measures to reduce any biases or confounding factors that would affect the analysis (Sedgwick, 2010). This was achieved by providing clear guidelines to ensure consistency in coding, verifying data sessions, and conducting regular cross-referencing to address any questions or concerns (Sedgwick, 2010).
- External Validity: When presenting research findings, it was important to consider how applicable they were to other settings or groups. To help readers assess external validity, document characteristics of the documents, including

sources, periods, and data contexts were captured. This provided readers with a better idea of whether the findings could be transferred to other populations or settings (Sedgwick, 2010).

Validity was ensured across these different dimensions and strengthened the overall quality of the research, providing confidence in the accuracy and relevance of the findings. The researcher employed multiple methods and measures to assess and report the validity of his studies.

It was also important to consider the generalisability or transferability of research findings. To do so, it was necessary to document the characteristics of the documents used in the study, including their sources, periods, and data contexts. This documentation enabled readers to assess the external validity of the findings and determine to what extent they can be applied to other settings or populations (Sedgwick, 2010).

- Inter-rater Reliability: To ensure consistency in coding, it was important for the researcher to conduct reliability checks and have multiple coders analysed as subsets of documents (Shweta, Bajpai and Chaturvedi, 2015).
- Intra-Rater Reliability: To ensure the reliability of the analysis, it was important to evaluate the consistency of coding performed by the same coder over time. One way to do this was to repeatedly code a subset of documents at different time points and calculate intra-rater agreement. Consistent coding by the same coder enhanced the reliability of the analysis (Shweta, Bajpai and Chaturvedi, 2015).
- Audit Trail: A comprehensive documentation trail of the analysis process was followed by the researcher, including the decisions made, coding rules, and modifications to the coding framework. This audit trail promoted transparency and facilitated audits and verification of the analysis.

It was important to ensure reliability in research and to improve the accuracy and precision of information and data, making the results more trustworthy.

3.8. Ethical Considerations

Additionally, ethical considerations, such as informed data consent and confidentiality, needed to be addressed throughout the research process, to ensure the integrity of the research. An ethical clearance certificate number EMINN/2022/34 was obtained and submitted to the university to ensure integrity and reliability. Ethical considerations were crucial in this research to protect the study credibility. The following needed to be considered to ensure that the study adhered to ethical requirements (Fleming and Zegwaard, 2018)

a. Voluntary and confidential participation by obtaining informed consent from the organisation in this study was ensured and adhered to ethical guidelines. Necessary approvals from relevant ethical review boards were obtained if required. Formal approval is attached to this report in Appendix 4.

a. When analysing documents, it was important to consider ethical factors such as obtaining necessary permissions to access or use the documents, ensuring confidentiality of sensitive information, and appropriately citing the sources of the analysed documents. Ethical considerations are important to ensure responsible and ethical handling of documents, texts, or any other written materials. These considerations ensured that individuals' privacy and confidentiality were protected, and information is used ethically.
b. Informed Consent: When analysing documents, it was important for the researcher to determine the need to obtain informed consent from the authors or individuals associated with the documents.
c. Privacy and Confidentiality: When the researcher analysed documents, it was important to protect the privacy and confidentiality of the authors or individuals associated with the documents. To prevent the identification of specific individuals or sensitive details, appropriate measures were taken to de-identify or anonymise information. The level of de-identification or anonymisation required depended on the nature of the documents and the research context (Camosun College, 2011).
d. Access and Permissions: It was also important to consider copyright, intellectual property rights, and terms of use of documents in the public domain.

e. Data Security: Secure storage and handling of documents are crucial to prevent unauthorized access, loss, or unintended disclosure (O'toole, Feeney, Heard and Naimpally, 2018). This was accomplished through the use of a password-protected computer.

3.9. Limitations

It is crucial to acknowledge the limitations of research studies by the researcher that may impact their scope, generalisability and conclusions. The most common limitations included:

- Generalisability: As the study concentrated only on 32 asbestos rehabilitation projects in South Africa, the conclusions drawn may not be universally applicable. However, they can still provide valuable insights and serve as a foundation for further research (E.Kuipa, n.d.). The factors that were found in the research were cross-referenced against literature conducted on global projects to draw similarities and differences.
- Bias: During the research process, it was important for the researcher to remain objective and be aware of his/her own biases (Simushi and Wium, 2020b). To minimise researcher bias, data was triangulated from multiple data and record sources. In this report, there were no impacts from bias and only data and information captured, from the reports formed the results emanating from the study.

3.10. Chapter Summary

The research methodology chapter provides an overview of the processes and procedures used to conduct the study on factors affecting asbestos rehabilitation projects in South Africa. The chapter discusses the research philosophy, mixed-methods research design, sampling strategy, data collection, data analysis, validity and reliability, ethical considerations, and limitations. The research methodology employed a mixed methods approach to gather and analyse data from various sources, ensuring a comprehensive understanding of the research questions. Validity and reliability were ensured through inter-rater reliability checks and ethical considerations were adhered to throughout the research process.

4. CHAPTER FOUR: RESULTS AND ANALYSIS

4.1. Introduction

The chapter provides an analysis of the 32 rehabilitation projects that were implemented between 2009 and 2020. The analysis covers completion status, timeframes, and budgets to identify the projects that were not completed as per the delivery targets. Using these results as a base, this chapter looks at the factors that affected the delivery and costs of the projects and provided insights into the extent to which these affected the successful implementation of D&O projects.

4.2. Description of 32 Asbestos Projects

The 32 asbestos projects are located in four provinces of South Africa, namely, Northern Cape, Limpopo, Western Cape, and KwaZulu-Natal. Table 3 below provides information on the location, year of implementation, and ownership of these projects.

Table 3: Case study location and ownership details

Case study number	Timeline Period	Province	Ownership
1	2009 - 2010	Northern Cape	Community
2	2009 - 2010	Northern Cape	Private
3	2009 - 2010	Northern Cape	Private
4	2009 - 2010	Northern Cape	Municipal
5	2010 - 2013	Northern Cape	Municipal
6	2010 - 2013	Northern Cape	Community
7	2010 - 2013	Northern Cape	Community
8	2010 - 2013	Northern Cape	Community
9	2010 - 2013	Northern Cape	Community
10	2010 - 2013	Northern Cape	Municipality
11	2010 - 2013	Limpopo	Community

12	2010 - 2013	Northern Cape	Community
13	2010 - 2013	Limpopo	Community
14	2010 - 2013	Northern Cape	Municipality
15	2010 - 2013	Northern cape	Private
16	2010 - 2013	Limpopo	Municipality
17	2010 - 2013	Limpopo	Municipality
18	2010 - 2013	Northern Cape	Municipality
19	2013 - 2016	Limpopo	Municipality
20	2013 - 2016	Limpopo	Municipality
21	2013 - 2016	Western Cape	Municipality
22	2013 - 2016	KZN	Municipality
23	2013 - 2016	Limpopo	Municipality
24	2013 - 2016	Limpopo	Municipality
25	2013 - 2016	KZN	Municipality
26	2013 - 2016	Limpopo	Municipality
27	2013 - 2016	Northern Cape	Municipality
28	2013 - 2016	Northern Cape	Municipality
29	2013 - 2016	Northern Cape	Municipality
30	2013 - 2016	Limpopo	Municipality
31	2016 - 2019	Limpopo	Municipality
32	2016 - 2019	Limpopo	Municipality

The case studies were analysed, and relevant information was extracted to analyse key components of project implementation. The factors underlying the implementation and assessment are explained in the next section.

4.3. Description of the critical elements of project implementation

The implementation phase of a project is an essential stage in rehabilitation projects, and this includes the transformation of defunct areas into productive areas. This process includes putting project ideas into action, planning and managing resources, and supervising operations to accomplish the goals of the rehabilitation projects. Within the framework of the rehabilitation of abandoned mines, the effective construction and execution of projects are crucial for the restoration of the environment, the well-being of the community, and compliance with legal requirements. The following provides an understanding of the important parts of the project's implementation:

4.3.1. Tendered Value:

It is the contractual evaluated cost a contractor agreed to in the tender document awarded to accomplish the rehabilitation of a project and the maximum value allowed to complete and deliver the project. It has a significant impact on the extent of rehabilitation operations as well as the quality of those activities, and it plays a critical role in deciding the financial resources that are allotted for the project. If the tendered value has challenges, the project will be impacted dynamically in the below points.

- Cost Estimation: The value that is being offered is based on the total contract cost presented and completed in the tendered Priced Bill of Quantities, which takes into account the costs associated with asbestos removal, design, environmental clean-up, sub-contracting and other required rehabilitation activities. To ensure the success of a project, accurate cost assessment is essential. The original project scope, environmental, and technical risk evaluations are closely connected to the bid value, which represents the expected outcome and final closing cost of the project. For accurate cost projection, it is vital to have a comprehensive grasp of the complexities of the project, which includes gaining access to the rehabilitation areas, the removal of asbestos and the restoration of the environment. The awarded contractor should already have considered all necessary and included technical and economic factors required in the tender amount for the final tender document at the time of submission. It is essential to conduct estimation and risk assessments to detect prospective issues, which in turn enables a more accurate projection of cost and expenses to facilitate better financial planning and project execution.

  ✓ The process of accurately estimating costs starts with a comprehensive knowledge and experience of the project scope, and design requirements, which include construction establishment for operations such as asbestos removal, construction planning, environmental clean-up, and any other further rehabilitation work.

- ✓ Risk assessment is to consider all possible impacts and enter a thorough process that determines and identifies prospective issues, it considers design criteria, asbestos safety and health, compliances, and contractual responsibilities and enables more accurate cost planning and execution to be done. The awarded contractor should already have included all these factors in his completed documents and project plans.

- Competitive Bidding: The tendered value is influenced by the process of competitive bidding, this changes and affects the bids submitted by contractors and may impact on the tendered total cost. It is common practice to engage in competitive bidding and evaluation as part of the process of finalising the offered value. The tender document includes the criteria required for technical evaluation as well as the scope of work line items to be completed for final submission. When awarding to the successful bidder financial budgets are not the only element taken into consideration; other aspects, such as technical competence, capacity and experience, and methods statements, are also taken into account. The establishment of transparent contractual agreements that define roles, contract data, duties, and deliverables is essential to evaluating and awarding a project to the successful bidder.
- The tendered value and final contract constitute the final agreement and financial contract price that hold fast until the completion of the project.
- Any variation or change of the final contract price cannot be made without official and contractual protocols.
- Final price is fixed and not negotiable.

4.3.2. Completed Value:

The final costs that were spent throughout the process of completing the rehabilitation project constitute the finished/completed value. The financial performance of the project is reflected in all the payment certificates, claims and payments that were made completing the project, and it is compared to the final value that was offered to determine if there were cost or time overruns or budget savings. To evaluate the financial success of the project, the completed value is compared to the bid value. The completed value is a reflection of the actual expenses that were incurred throughout the execution of the project. The monitoring of claims, payments and costs, is a critical component of efficient project management, including financial management, which guarantees that the project will remain within the financial amount that has been agreed to in a tender document contract. More so, the following are important:

- Actual Expenditure: The finished value is a reflection of the actual expenditures that were spent throughout the execution of the project. These actual expenditures include establishment, stakeholder engagement, procurement, labour, material, equipment, management and any other running costs. Any extra expenses not anticipated are over and above the actual cost and must follow protocols like claims and all documented administration requirements.
- Budget Management: The contractor and employer must have an efficient and strict budget management system in place to guarantee that the final value is under or according to the original financial plan.

  - ✓ Monitoring Cost and Expenditure: The process of continuously monitoring expenditures is essential to guarantee that projects remain within its budgetary constraints. Strict monitoring is achieved by administrative requirements like claims, site diaries, meetings, certificates, site instructions and reports. This process includes minutes and an attendance register of meetings to ensure accurate and adequate monitoring tools for reliable management. To avoid cost overruns, deviations or changes need to be investigated and dealt with as soon as possible. Project monitoring is also to ensure that challenges will be identified and addressed through factors that indicate impacts on financial indicators, and good record keeping.
  - ✓ Providing stakeholders with transparent reports and records is critical for the financial health of the projects and facilitates effective decision-making, this benefits projects through transparent and accurate financial reporting. Factors and defaults on the contractor's and employer’s part can impact greatly the outcomes of projects and dates. Examples of this are quantity survey reports, payment and progress certificates, diaries, meeting minutes and project spreadsheets for financial management.

4.3.3. Differences:

The disparity between the value that was bid, and the value that was finished is indicative of the financial success and difficulties that were encountered throughout the execution of the project and factors that need to be analysed that cause these challenges.

- Cost Overruns:

  This circumstance is indicative of cost overruns where the final value was higher than the value that was offered. To properly prepare for the future, it is vital to determine the factors that led to these cost overruns, such as unanticipated project issues or insufficient risk assessment. Cost overruns directly relate to challenges found on-site and, in the environment, where projects were executed. The cost of projects is directly related to default factors that cause delays or cost issues. The cost or time issues can be identified through claims, site diaries and also meeting minutes. The bill of quantities and pricing data also indicate the areas where these challenges presented the thematic impact. By studying these areas, it can be analysed and addressed directly.

- Cost Savings:

  On the other hand, if the finished value is lower than the value that was tendered, this might indicate that there is time and money saved. A better understanding of the elements that contributed to these savings might help improve the budgeting process for future projects. The fact that the budget finished under tendered value does not mean that there were no other challenges. Effective contract management, financial management and procurement may have helped the effective and timely completion of the project. In some cases, it may also be due to the contract type, fixed price or re-measured contract type. In fixed price contracts the contractor could have more space to manoeuvre finances whereas in the case of re-measurable contracts not. Re-measurable contracts place heavy pressure on actual line items and evaluation in the Priced Bill of Quantities.

- Identifying Variances in the Data:

  - ✓ Root Cause Analysis: It is important to do a thorough root cause analysis to evaluate any discrepancies that exist between the values that were tendered and those that were finalized. Factors needed to be identified and allocated to the variances that happened in four of the case studies. When planning for future projects, it is helpful to have an understanding of the causes underlying and causing deviations and apply them to themes and factors found.
  - ✓ The use of mitigation methods that are based on the lessons learnt from previous projects may be an effective means of preventing discrepancies of a similar kind in the context of future projects. Solutions and mitigations applied and implemented were addressed through reports, claims and documents that approved further activities to action and solve challenges

4.3.4. Time Started vs Completed:

By analysing the amount of time that passed from the beginning of the project to its conclusion, one may get valuable insights about the effectiveness of project management. Delays may be caused by a variety of circumstances, which can have an effect on the overall performance of the project and perhaps lead to an increase in expenses and time.

- Site establishment and access.

The site establishment process required by contractors has to comply with required documentation and administration processes before getting approval for site access. The contractual requirements to start and be onsite can present many challenges to contractors including things like contract signatures, purchase orders, safety and health plans, construction plans, cost and expenditure programs, asbestos and safety health requirements. These activities are all managed and monitored in control documents and managed by the contractor and employer. The start-up time can also be greatly impacted by stakeholder management. A good example of this is a Social License to Operate from the local communities and traditional leaders, this will include the municipal authorities.

- Delays in Project Completion:

  Delays in project completion may manifest themselves as a result of technical challenges, regulatory obstacles, or environmental problems that were not expected. To finish the project on time, it is essential to identify and manage any delays that may occur. A good example of a delay in project completion could be topographical and technical challenges faced while in construction. Unplanned occurrences and events while in the construction phase of projects. Labour and procurement are also a good example that can affect project timelines dynamically.

- Adherence to the timeline:

  One way to get insight into the effectiveness of project management and execution was to gain an understanding of the reasons behind any deviations from originally approved construction programs that occurred between the time the project began and the time it was completed. The project construction program is a contractual requirement and needs to be managed accurately and provide transparency during the project construction period from start to completion. Any default challenge needs to be investigated, managed and approved by the project managers on the project. If the timeline and management of approved contract timelines are not managed and respected by the construction company the adverse effects are direct and cause delays and cost effects. An example of this is when the design needs additional technical support and needs to be changed, the timeline needs approval and needs to be submitted by the contractor for processing and contractual procedural requirements. If not adjusted the project will face serious resulting challenges and impacts. Strict construction program management is critical.

4.3.5. Project Dates:

To determine whether or not the project schedule is being adhered to, it is essential to have a thorough understanding of the dates on which the project will begin and end. When it comes to mitigating the project's environmental concerns that are linked with abandoned mines, timely completion is very necessary. It is essential for the conservation of the environment and the safety of the community that the scheduled project dates be adhered to. In the event of delays, communities may be subjected to extended exposure to certain toxins, including asbestos. The process of evaluating project dates enables the identification of possible risks, and the development of solutions to mitigate such risks to guarantee timely completion of the project. To accept unanticipated conditions without jeopardizing the overall timeframe, flexibility and adaptability are very important.

- Following the Schedule:

  It is essential for the preservation of the environment and the safety of the community to follow the dates that have been established for the project. It is important to reduce the environmental impact to the minimum and finish the projects on time and as planned to not extend and increase the risks related to rehabilitation projects, like dust and contamination. There is a possibility that delays may result from more exposure to asbestos and other pollutants.

  The project schedule ensures that the construction company understands the lifecycle of the project and can plan accordingly to ensure that the completion date will be met. Schedules of construction program activities are essential to ensure that contractors understand the requirements of all the execution items for the project in due time. Management and strict control of the schedule is a critical components of project management to try to prevent delay and costs or to be able to address challenges timeously. A practical example of this is that a contractor could be facing procurement or cash-flow issues and this places a direct delay in the timeline. If the challenge is not addressed directly and speedily this can get out of hand and move the schedule in various ways adversely.

- Risk Mitigation:

The process of evaluating and managing project dates enables the identification of possible risks and the adoption of the necessary mitigation measures to guarantee that the project will be finished on time. Risk mitigation is addressed directly through hands-on safety and health management. This includes meetings and sufficient project management methods to deal with challenges and incidents immediately. A good example of this would be that when there is a force majeure situation like a flash flood, the project management team can be on hand immediately and mitigate and address the challenge without delay.

- Flexibility and Adaptability: Although adherence is of the utmost importance, project managers also need to display flexibility and adaptability to accept unanticipated events without jeopardizing the overall timetable. Management of projects needs to be open and experienced with the requirements of the projects to be able to manage and address all factors that result from issues on the project timely. The identification and development of project risk and factor changes need to be ongoing and this requires flexibility and adaptability from all managers and project teams.

4.3.6. Time Allowed:

The amount of time that has been allotted for the completion of the project is a predetermined amount of time within which the rehabilitation operations have to be finished. The overall performance of the rehabilitation project might be negatively impacted by deviations from the time frame that has been established, which can also have financial repercussions. The amount of time that is allotted for the completion of the project is a predetermined timeframe that is essential for effective restoration. In addition to having an impact on the overall performance of the project, delays that extend beyond this period may also have financial repercussions. Planning a project thoroughly, which includes establishing realistic timetables and clearly defined milestones, is one factor that leads to effective time management.

- Contractual Agreements: The amount of time that is permitted must always be specified. Any delays that exceed this deadline may result in contractual repercussions, such as fines, or the need to renegotiate the agreement. The amount of time that is permitted is often specified in commercial agreements. In light of the fact that failure to fulfil these commitments may result in legal repercussions, it is especially important to adhere to the timetables that have been agreed upon. Contractual management protocols play a major role in the implications and challenges to deal with time on projects. Notifications and contractual protocols should be strictly managed by contract and all deviations need to be recorded and approved by managers. A good example is that when a natural delay occurs the event need to be recorded and captured in a report and claim to be approved by the required engineers and agents for an extension of time and cost implications. Contract management must be understood and contractor well versed in the applications of the relevant contract agreed and signed for.

- Making preparations for unexpected circumstances: including the possibility of delays into the earliest planning stages of a project is an effective way to reduce the risks that are connected with unanticipated obstacles. Planning a project thoroughly, which includes establishing realistic timetables and clearly defined milestones, is one factor that leads to effective time management. Contingency planning and the “what if” planning mentality provide and make provision for enough room in time and planning to ensure that factors related to unforeseen circumstances and events can be addressed before they occur. This requires experience and accurate planning from contractors and managers before the project starts. An example of this if an access road is very steep and requires extra planning for water flow and landslides, this needs to be included in the planning and construction program as a possible event to deal with to prevent time and cost implications.

4.4. Case study analysis results

Table 4 below provides the cost and time results for the 32 case studies. As defined above, the table shows the tendered value, completed value, discrepancies, timelines, and other key information. Details on the case studies are provided below in a table to visualise the results discussed and listed.

Table 4: Cost and Time Results for 32 case studies.

32 Asbestos Rehabilitation Case Studies Timelines and Costs							
Case Study	Timeline Period Contract	Internal/External Management	Tendered value	Completed Value	Balance (Credit)	cost overrun	Days left on Contract
Case Study 1	2009 - 2010	Internal	ZAR 426,147.00	ZAR 426,147.00	ZAR -	ZAR -	6
Case Study 2	2009 - 2010	Internal	ZAR 4,777,201.00	ZAR 4,798,001.00	ZAR 20,800.00	ZAR 20,800.00	11
Case Study 3	2009 - 2010	Internal	ZAR 5,997,536.00	ZAR 4,798,001.00	ZAR (1,199,535.00)	ZAR (1,199,535.00)	30
Case Study 4	2009 - 2010	Internal	ZAR 2,524,060.00	ZAR 2,524,060.00	ZAR -	ZAR -	7
Excluded as case study	2010 - 2013	Internal	ZAR 47,000.00	ZAR 47,000.00	ZAR -	ZAR -	3
Case Study 5	2010 - 2013	Internal	ZAR 6,533,153.00	ZAR 6,533,153.00	ZAR -	ZAR -	10
Case Study 6	2010 - 2013	Internal	ZAR 4,396,446.00	ZAR 4,396,446.00	ZAR -	ZAR -	19
Case Study 7	2010 - 2013	Internal	ZAR 2,865,362.00	ZAR 2,865,362.00	ZAR -	ZAR -	19
Case Study 8	2010 - 2013	Internal	ZAR 3,432,322.00	ZAR 3,432,322.00	ZAR -	ZAR -	19
Case Study 9	2010 - 2013	Internal	ZAR 2,400,000.00	ZAR 2,400,000.00	ZAR -	ZAR -	0
Case Study 10	2010 - 2013	Internal	ZAR 1,770,933.00	ZAR 1,770,933.00	ZAR -	ZAR -	2
Case Study 11	2010 - 2013	Internal	ZAR 11,526,318.00	ZAR 11,526,318.00	ZAR -	ZAR -	20
Case Study 12	2010 - 2013	Internal	ZAR 2,445,983.00	ZAR 2,445,983.00	ZAR -	ZAR -	4
Case Study 13	2010 - 2013	Internal	ZAR 1,893,012.00	ZAR 1,893,012.00	ZAR -	ZAR -	3
Case Study 14	2010 - 2013	Internal	ZAR 2,032,860.00	ZAR 2,032,860.00	ZAR -	ZAR -	28
Case Study 15	2010 - 2013	Internal	ZAR 7,555,232.00	ZAR 7,555,232.00	ZAR -	ZAR -	29
Case Study 16	2010 - 2013	Internal	ZAR 1,981,125.00	ZAR 1,973,125.00	ZAR (8,000.00)	ZAR (8,000.00)	1
Case Study 17	2010 - 2013	Internal	ZAR 1,807,694.00	ZAR 1,807,694.00	ZAR -	ZAR -	23
Case Study 18	2013 - 2016	Internal	ZAR 3,017,248.00	ZAR 3,017,248.00	ZAR -	ZAR -	1
Case Study 19	2013 - 2016	External Consultants	ZAR 5,574,941.00	ZAR 5,574,991.09	ZAR 50.09	ZAR 50.09	21
Case Study 20	2013 - 2016	External Consultants	ZAR 5,170,908.00	ZAR 3,920,180.51	ZAR (1,250,727.49)	ZAR (1,250,727.49)	18
Case Study 21	2013 - 2016	Internal	ZAR 327,562.00	ZAR 327,562.00	ZAR -	ZAR -	0
Case Study 22	2013 - 2016	Internal	ZAR 1,299,767.00	ZAR 805,113.00	ZAR (494,654.00)	ZAR (494,654.00)	21
Case Study 23	2013 - 2016	Internal	ZAR 6,288,488.00	ZAR 4,617,964.00	ZAR (1,670,524.00)	ZAR (1,670,524.00)	3
Case Study 24	2013 - 2016	External Consultants	ZAR 6,561,648.00	ZAR 5,041,311.00	ZAR (1,520,337.00)	ZAR (1,520,337.00)	-155
Case Study 25	2013 - 2016	Internal	ZAR 7,989,556.00	ZAR 7,989,556.00	ZAR -	ZAR -	56
Case Study 26	2013 - 2016	Internal	ZAR 1,204,274.00	ZAR 918,475.00	ZAR (285,799.00)	ZAR (285,799.00)	-3
Case Study 27	2013 - 2016	External Consultants	ZAR 13,892,518.00	ZAR 9,978,886.00	ZAR (3,913,632.00)	ZAR (3,913,632.00)	50
Case Study 28	2013 - 2016	External Consultants	ZAR 9,958,402.00	ZAR 8,808,345.78	ZAR (1,150,056.22)	ZAR (1,150,056.22)	14
Case Study 29	2013 - 2016	External Consultants	ZAR 21,753,539.00	ZAR 19,564,905.74	ZAR (2,188,633.26)	ZAR (2,188,633.26)	-280
Case Study 30	2016 - 2019	External Consultants	ZAR 4,624,819.00	ZAR 3,304,160.78	ZAR (1,320,658.22)	ZAR (1,320,658.22)	-155
Case Study 31	2016 - 2019	External Consultants	ZAR 45,607,135.08	ZAR 33,699,512.00	ZAR (11,907,623.08)	ZAR (11,907,623.08)	-366
Case Study 32	2016 - 2019	External Consultants	ZAR 4,223,139.00	ZAR 3,839,218.00	ZAR (383,921.00)	ZAR (383,921.00)	-2

On Budget		Over Time Date/days	
Under Budget		Under Time Date/days	
Over Budget		On Time Date/days	

Case Study 1:

1. Construction Period:

    - Observation: The construction period for Case Study 1 was from March 10 to May 10. The project was completed in 61 days.

2. Tender Values and Completed Values:

    - Observation: The tendered value for Case Study 1 was ZAR 2,500,000.00, and the completed value was ZAR 2,480,000.00. The completed value is less than the tendered value, indicating a negative balance of ZAR -20,000.00.

3. Balance (Credit) and Cost Overrun:

    - Observation: A negative balance suggests a cost overrun. The project incurred a cost overrun of ZAR -20,000.00, indicating that it exceeded the estimated budget.

4. Days Left on Contract:

- Observation: The project was completed 9 days earlier than the allocated time. Completing ahead of schedule provides a buffer, but the negative balance suggests potential budget concerns.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 61 days, less than the allowed 70 days. While the project was completed ahead of schedule, the negative balance implies cost challenges. Case Study 1 experienced a cost overrun, completed ahead of schedule. The negative balance indicates potential budget challenges and further analysis may be needed to understand the reasons behind the cost overrun and explore opportunities for cost optimization.

Case Study 2:

1. Construction Period:

- Observation: Case Study 2 was completed in 59 days, slightly ahead of the allocated 70 days. The project demonstrates efficiency in construction, finishing before the scheduled timeline.

2. Tender Values and Completed Values:

- Observation: The tendered value and completed value are close, with a positive balance of ZAR 20,800.00. The project was executed within the estimated budget, with a slight positive balance indicating cost savings.

3. Balance (Credit) and Cost Overrun:

- Observation: A positive balance suggests cost savings. The project managed to complete with cost savings, indicating effective cost management strategies.

4. Days Left on Contract:

- Observation: The project finished 11 days earlier than the allocated time. Completing ahead of schedule provides a buffer and reflects efficient project management.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 59 days, less than the allowed 70 days. Efficient project execution resulted in completing the project within a shorter timeframe.

Case Study 3:

1. Construction Period:

- Observation: Case Study 3 had a construction period of 120 days, exceeding the allocated 150 days. The extended construction period raises concerns about potential project inefficiencies or delays.

2. Tender Values and Completed Values:

- Observation: The completed value is less than the tendered value, resulting in a negative balance. Further investigation is needed to understand the reasons for the negative balance and potential cost overruns.

3. Balance (Credit) and Cost Overrun:

- Observation: A negative balance indicates potential cost overruns. Analyse the factors contributing to the negative balance to identify and address cost overrun issues.

4. Days Left on Contract:

- Observation: There were 30 days left on the contract after project completion. Although the project finished late, having days left on the contract provides a buffer for unforeseen delays.

5. Project Days Construction and Project Days Allowed:

- Observation: The project exceeded the allowed time by 30 days. A detailed analysis is needed to understand the specific reasons for delays and to implement corrective measures.

Case Study 4:

1. Construction Period:

- Observation: Case Study 4 was completed in 153 days, slightly beyond the allocated 160 days. The project experienced a minor delay, and a closer examination is needed to determine the causes.

2. Tender Values and Completed Values:

- Observation: The tendered value and completed value are identical. The project was executed within the estimated budget, with no significant cost overruns or savings.

3. Balance (Credit) and Cost Overrun:

- Observation: The balance column shows no credit or overrun. The project was completed within the budget, indicating effective cost control.

4. Days Left on Contract:

- Observation: There were 7 days left on the contract after project completion. The project finished slightly behind schedule, but the days left on the contract provide a slight buffer.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 153 days, just 7 days beyond the allowed time. Although there was a slight delay, the project was overall well-managed within a reasonable timeframe.

Case Study 5:

1. Construction Period:

- Observation: Case Study 5 was completed in 90 days, meeting the allowed 100 days. The project was efficiently executed within the planned timeline.

2. Tender Values and Completed Values:

- Observation: The tendered value and completed value are identical. The project was executed within the estimated budget, with no significant cost overruns or savings.

3. Balance (Credit) and Cost Overrun:

- Observation: The balance column shows no credit or overrun. The project was completed within the budget, indicating effective cost control.

4. Days Left on Contract:

- Observation: There were 10 days left on the contract after project completion. The project finished ahead of schedule, providing a buffer of 10 days.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 90 days, meeting the allowed 100 days. The project was completed efficiently within the allocated time.

Case Study 6:

1. Construction Period:

- Observation: Case Study 6 was completed in 91 days, within the allowed 110 days. The project was efficiently executed within the planned timeline.

2. Tender Values and Completed Values:

- Observation: The tendered value and completed value are identical. The project was executed within the estimated budget, with no significant cost overruns or savings.

3. Balance (Credit) and Cost Overrun:

- Observation: The balance column shows no credit or overrun. The project was completed within the budget, indicating effective cost control.

4. Days Left on Contract:

- Observation: There were 19 days left on the contract after project completion. The project finished ahead of schedule, providing a substantial buffer of 19 days.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 91 days, meeting the allowed 110 days. The project was completed efficiently within the allocated time.

Case Study 7:

1. Construction Period:

- Observation: Case Study 7 was completed in 91 days, within the allowed 110 days. The project was efficiently executed within the planned timeline.

2. Tender Values and Completed Values:

- Observation: The tendered value and completed value are identical. The project was executed within the estimated budget, with no significant cost overruns or savings.

3. Balance (Credit) and Cost Overrun:

- Observation: The balance column shows no credit or overrun. The project was completed within the budget, indicating effective cost control.

4. Days Left on Contract:

- Observation: There were 19 days left on the contract after project completion. The project finished ahead of schedule, providing a substantial buffer of 19 days.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 91 days, meeting the allowed 110 days. The project was completed efficiently within the allocated time.

Case Study 8:

1. Construction Period:

- Observation: Case Study 8 was completed in 91 days, within the allowed 110 days. The project was efficiently executed within the planned timeline.

2. Tender Values and Completed Values:

- Observation: The tendered value and completed value are identical. The project was executed within the estimated budget, with no significant cost overruns or savings.

3. Balance (Credit) and Cost Overrun:

- Observation: The balance column shows no credit or overrun. The project was completed within the budget, indicating effective cost control.

4. Days Left on Contract:

- Observation: There were 19 days left on the contract after project completion. The project finished ahead of schedule, providing a substantial buffer of 19 days.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 91 days, meeting the allowed 110 days. The project was completed efficiently within the allocated time.

Case Study 9:

1. Construction Period:

- Observation: Case Study 9 was completed in 90 days, meeting the allowed 90 days. The project was efficiently executed within the planned timeline.

2. Tender Values and Completed Values:

- Observation: The tendered value and completed value are identical. The project was executed within the estimated budget, with no significant cost overruns or savings.

3. Balance (Credit) and Cost Overrun:

- Observation: The balance column shows no credit or overrun. The project was completed within the budget, indicating effective cost control.

4. Days Left on Contract:

- Observation: There were 0 days left on the contract after project completion. The project finished exactly on schedule, with no additional buffer days.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 90 days, meeting the allowed 90 days. The project was completed efficiently within the allocated time.

Case Study 10:

1. Construction Period:

- Observation: Case Study 10 was completed in 58 days, meeting the allowed 60 days. The project was efficiently executed within the planned timeline.

2. Tender Values and Completed Values:

- Observation: The tendered value and completed value are identical. The project was executed within the estimated budget, with no significant cost overruns or savings.

3. Balance (Credit) and Cost Overrun:

- Observation: The balance column shows no credit or overrun. The project was completed within the budget, indicating effective cost control.

4. Days Left on Contract:

- Observation: There were 2 days left on the contract after project completion. The project finished slightly ahead of schedule, providing a small buffer of 2 days.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 58 days, meeting the allowed 60 days. The project was completed efficiently within the allocated time.

Case Study 11:

1. Construction Period:

- Observation: Case Study 12 was completed in 61 days, meeting the allowed 65 days. The project was efficiently executed within the planned timeline.

2. Tender Values and Completed Values:

- Observation: The tendered value and completed value are identical. The project was executed within the estimated budget, with no significant cost overruns or savings.

3. Balance (Credit) and Cost Overrun:

- Observation: The balance column shows no credit or overrun. The project was completed within the budget, indicating effective cost control.

4. Days Left on Contract:

- Observation: There were 4 days left on the contract after project completion. The project finished ahead of schedule, providing a small buffer of 4 days.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 61 days, meeting the allowed 65 days. The project was completed efficiently within the allocated time.

Case Study 12:

1. Construction Period:

- Observation: Case Study 13 was completed in 62 days, meeting the allowed 65 days. The project was efficiently executed within the planned timeline.

2. Tender Values and Completed Values:

- Observation: The tendered value and completed value are identical. The project was executed within the estimated budget, with no significant cost overruns or savings.

3. Balance (Credit) and Cost Overrun:

- Observation: The balance column shows no credit or overrun. The project was completed within the budget, indicating effective cost control.

4. Days Left on Contract:

- Observation: There were 3 days left on the contract after project completion. The project finished ahead of schedule, providing a small buffer of 3 days.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 62 days, meeting the allowed 65 days. The project was completed efficiently within the allocated time.

Case Study 13:

1. Construction Period:

- Observation: Case Study 16 was completed in 59 days, meeting the allowed 60 days. The project was efficiently executed within the planned timeline.

2. Tender Values and Completed Values:

- Observation: The tendered value and completed value are slightly different, with a credit of ZAR 8,000.00. The project was completed within the estimated budget, with a minor credit indicating cost savings.

3. Balance (Credit) and Cost Overrun:

- Observation: The project shows a credit of ZAR 8,000.00. The project was completed with a cost saving of ZAR 8,000.00, reflecting efficient resource utilization.

4. Days Left on Contract:

- Observation: There was 1 day left on the contract after project completion. The project finished slightly ahead of schedule, providing a small buffer of 1 day.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 59 days, meeting the allowed 60 days. The project was completed efficiently within the allocated time.

Case Study 14:

1. Construction Period:

- Observation: Case Study 17 was completed in 37 days, meeting the allowed 60 days. The project was completed efficiently within the planned timeline.

2. Tender Values and Completed Values:

- Observation: The tendered value and completed value are identical. The project was executed within the estimated budget, with no significant cost overruns or savings.

3. Balance (Credit) and Cost Overrun: The balance column shows no credit or overrun. The project was completed within the budget, indicating effective cost control.

4. Days Left on Contract:

- Observation: There were 23 days left on the contract after project completion. The project finished ahead of schedule, providing a buffer of 23 days.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 37 days, meeting the allowed 60 days. The project was completed efficiently within the allocated time.

Case Study 15:

1. Construction Period:

    - Observation: Case Study 19 was completed in 179 days, exceeding the allowed 200 days. The project experienced a delay in construction, indicating potential challenges or issues that need further investigation.

2. Tender Values and Completed Values:

    - Observation: The completed value is slightly higher than the tendered value, with a credit of ZAR 50.09. While the project was completed within budget, the credit suggests potential cost savings.

3. Balance (Credit) and Cost Overrun:

    - Observation: The project had a credit of ZAR 50.09. The credit may indicate efficient cost management, but further analysis is needed to understand the specifics.

4. Days Left on Contract:

    - Observation: There were 21 days left on the contract after project completion. The project finished ahead of schedule, providing a buffer of 21 days.

5. Project Days Construction and Project Days Allowed:

    - Observation: The project took 179 days, exceeding the allowed 200 days. The extended construction period requires further investigation to identify the causes and potential areas for improvement.

Case Study 16:

1. Construction Period:

    - Observation: Case Study 20 was completed in 142 days, meeting the allowed 160 days. The project was efficiently executed within the planned timeline.

2. Tender Values and Completed Values:

- Observation: The completed value is lower than the tendered value, with a cost overrun of ZAR (1,250,727.49). The cost overrun suggests challenges in cost management that need further exploration.

3. Balance (Credit) and Cost Overrun:

- Observation: The project had a cost overrun of ZAR (1,250,727.49). The cost overrun requires a detailed analysis to identify the contributing factors and areas for improvement.

4. Days Left on Contract:

- Observation: There were 18 days left on the contract after project completion. The project finished slightly ahead of schedule, providing a small buffer of 18 days.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 142 days, meeting the allowed 160 days. The project was completed efficiently within the allocated time.

Case Study 17 Analysis:

1. Construction Period:

- Observation: Case Study 22 was completed in 69 days, meeting the allowed 90 days. The project was efficiently executed within the planned timeline.

2. Tender Values and Completed Values:

- Observation: The completed value is lower than the tendered value, with a cost overrun of ZAR (494,654.00). The cost overrun suggests challenges in cost management that need further exploration.

3. Balance (Credit) and Cost Overrun:

- Observation: The project had a cost overrun of ZAR (494,654.00). The cost overrun requires a detailed analysis to identify the contributing factors and areas for improvement.

4. Days Left on Contract:

- Observation: There were 21 days left on the contract after project completion. The project finished slightly ahead of schedule, providing a small buffer of 21 days.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 69 days, meeting the allowed 90 days. The project was completed efficiently within the allocated time.

Case Study 18:

1. Construction Period:

- Observation: Case Study 23 was completed in 212 days, exceeding the allowed 215 days. The project experienced a slight delay, and further investigation is needed to understand the reasons behind the extended construction period.

2. Tender Values and Completed Values:

- Observation: The completed value is lower than the tendered value, with a cost overrun of ZAR (1,670,524.00). The cost overrun suggests challenges in cost management that need detailed analysis.

3. Balance (Credit) and Cost Overrun:

- Observation: The project had a cost overrun of ZAR (1,670,524.00). A comprehensive analysis is required to identify the specific factors contributing to the cost overrun.

4. Days Left on Contract:

- Observation: There were 3 days left on the contract after project completion. The project finished slightly ahead of schedule, providing a small buffer.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 212 days, exceeding the allowed 215 days. A detailed investigation is needed to understand the reasons behind the extended construction period.

Case Study 19:

1. Construction Period:

- Observation: Case Study 24 was completed in 425 days, exceeding the allowed 270 days. The project experienced a significant delay, and a thorough investigation is necessary to understand the reasons behind the extended construction period.

2. Tender Values and Completed Values:

- Observation: The completed value is lower than the tendered value, with a cost overrun of ZAR (1,520,337.00). The cost overrun suggests challenges in cost management that need detailed analysis.

3. Balance (Credit) and Cost Overrun:

- Observation: The project had a cost overrun of ZAR (1,520,337.00). A comprehensive analysis is required to identify the specific factors contributing to the cost overrun.

4. Days Left on Contract:

- Observation: There were -155 days left on the contract after project completion, indicating a substantial delay. The negative days left on the contract emphasize the urgency of identifying and addressing issues that led to the delay.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 425 days, exceeding the allowed 270 days. A detailed investigation is needed to understand the reasons behind the extended construction period.

Case Study 20:

1. Construction Period:

- Observation: Case Study 26 was completed in 123 days, within the allowed 120 days. The project was completed on time, demonstrating effective project management.

2. Tender Values and Completed Values:

- Observation: The completed value is lower than the tendered value, with a cost overrun of ZAR (285,799.00). A detailed analysis is needed to understand the reasons behind the cost overrun in Case Study 26.

3. Balance (Credit) and Cost Overrun:

- Observation: The project had a cost overrun of ZAR (285,799.00). A comprehensive analysis is required to identify the specific factors contributing to the cost overrun.

4. Days Left on Contract:

- Observation: There were -3 days left on the contract after project completion, indicating a slight delay. The negative days left on the contract highlight the need to address issues that led to the delay.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 123 days, within the allowed 120 days. The project was completed on time, with a slight delay reflected in the negative days left on the contract.

Case Study 21:

1. Construction Period:

- Observation: Case Study 27 was completed in 550 days, exceeding the allowed 600 days. The project experienced a significant delay, and a detailed analysis is needed to understand the reasons behind the extended construction period.

2. Tender Values and Completed Values:

- Observation: The completed value is lower than the tendered value, with a substantial cost overrun of ZAR (3,913,632.00). The project incurred a significant cost overrun, indicating the need for a thorough investigation into the factors contributing to the financial deviation.

3. Balance (Credit) and Cost Overrun:

- Observation: The project had a cost overrun of ZAR (3,913,632.00). A comprehensive analysis is crucial to identify the specific factors leading to the substantial cost overrun in Case Study 27.

4. Days Left on Contract:

- Observation: There were 50 days left on the contract after project completion. Despite the significant delay, the project finished with a limited buffer, emphasizing the need for improved time management.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 550 days, exceeding the allowed 600 days. The extended construction period raises concerns about project efficiency, and an in-depth investigation is required to address the delay.

Case Study 22:

1. Construction Period:

- Observation: Case Study 29 was completed in 670 days, exceeding the allowed 390 days. The project experienced a substantial delay, warranting a detailed analysis to understand the reasons behind the extended construction period.

2. Tender Values and Completed Values:

- Observation: The completed value is lower than the tendered value, with a significant cost overrun of ZAR (2,188,633.26). The project incurred a substantial cost overrun, necessitating a thorough investigation into the factors contributing to the financial deviation.

3. Balance (Credit) and Cost Overrun:

- Observation: The project had a cost overrun of ZAR (2,188,633.26). A comprehensive analysis is crucial to identify the specific factors leading to the significant cost overrun in Case Study 29.

4. Days Left on Contract:

- Observation: There were -280 days left on the contract after project completion. The negative value indicates that the project exceeded the allowed time, emphasizing the need for improved time management.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 670 days, exceeding the allowed 390 days. The extended construction period raises concerns about project efficiency, and an in-depth investigation is required to address the delay.

Case Study 23:

1. Construction Period:
   - Observation: Case Study 30 was completed in 425 days, exceeding the allowed 270 days. The project experienced a significant delay, and a detailed analysis is needed to understand the reasons behind the extended construction period.
2. Tender Values and Completed Values:
   - Observation: The completed value is lower than the tendered value, with a substantial cost overrun of ZAR (1,320,658.22). The project incurred a significant cost overrun, indicating the need for a thorough investigation into the factors contributing to the financial deviation.
3. Balance (Credit) and Cost Overrun:
   - Observation: The project had a cost overrun of ZAR (1,320,658.22). A comprehensive analysis is crucial to identify the specific factors leading to the significant cost overrun in Case Study 30.
4. Days Left on Contract:
   - Observation: There were -155 days left on the contract after project completion. The negative value indicates that the project exceeded the allowed time, emphasizing the need for improved time management.
5. Project Days Construction and Project Days Allowed:
   - Observation: The project took 425 days, exceeding the allowed 270 days. The extended construction period raises concerns about project efficiency, and an in-depth investigation is required to address the delay.

Case Study 24:

1. Construction Period:
   - Observation: Case Study 31 was completed in 761 days, significantly exceeding the allowed 395 days.

- Results Discussion: The project experienced a substantial delay, and an in-depth analysis is necessary to understand the factors contributing to the extended construction period.

2. Tender Values and Completed Values:

- Observation: The completed value is lower than the tendered value, with a considerable cost overrun of ZAR (11,907,623.08). The project incurred a substantial cost overrun, indicating the need for a detailed investigation into the factors contributing to the financial deviation.

3. Balance (Credit) and Cost Overrun:

- Observation: The project had a cost overrun of ZAR (11,907,623.08). A comprehensive analysis is crucial to identify the specific factors leading to the significant cost overrun in Case Study 31.

4. Days Left on Contract:

- Observation: There were -366 days left on the contract after project completion. The negative value indicates that the project exceeded the allowed time, emphasizing the need for improved time management.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 761 days, significantly exceeding the allowed 395 days. The extended construction period raises concerns about project efficiency, and a detailed investigation is required to address the delay.

Case Study 25:

1. Construction Period:

- Observation: Case Study 32 was completed in 122 days, slightly exceeding the allowed 120 days. The project experienced a minor delay, and an analysis is necessary to understand the factors contributing to the extended construction period.

2. Tender Values and Completed Values:

- Observation: The completed value is lower than the tendered value, with a cost overrun of ZAR (383,921.00). The project incurred a cost overrun, indicating the need for an analysis into the factors contributing to the financial deviation.

3. Balance (Credit) and Cost Overrun:

- Observation: The project had a cost overrun of ZAR (383,921.00). A comprehensive analysis is crucial to identify the specific factors leading to the cost overrun in Case Study 32.

4. Days Left on Contract:

- Observation: There were -2 days left on the contract after project completion. The negative value indicates that the project slightly exceeded the allowed time, emphasizing the need for improved time management.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 122 days, slightly exceeding the allowed 120 days. The minor delay in construction raises questions about project efficiency, and an analysis is required to address the contributing factors.

Case Study 26:

1. Construction Period:

- Observation: Case Study 33 was completed in 122 days, slightly exceeding the allowed 120 days. The project experienced a minor delay, and an analysis is necessary to understand the factors contributing to the extended construction period.

2. Tender Values and Completed Values:

- Observation: The completed value is lower than the tendered value, with a cost overrun of ZAR (383,921.00). The project incurred a cost overrun, indicating the need for an analysis into the factors contributing to the financial deviation.

3. Balance (Credit) and Cost Overrun:

- Observation: The project had a cost overrun of ZAR (383,921.00). A comprehensive analysis is crucial to identify the specific factors leading to the cost overrun in Case Study 33.

4. Days Left on Contract:

- Observation: There were -2 days left on the contract after project completion. The negative value indicates that the project slightly exceeded the allowed time, emphasizing the need for improved time management.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 122 days, slightly exceeding the allowed 120 days. The minor delay in construction raises questions about project efficiency, and an analysis is required to address the contributing factors.

Case Study 27:

1. Construction Period:

- Observation: Case Study 34 was completed in 122 days, slightly exceeding the allowed 120 days. The project experienced a minor delay, and an analysis is necessary to understand the factors contributing to the extended construction period.

2. Tender Values and Completed Values:

- Observation: The completed value is lower than the tendered value, with a cost overrun of ZAR (383,921.00). The project incurred a cost overrun, indicating the need for an analysis into the factors contributing to the financial deviation.

3. Balance (Credit) and Cost Overrun:

- Observation: The project had a cost overrun of ZAR (383,921.00). A comprehensive analysis is crucial to identify the specific factors leading to the cost overrun in Case Study 34.

4. Days Left on Contract:

- Observation: There were -2 days left on the contract after project completion. The negative value indicates that the project slightly exceeded the allowed time, emphasizing the need for improved time management.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 122 days, slightly exceeding the allowed 120 days. The minor delay in construction raises questions about project efficiency, and an analysis is required to address the contributing factors.

Case Study 28:

1. Construction Period:

- Observation: Case Study 35 was completed in 244 days, exceeding the allowed 200 days. The project experienced a significant delay, warranting an in-depth analysis to identify the root causes.

2. Tender Values and Completed Values:

- Observation: The completed value is equal to the tendered value, indicating no cost overrun. While there was no cost overrun, the focus should be on understanding the reasons behind the extended construction period.

3. Balance (Credit) and Cost Overrun:

- Observation: There was no cost overrun; the balance (credit) is not applicable. The absence of a cost overrun is positive, but attention should be given to the delay in project completion.

4. Days Left on Contract:

- Observation: There were 56 days left on the contract after project completion. The surplus days indicate that the project finished well before the allowed time, despite the overall delay.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 244 days, exceeding the allowed 200 days. The substantial delay suggests potential issues in project planning or execution that require further investigation.

Case Study 29:

1. Construction Period:

- Observation: Case Study 36 was completed in 123 days, slightly exceeding the allowed 120 days. The project experienced a minor delay, and an analysis is necessary to understand the factors contributing to the extended construction period.

2. Tender Values and Completed Values:

- Observation: The completed value is lower than the tendered value, with a cost overrun of ZAR (36,755.00). The project incurred a cost overrun, indicating the need for an analysis into the factors contributing to the financial deviation.

3. Balance (Credit) and Cost Overrun:

- Observation: The project had a cost overrun of ZAR (36,755.00). A comprehensive analysis is crucial to identify the specific factors leading to the cost overrun in Case Study 36.

4. Days Left on Contract:

- Observation: There were -3 days left on the contract after project completion. The negative value indicates that the project slightly exceeded the allowed time, emphasizing the need for improved time management.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 123 days, slightly exceeding the allowed 120 days. The minor delay in construction raises questions about project efficiency, and an analysis is required to address the contributing factors.

Case Study 30:

1. Construction Period:

- Observation: Case Study 37 was completed in 550 days, exceeding the allowed 500 days. The project experienced a notable delay, requiring a comprehensive analysis to understand the reasons behind the extended construction period.

2. Tender Values and Completed Values:

- Observation: The completed value is lower than the tendered value, with a cost overrun of ZAR (3,913,632.00). The substantial cost overrun suggests the need for a detailed analysis to identify the factors contributing to the financial deviation.

3. Balance (Credit) and Cost Overrun:

- Observation: The project had a cost overrun of ZAR (3,913,632.00). A thorough analysis is crucial to pinpoint the specific factors leading to the significant cost overrun in Case Study 37.

4. Days Left on Contract:

- Observation: There were 50 days left on the contract after project completion. The surplus days indicate that the project finished within the allowed time, despite the overall delay.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 550 days, exceeding the allowed 500 days. The notable delay in construction raises concerns about project efficiency and potential areas for improvement.

Case Study 31:

1. Construction Period:

- Observation: Case Study 14 was completed in 62 days, meeting the allowed 90 days. The project was efficiently executed within the planned timeline.

2. Tender Values and Completed Values:

- Observation: The tendered value and completed value are identical. The project was executed within the estimated budget, with no significant cost overruns or savings.

3. Balance (Credit) and Cost Overrun:

- Observation: The balance column shows no credit or overrun. The project was completed within the budget, indicating effective cost control.

4. Days Left on Contract:

- Observation: There were 28 days left on the contract after project completion. The project finished ahead of schedule, providing a substantial buffer of 28 days.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 62 days, meeting the allowed 90 days. The project was completed efficiently within the allocated time.

Case Study 32:

1. Construction Period:

- Observation: Case Study 38 was completed in 366 days, exceeding the allowed 340 days. The project experienced a minor delay, and an analysis is necessary to understand the factors contributing to the extended construction period.

2. Tender Values and Completed Values:

- Observation: The completed value is lower than the tendered value, with a cost overrun of ZAR (1,150,056.22). The project incurred a cost overrun, indicating the need for an analysis into the factors contributing to the financial deviation.

3. Balance (Credit) and Cost Overrun:

- Observation: The project had a cost overrun of ZAR (1,150,056.22). A comprehensive analysis is crucial to identify the specific factors leading to the cost overrun in Case Study 38.

4. Days Left on Contract:

- Observation: There were 14 days left on the contract after project completion. The surplus days indicate that the project finished within the allowed time, despite the overall delay.

5. Project Days Construction and Project Days Allowed:

- Observation: The project took 366 days, exceeding the allowed 340 days. The minor delay in construction raises questions about project efficiency, and an analysis is required to address the contributing factors.

4.5. Overall analysis of the case studies

4.5.1. Construction Period:

It is worth mentioning that the duration of construction varied significantly across several projects. Some of the projects took significantly longer than expected, causing delays. The inconsistent completion times reveal the difficulties in managing construction timelines for multiple mine rehabilitation projects, and raises concerns over project efficiency.

Upon closer examination, it became apparent that some projects faced challenges in adhering to their planned construction periods. To identify any recurring issues and improve project efficiency, it was essential to conduct a detailed analysis of the reasons behind these delays. Factors found affecting projects and causing delays are outlined and discussed in section 4.6 below.

4.5.2. Financial Deviations:

Cost overruns are commonly observed only in four case studies. While some projects faced delays, others were completed before the agreed-upon deadline, leaving surplus days. This indicates that there is some degree of flexibility or contingency planning in project timelines and timely completion was reached. It also indicates that the internal management and effectiveness of some projects were more efficient and better managed by contractors. Financial deviations had either time or cost implications for the projects.

4.5.3. Project Days: Construction vs. Project Days Allowed

It was important to examine the difference between the actual number of days taken to complete a project and the number of days allowed for it as tendered. This analysis helped to understand the variability in the relationship between actual project days and allowed days. Efficient management strategies or the availability of contingency plans can be identified on projects that are completed within the allowed time, even with delays. Most of the projects were completed on time and had days to spare. There were six projects that were delayed and four of these projects were delayed by more than 100 days. There are two projects that were delayed by close to a year.

4.6. Factors affecting the delivery of projects

To complete restoration and project well-being, project management must have a thorough understanding of the issues affecting the implementation of D&O projects and take action to address them. During the project delivery, several factors were identified to have affected the delivery of the projects, as listed in Appendix 2. Two sets of challenges were identified that affected timelines and costs. Figure 4 and Figure 5 show the factors that were coded from the collected data. The y-axis reflects the impacts of factors on 32 projects converted to percentages over 32 studies. The X-axis identifies the factor found.

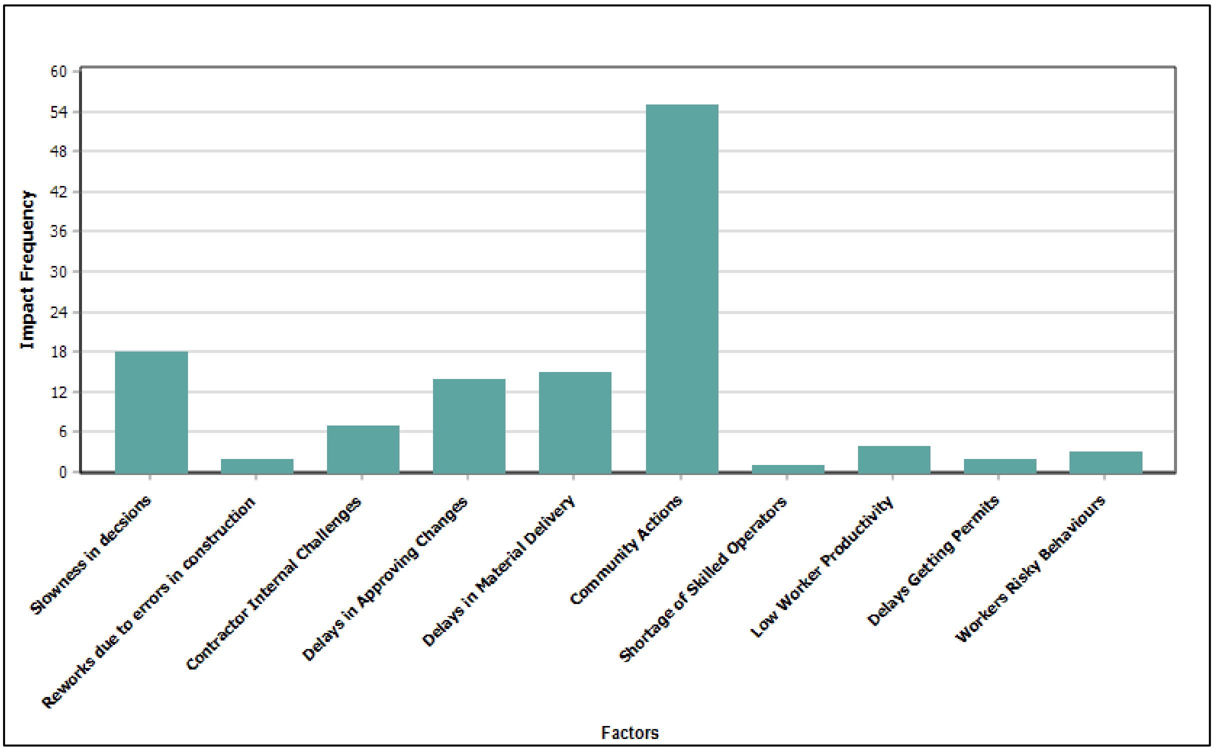

Figure 4: Time Overrun Causals

The project timelines were affected by several factors, namely, slowness in decision-making by the contractors before and during construction, internal challenges faced by the contractors, time delays in material and stock deliveries, community activities resulting from contractor defaults, worker productivity, and risky behaviour of workers were the primary reasons. However, the largest cause was delayed delivery of materials and construction requirements.

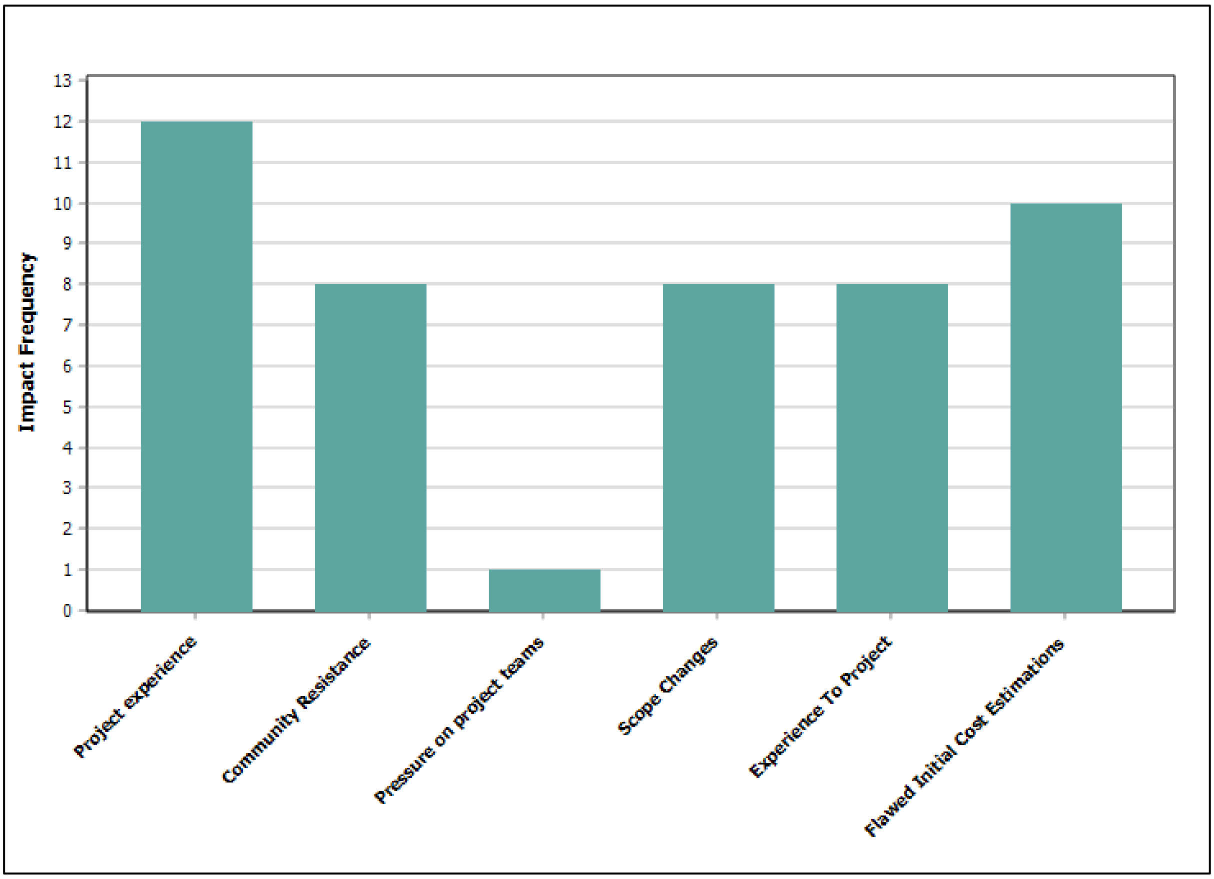

Figure 5: Impact Causals on Cost Overrun

Figure 5 analysis reveals that contractors have a lack of project-specific experience and this affects the successful implementation of rehabilitation projects. Additionally, organizational management and decisions made during projects may cause resistance from communities, leading to further delays. The other factor that affects project implementation encompasses the decisions made by external project supporters (i.e., DMRE). This results in the project team experiencing increased pressure, which necessitates additional efforts and input from all stakeholders. This pressure can lead to project scope challenges.

As alluded to, out of the total of 32 projects, 28 were completed within the required timelines, and some even before the final expected completion dates. The projects that were completed before the expected completion dates exhibited evidence that they were correctly managed and controlled in terms of the following:

- Site establishment was timely and correct according to specification. There were no time or administration challenges by the contractors preparing for construction on-site. The contractors were professional and complied with the required specifications for site establishment and on time.
- Time management was efficient and followed the approved construction program for the project. Scheduling and planning were effectively managed and executed for project plans.
- Material handling and procurement of stocks and equipment was correctly done by the contractors, and they were experienced in applying project plans following construction programs while doing the rehabilitations.
- Contractor internal procedures and management were well structured and organised professionally. The project teams were well organised, and the projects were well executed while complying with technical requirements. Communication was clear and contract management specific and accurate.
- Project Construction Programs were accurately adhered to and updated in good time when challenges or adjustments were required. Communication and approvals of construction programs were applied when required. Construction programs were always up to date and maintained by the companies.
- Local dynamics with stakeholders were followed and respected with good and transparent communication and by respecting local communities and authorities. The contractors were compliant and cooperative with all stakeholders. For example, local authorities were consulted when there was a requirement for any approvals and all challenges were addressed well with local and all stakeholders involved. Community resistance and challenges were addressed when the requirement arose. The contractors had a good relationship with the communities and showed experience in handling community and stakeholder engagements.
- Project Design Plans were correctly executed, and technical specifications were well understood and applied according to the tender requirements. When

changes or support were a requirement, the contractors understood contract management and protocols well.

- Site managers were experienced and followed instructions and prescripts by exhibiting knowledge and technical expertise while executing the construction programs. Safety and health protocols were followed to comply with the Mine Health and Safety Acts as well as Asbestos regulations. Contractors had good experience with the Occupational Health and Safety Act as well and managed correctly.
- Fewer scope changes were required by holding and understanding the technical specifications for the project. The scope was well understood and the installation was according to design. Proper planning and scheduling of project construction programs ensured correct scope completion without needing to take shortcuts to save time.
- Worker productivity was managed, monitored, and controlled effectively by correctly following all the requirements of the Labour Act. Clear instructions and scope management was done with all labour and the project was well executed with all workers. Regular and timely onsite management and supervision of workers were effective by contract managers.
- Construction equipment was managed well and technical support was available when there were any breakdowns of equipment. Equipment operators were experienced and efficient.

Again, there were four projects, namely studies 24, 29, 30, and 31 that overran timelines. The projects that were completed after the expected completion dates exhibited evidence that they were incorrectly managed and controlled in the following factors analysed:

- Site establishment was delayed, incorrect and inefficient by the contractors, the process of administration and submitting compliances to get approval for site access was slow and contractors were not timely in getting all administration and compliances in place according to the contract. The projects then already started with a slow startup and this included accurate and efficient site establishment according to the technical requirements.

- Time management was unprofessional and inexperienced, project managers were not efficient in time management and often did not consider construction programs. Onsite construction management was inefficient and a lack of experience in technical execution often resulted in delays and challenges.
- Material handling and procurement was often a challenge and delayed planning and ordering of materials often exhibited a lack of clear understanding of the scope of works and the technical installation requirements of the work.
- Community resistance was experienced due to contractors not having professional and efficient procedures when employing workers. Timely and inaccurate management of salaries and wages was often the case and caused community and worker disparity. Contractors not following efficient labour contract management also causes many challenges for workers and communities. An example is employment contracts and conditions and often the administration of workers is not compliant with labour laws and requirements. Transparent communication with communities and traditional structures is common and develops many challenges.
- Contractor internal management and procedures are not always professional and experienced and there are default conditions that arise due to a lack of experience and management procedures. The contractor's lack of resources and finances also presented challenges in the form of cash-flow issues. Lack of payments and supplier accounts sometimes caused delays and time constraints. Local sub-contractors often lodge complaints of inefficient and lack of timely account settlements by contractors.
- Project Construction Programs were not updated according to contract requirements. Contracts require that an approved construction program be the foundation for all construction and execution of the project installation. If the construction program is not approved and updated the contractor is in breach of contract and not complaint. Inexperienced management by contractors on the construction program results in time and cost impacts. Poor construction and project planning from a lack of experience or technical experience results in poorly managed programs or non-compliance.
- Local dynamics with stakeholders are not transparent and open and often the communication with communities breaks down. The contractors fail to hold a

good relationship with the local communities and traditional infrastructure and the tension of resistance often develops with the locals on project locations.

- Decisions onsite are often delayed and poorly managed with site management and communication breakdowns between site managers and contract owners result in management challenges.
- Project Design Plans were incorrectly interpreted. The reading and technical interpretation of technical design and drawings for the projects are critical and need to be understood. Due to the nature and the areas of the rehabilitations, the topography and layouts of the sites require experience and engineering background from the contractor team. The challenges with access, steep slopes and elevated rehabilitation areas add extra difficulty and professional requirements to the projects and often the contractor teams do not have the required background and technical know-how to ensure correct planning and execution to complete the projects in time and to reduce costs.
- Local Authorities and traditional structures were not considered. The contractors on the projects did not follow the official protocols regarding stakeholder engagement and end up facing challenges from local authorities and traditional structures. Contractors and staff did not always understand the dynamics involved with the authorities causing default issues in the projects. Some delays were caused due to the contractors committing to and allowing pressures outside of standard contract allowances. An example of this is that in some cases the contractor committed to providing or benefitting the community or traditional structure in a way not stipulated in the contract or scope of works. The contractor then faces challenges caused by agreements made outside of the project contract and that causes many unforeseen issues.
- Asbestos Safety and Health requirements presented and required a high level of execution and some of the contractors did not have the background and experience to timely install and provide the requirements without delays and costs. An example of this is the design and installation of the Decontamination Unit to ensure the effective and safe treatment of workers when entering and exiting the work site. The requirements of the installation are quite complex and, in some cases, the contractors had serious issues getting the correct standards and regulations in place with the installation of the unit.

- Scope changes were required with some projects due to the lack of professional experience in some of the technical design criteria on projects. In most of the rehabilitation projects access road construction is required to access the rehabilitation areas. The contractors need a high level of experience and technical knowledge to design and install such a road.
- Management of workforce and time management created challenges on the projects that overran on time or cost, Poor productivity management and supervision gave challenges on the construction sites. Workers often had challenges getting to the locations in good time due to walking distances and getting to the workplace safely and on time.
- Construction equipment was not always managed and maintained well to ensure no stoppages, and mechanical failures occurred without adequate technical and repair support plans, support. In some cases, it was also due to sub-standard equipment contracted from local suppliers not able to afford or do repairs.

These various factors can be categorised into technical, economic, psychological, political, management, and legislative themes. The broad factors are discussed below.

4.6.1. Technical Factors

The process of rehabilitating abandoned mines and cleaning up the environment was often hindered by significant technical challenges. Several factors contributed to these challenges, such as the complexity of asbestos rehabilitation, the unique characteristics of the sites, and the requirements for specialized procedures. Figure 6 shows technical challenges, and these are mapped according to the frequency with which they affected the various projects from the data captured on all projects studied and analysed. The frequencies were then calculated and extracted from all the control data documents including the reports with certificates and claims on challenges that were experienced and the thematic data frequency occurrence recorded according to the impact. This method was applied to all the different issues and outcomes from the analysis for graphical presentation. The various challenges are discussed below.

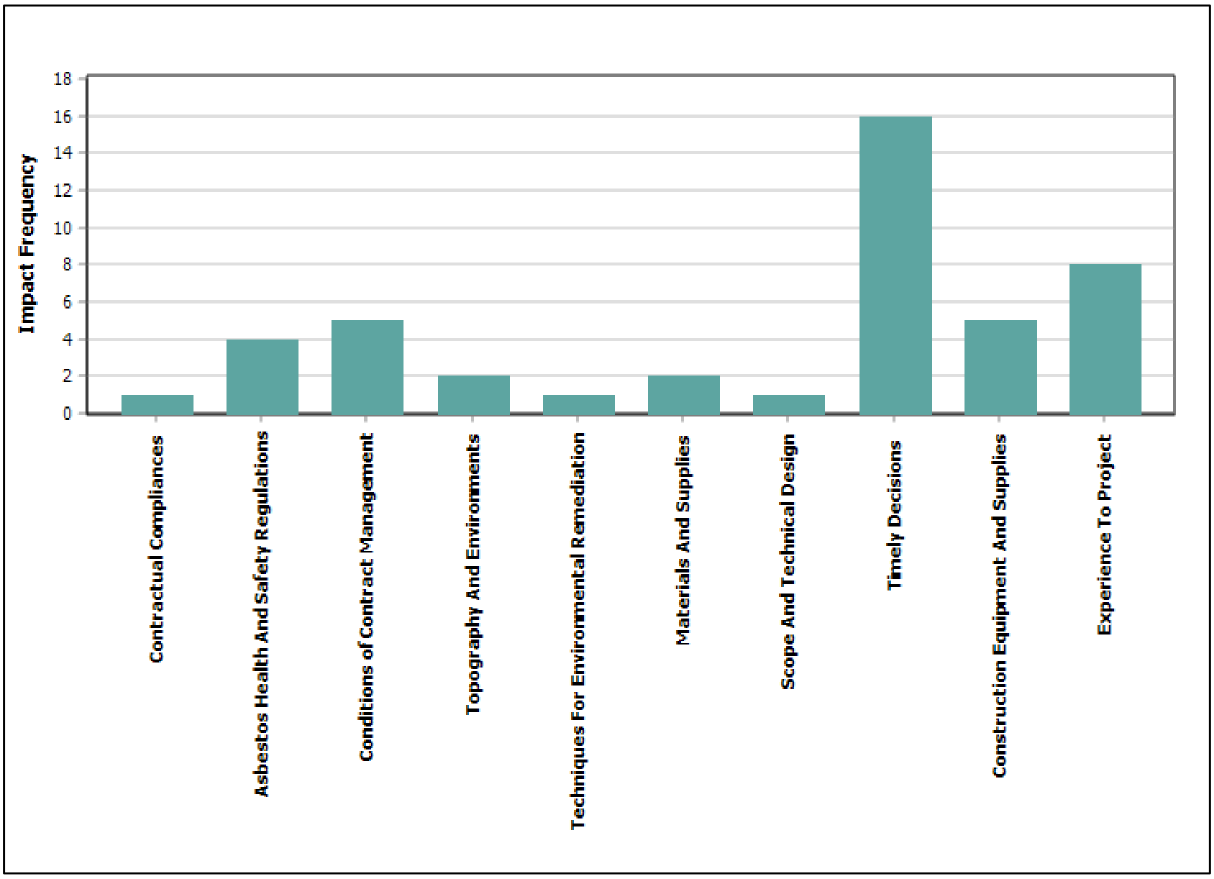

Figure 6: Technical Factors and Impacts

Contractual compliances and requirements for site access and establishment for construction. Contractors regularly had delays getting administrative and contractual documentation prepared and submitted for site establishment and access allowance.

- Technically these environments of asbestos-contaminated areas require strict management of all the compliances and this presented some challenges to inexperienced teams and managers of projects. The act requires specialised equipment and facilities for the management of asbestos construction sites, an example is a decontamination unit for putting on Personal Protective Equipment and after the normal workday, returning to decontaminate by washing and showering before going off shift. The challenges on site are exacerbated by a lack of information, training, and direct background on how to install and construct the facilities. In many cases, the contractor failed due to non-compliance with health and safety standards.
- Condition for contract management and contract data compliances. Timely contract data and General Conditions for Contract management and administration regularly resulted in delays and a lack of approvals from the

employer and engineer for effective contract and project execution by contractors.

- Topography and environments around asbestos sites are difficult to reach and access is a challenge. Designing and having construction equipment to reach the areas needing to be rehabilitated, requires specialised planning and methods and some contractors do not have the subject matter expertise to successfully access the site in time and with low costs in a safe manner.
- The selection of techniques for rehabilitation is crucial, and the implementation of appropriate solutions affects the methods and rehabilitation challenges. A high level of professional experience is required when doing rehabilitation projects. Often contractors did not have sufficient experience in rehabilitation projects and had a shortfall on execution methods and construction.
- Materials and supplies to the projects were often a challenge for contractors and effective procurement processes required to accurately manage and execute projects were absent.
- Scope and technical design changes affected the projects when contractors were not well experienced and often the contractors took shortcuts and did not adhere to technical designs, due to poor and insufficient planning and experienced project management.
- Timely decisions internally with contractors often presented challenges and delays.
- Construction equipment and supplies presented challenges due to low-quality equipment and lack of support with failures and breakdowns.
- Contractors often lacked experience and proper technical background and this placed pressure on all stakeholders having to invest efforts to compensate for contractors' experience and shortfalls.

4.6.2. Economic Factors

The success of restoration projects and their effectiveness were also influenced by various economic factors. Figure 7 shows the economic factors and these included the limited availability of funds, flaws in cost estimations, poor procurement, and cash-flow challenges. These are elaborated below.

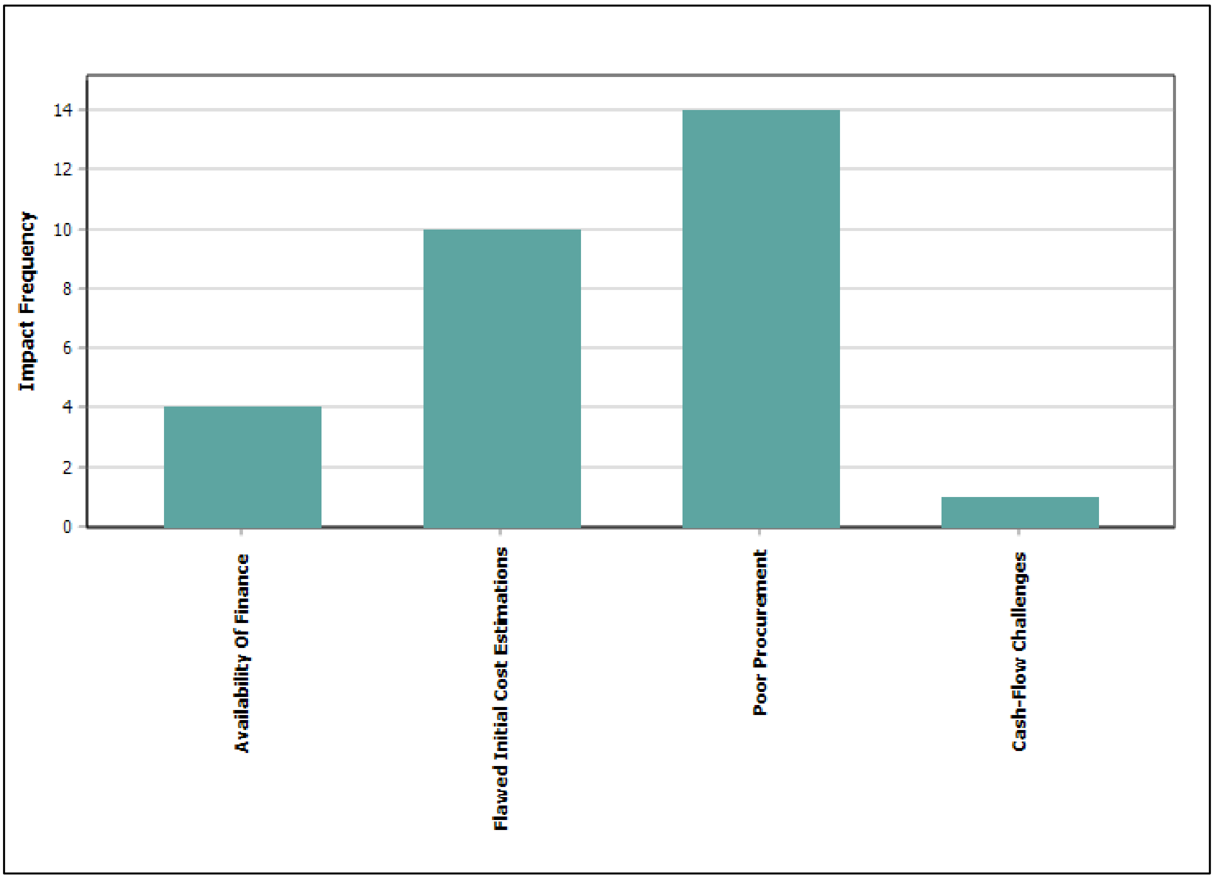

Figure 7: Economical Factors

- The availability of financing: Financing or budget constraints affect the extent and scope of rehabilitation work by contractors. Limited financial resources or changes in financing during the project impact the scope and pace of rehabilitation operations by contractors. The availability of sufficient financial resources also influences the time and execution ability of contractors greatly. Due to limited funds, some initiatives and/or activities are prioritised over others. Sometimes the wrong priority is given preference over more critical components due to lack of funds.
- A flawed initial cost estimation results in a shortage of funds, which hinders the completion of rehabilitation projects. Often the contractor has not planned and estimated the costs of all the components effectively and runs into challenges due to lack of resources and finance.
- Due to weak procurement planning and poor timeline execution contractors often end up running behind with materials and other supplies for projects.

- Cash-flow challenges cause many secondary challenges which include delayed supplier and employee payments. Contractors made late payments to local suppliers and caused delays and time challenges resulting from a lack of supplies and stocks for construction, this challenges when local suppliers were involved. Contractors who experienced cash-flow also paid salaries late at times and this caused issues and stoppages on some of the projects.

4.6.3. Psychological Factors

There are several psychological factors that affect rehabilitation projects illustrated in Figure 8 below. The support or opposition of the community was influenced by the impact on their health, particularly in cases of asbestos exposure. Concerns regarding the health of the community and how the general public views the health hazards that are linked with asbestos exposure affect whether or not the community supports rehabilitation efforts.

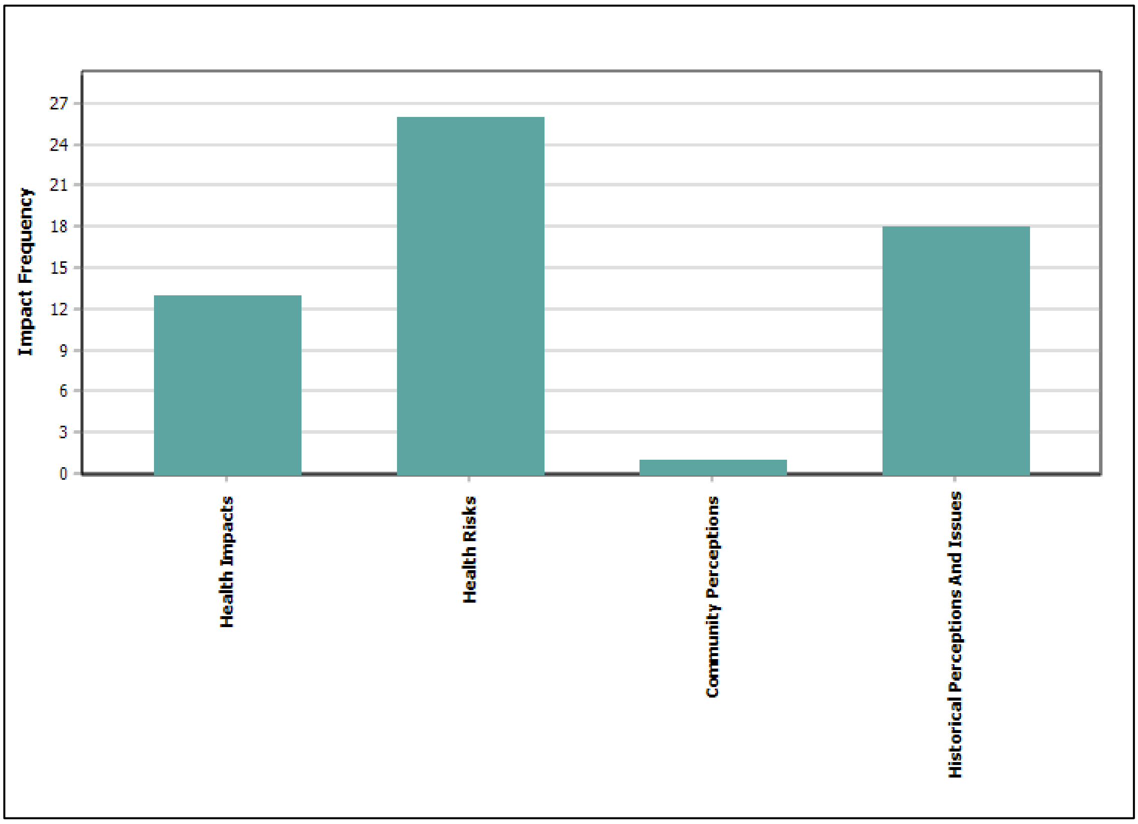

Figure 8: Psychological Factors

The health risks associated with asbestos exposure create fear and resistance in local communities. The success of a rehabilitation project greatly depends on public perception of its effectiveness and safety. Concerns surrounding the health risks associated with asbestos exposure also affect community support and project dynamics. Historical perceptions and adverse health impacts caused by asbestos mining operations in communities also affect the license to operate towards asbestos rehabilitation projects.

4.6.4. Political factors

Abandoned mine rehabilitation projects are significantly impacted by political factors. Figure 9 shows the various factors, and these include issues with traditional authorities, communities, political stability and stakeholder influences. The political environment, both at the local and national levels, influences project feasibility, funding, and regulatory frameworks. The political factors associated with abandoned mining rehabilitation are elaborated below:

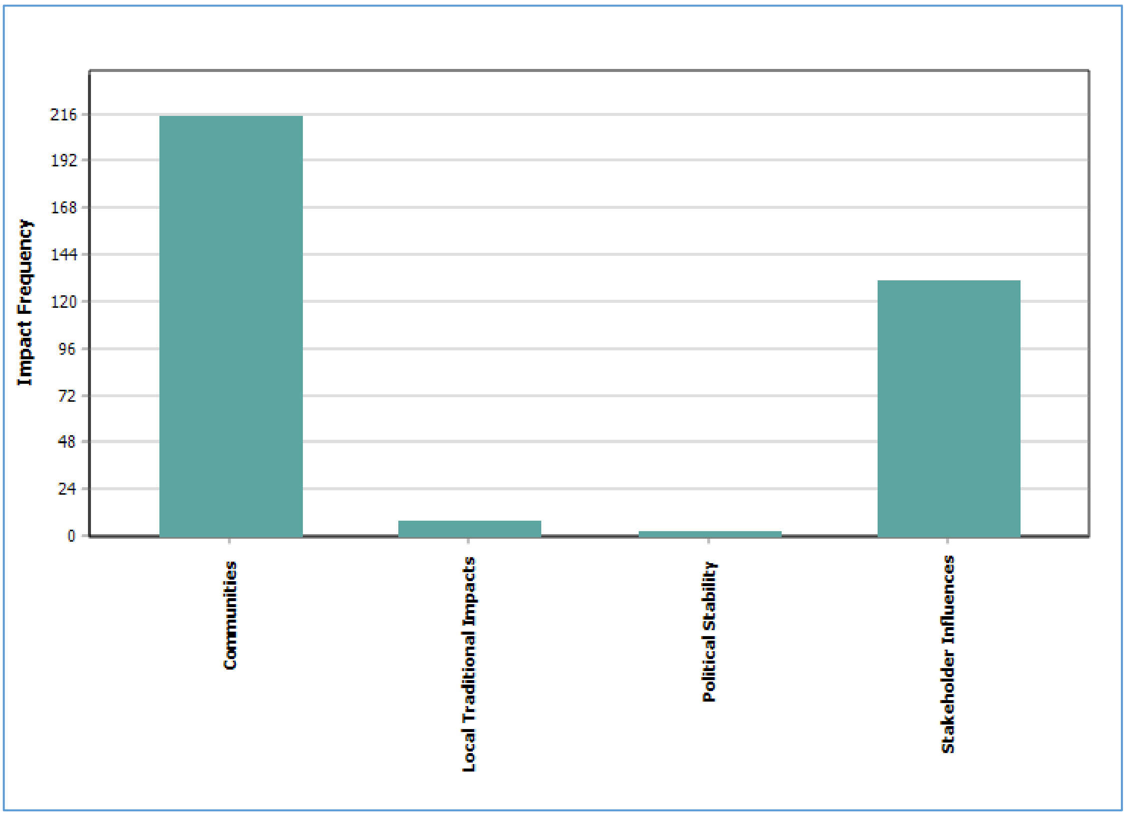

Figure 9: Political Factors

Furthermore, community and stakeholder involvement in rehabilitation projects is often mandated by law, especially when these projects impact local communities, environments, or ecosystems. Failing to meet these requirements can lead to resistance, opposition, legal challenges, and project delays and the contractors are not always versed and experienced in handling these issues correctly. Contractors had many cases of pressure from communities and affected people placing extra pressure on employment, local procurement and demands from suppliers. Political stability plays a crucial role in the consistent and effective implementation of government policies. A stable political environment provides the necessary support and continuity for rehabilitation projects. It ensures that decisions related to funding, permits, and project approvals remain consistent over time. Political instability presents significant obstacles to rehabilitation initiatives. Political decisions are influenced by the opinions and concerns of local community stakeholders and forums.

Changes in challenging political and social environments also occurred, this ultimately resulted in increased project costs and construction times due to unplanned delays from local employment and wage negotiations. A good example was the disparity of traditional leadership and the infighting of local leaders. Local Tribal Meetings and gatherings impacted rehabilitation projects particularly where there were community and local tribal disparities. Local Business forums often placed pressure on contractors by the demands for procurement and supply of services on the projects. The projects require strict management and compliance with all regulations as stipulated by the Provisional Financial Management Act and many forums were not compliant and did not qualify to supply the services and provide products required by the projects. This was met with resistance and some informal business forums tried to interrupt and cause stoppages on some of the projects for financial gain.

4.6.5. Management Factors

Figure 10 shows management factors that affected the delivery of rehabilitation projects. Effective management of a project involves several crucial aspects such as ensuring compliance with regulations and environmental laws, as well as efficiently engaging stakeholders. Failure to meet these requirements hinders the progress of a project and jeopardizes its successful completion. The management factors that were identified included issues relating to stakeholder engagement, transparency, management of resources, and aspects that cover closure and rehabilitation plans. These aspects are discussed below.

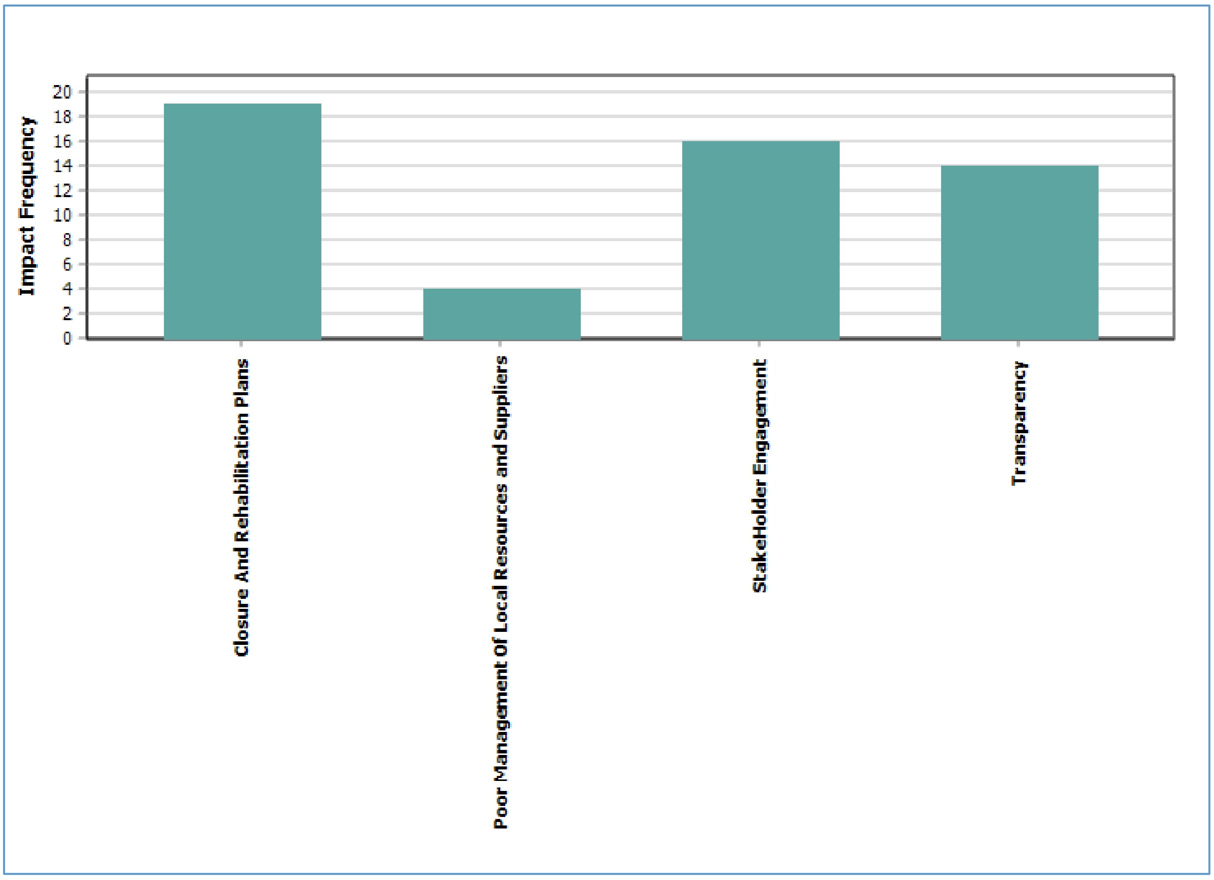

Figure 10: Management Factors

Contractors had regularly had challenges keeping up with safety and health standards, as well as the closure and rehabilitation planning and design requirements. The lack of management on strict compliance with Health and Safety Standards regularly caused internal issues with project managers and workers. A good example was the correct management of decontamination units for staff and workers. The lack of proper management caused many dissatisfactions and delays with workers and communities.

- ✓ Contractors did not always accurately stick to approved design plans and the accurate and effective management of resources and supplies, for timely and cost-effective rehabilitation and completion.

- ✓ Timely and honest stakeholder management and engagement was a challenge on some of the projects due to a lack of experience and protocol management for the projects.
- ✓ Management of local suppliers led to resistance and disagreement, timely payment and incorrect material price rate confirmations regularly led to challenges and communication delays. Contractors do not properly have relationships and stakeholder engagement with suppliers and service providers.
- ✓ To maintain a good relationship with the community, it is important to comply with employment laws and the contractors had issues with timely employment contract management and salary requirements.
- ✓ Meetings and stakeholder engagements within local communities were not always transparent and clear and the results were resistance and communication difficulties.

4.6.6. Legislation Challenges

Legislation challenges play a significant role in shaping and influencing various aspects of projects, especially those involving environmental remediation and rehabilitation of abandoned mines. Figure 11 maps the challenges that were extracted and these are discussed below.

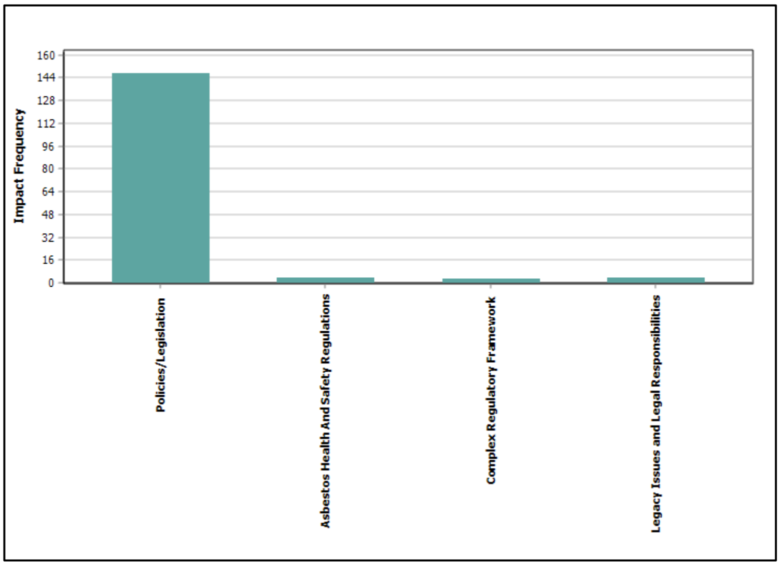

Figure 11: Legislation Challenges

The rehabilitation of abandoned mines is governed by a complex set of laws and regulations that encompass environmental protection, mining rehabilitation practices, health and safety, and land re-use and reclamation. It is a daunting task for project managers and stakeholders to navigate through this intricate regulatory framework, requiring significant time and resources to ensure compliance with all the regulations.

Contractors have dynamic challenges adhering to and complying with all the regulations and laws related to asbestos safety and health. Moreover, the nuances of the local traditional structure led to delays in obtaining leadership and community support and approvals, and contractors regularly did not correctly anticipate these challenges, like water licenses for dust control take time, and contractors do not factor it into their planning and timelines. Asbestos decontamination laws necessitate constant management and regulatory monitoring of standards.

Asbestos, due to its hazardous nature, is subject to strict regulations and guidelines governing its removal, transportation, and disposal. Correct handling, removal, and consolidation of materials containing asbestos demand special legal certification and experience, in asbestos rehabilitation contracts this causes leading times and increased costs to ensure delivery and proper construction. The contractors do not always have the background and experience with the projects with all the requirements and laws involved. Additionally rehabilitating abandoned mines involves dealing with some historical mining health and legacy issues, such as soil contamination, water pollution, and habitat destruction.

4.7. Overall discussion of key findings

Technical factors play a significant role in mine rehabilitation projects, as evidenced by the impacts on construction periods and the added extra cost caused by time delays in some of the case studies. The technical challenges, as indicated by the deviations caused in construction periods, highlight the need for a detailed examination of the specific technical factors that influence and could affect project timelines. Key technical considerations should include and consider environmental conditions, technical requirements, geological complexities, and the effectiveness of construction methods and processes. Amongst the key findings include the difficulties resulting from topography and environments surrounding asbestos sites. This was raised by Menegaki and Nair (2019), that each project is different and influenced by many factors that depend on the specific area where the abandoned mine is located. The complexities associated with individual sites therefore require “out-of-the-box thinking” and this further adds to the rehabilitation process and costs (Menegaki and Nair, 2019)

According to Bennett (2016), resources for cleaning up abandoned mines are very limited in most jurisdictions. This includes funding, experience, and a better understanding of the challenges. It was found that rehabilitation projects were affected by contractors’ lack of experience and technical background. Understanding these factors is crucial for effective project planning completion and execution. The presence of projects with surplus days left on contracts suggests that certain technical aspects were managed efficiently and allowed more flexibility within the stipulated timelines and costs.

Cornelissen mentions for economic reasons the local communities tend to look for sellable and valuable products left in the old asbestos waste like old steel and other materials. This disturbs and releases asbestos contamination again after rehabilitation and needs to be added as a design challenge in the planning and scoping of the projects (Cornelissen, Watson, Adam and Malefetse, 2019b).

Economic impacts emerge as a recurring theme across some of the case studies, impacting project budgets and outcomes through community and local labour challenges due to needs and requirements outside of the normal project scope. Financial and effective management practices, resource and time allocation, and procurement are critical. Cornelissen et al (2019) highlighted the implications of short planning horizons on rehabilitation projects with projects scheduled to be completed in one year. The handling of unexpected conditions, including changes in procritical impacting factors needs careful and expert attention on future projects. Careful consideration of sustainable goals needs to be included in project and tender planning.

Simushi and Wium, (2020a) noted that communities and local dynamics affect how the projects are executed through good communication and stakeholder engagement. Stakeholder communication and transparent management practises, identified, as both psychological and management factors, are crucial, especially in cases of delays and financial challenges. Effective communication with stakeholders is paramount for the success of mine rehabilitation projects. Delays, cost overruns, or other challenges should be communicated transparently and trust maintained and built on sound management and communication practices with stakeholders and communities. An example would be, that if cashflow challenges arise direct and honest communication must be done by the contractor with stakeholders and affected parties.

Political stakeholders and influences greatly affect and influence stakeholder communication and adherence to regulatory requirements and policies is critical. Kuipa (2023), indicated that a lack of understanding and experience with complying with policies add to the political and stakeholder challenges in projects. Political factors include regulatory compliance and require reliable and honest community engagement with consideration of social and economic environments (Kuipa, 2023). Failure to meet these requirements can lead to project delays and financial implications.

5. CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1. Introduction

The previous chapters have thoroughly examined the impacts of various factors on asbestos rehabilitation projects within the South African context. Each chapter, from the initial identification of the research problem to the study's design and execution, has contributed to fulfilling the research objectives. In this chapter, the conclusion is provided and some recommendations made based on the research findings are presented with suggestions on how stakeholders can improve the rehabilitation of abandoned mines in South Africa.

5.2. Conclusion

Asbestos used to be a popular mineral that found use in many applications. Because of its health and safety implications, the exploitation and use of the mineral was banned in many countries including South Africa. Asbestos mining was banned in the country in 2009. After new regulations were enacted, the government designated some abandoned asbestos mines as Derelict and Ownerless Mines. The D&O mines are those that are ownerless (i.e., no official owner or liability could be established for rehabilitation or restoration after mining closure by the state). The DMRE has as a result taken the responsibility of rehabilitating these mine sites.

The D&O mine sites cover several mineral commodities including asbestos and because of the dangers of asbestos, it has been prioritised. This is because abandoned asbestos mines in South Africa contribute to environmental degradation, including soil erosion, water contamination, and loss of biodiversity. The release of asbestos fibres poses severe health risks to nearby communities.

Over the past 12 years of rehabilitation of D&O mines, there have been concerns about the delivery of the D&O project commitments. Project costs and project timeframes have not been adhered to as agreed upon in the tender award conditions. The challenges associated with the implementation of the D&O project have necessitated the need to understand the factors influencing the rehabilitation process.

The study aimed to provide a comprehensive analysis of the factors affecting the rehabilitation of abandoned asbestos mines in South Africa. By understanding these factors, the research seeks to contribute valuable insights and recommendations for the development of effective and sustainable rehabilitation management strategies.

The research methodology for this study involved a mixed approach that combined quantitative and comparative data. The data collection process included reports, technical and engineering tools, financial statements and spreadsheets, project progress reports, site diaries, construction programs, and document analysis, along with the capturing of technical information. The collected data was analysed using thematic coding and analysis to identify and analyse recurring themes or patterns within the control documents.

The study identified several factors affecting project time and cost delivery of projects. The factors that resulted in time overruns included aspects like slowness in decision-making, financial management and issues experienced by projects before and during construction, internal challenges by contractors, time delays in material and stock delivery, community impacts and activities that resulted from challenges, worker productivity, and risky behaviour of workers. Community resistance caused by default failures in the factors was identified as one of the leading causes resulting in time overruns. The factors that resulted in cost overruns included a lack of project-specific experience by project teams (i.e., on asbestos mining), changes in project scope, and community issues caused by internal management and communication challenges.

Broadly, these factors were categorised into six areas, namely, technical issues, economic or financial issues, management challenges, psychological influences, political impacts, and policies and legislative challenges. The technical challenges encompass the complexity of asbestos rehabilitation having to take into account the unique and changing characteristics and the requirements in terms of the specialised techniques that need to be implemented. Effective management of designs and inclusion of site-specific aspects in asbestos rehabilitation is required. The lack of experience in asbestos rehabilitation can lead to technical challenges and poor project outcomes. The challenging geographical environments also affect the successful completion of projects.

The financial and economic factors included the lack of effective planning and estimation of project costs during the rehabilitation process. Changes in project scope also affect rehabilitation projects. It was highlighted that contractors tend to focus on maximising savings rather than successful project outcomes which leads to poor allocation of resources. Lack of experience and poor management of resources also resulted in delays in project periods and material deliveries.

The psychological factors identified were underpinned by concerns around the impacts of asbestos on the health of communities and largely resulted from perceptions of communities towards the projects. Management factors included issues around stakeholder expectations. Communication and transparency presented challenges and this included stakeholder buy-ins and collaborations. It was noted that contractors often fail to communicate and interact with stakeholders on projects. The political and legislative factors included the complexity of current legal frameworks and strict requirements in terms of the removal, transportation, and disposal of asbestos being hazardous.

5.3. Recommendations

After conducting a thorough analysis, the following suggestions are being proposed as a continuation of the conclusions drawn.

5.3.1. Conditions of Contract management and signed contracts

It is advisable to carefully select the project management contract type before implementing rehabilitation to ensure that the management and outcome controls are strong and can be identified and managed through regulatory frameworks for project success. The contract conditions should ensure effective and rapid decision-making strategies and tools. The management of contract conditions is often overlooked, and it is recommended that tender contract data should inform and provide guidelines for effectively clarifying contract management requirements. Signing the contract is a critical and compliant requirement, and timely execution is essential for timeline and cost planning. The specific contract should be identified, and assurance of contract management ability must be confirmed to address factors that could cause delays and impacts. It is suggested that all the lessons learnt from analysing issues like stakeholder engagement, and other factors be inserted into the project scoping to avoid future defaults and misinterpretations.

5.3.2. Project Progress Monitoring and Evaluation

Monitoring and progress evaluation (M&E) play a vital role in abandoned mine rehabilitation projects. These processes are crucial to assess the effectiveness of project timelines and performance in construction planning and efforts, as they will assist in ensuring compliance with regulations and policies, and provide valuable feedback for adaptive action management.

The monitoring and evaluation team should comprise technical and subject matter experts who converse with the Asbestos Rehabilitation process and requirements. The monitoring of the projects should have the tools and processes to ensure accurate evaluation including time and costs and must be continuous during the rehabilitation and construction process. Measurement and control mechanisms need to be designed and implemented to ensure confluence and synchronisation on all technical design and regulatory legislation requirements.

To address issues relating to asbestos regulations, compliances, safety, health, and legislation specifications, it is recommended that Subject Matter Experts (SMEs) be included in the scoping, scheduling and planning stages of the projects. The SMEs should be an interdisciplinary team with adequate experience and background, and they should have onsite evaluation and technical controls to be directly involvement in checking and ensuring qualitive control on the management and monitoring of the projects.

Having controls and measures is critical as this will help in making timely and informed decisions by addressing challenges promptly and accurately. An example would be that when a community issue arises. This will be immediately identified and mitigated before an escalation can develop.

To ensure accurate and effective monitoring and evaluation, it is recommended that the contract data clauses in tenders be adapted to address factors and challenges predicted before they can cause challenges. Contract data in all tenders is the clause effective in having added management ability in addressing focus to extra requirements and specifications in a tender over and above the standard tender management contract conditions. The contract type, General Conditions of Contract or contract type is supplemented by this clause, and can effectively be used to prevent defaults and failures involving impacts and compliances.

It is essential to continuously monitor the progress and performance of a project to ensure that rehabilitation activities and technical standards are met and carried out as per the established timelines and milestones. This monitoring helps project managers to keep track of the completion of specific tasks, identify potential delays, and access direct information for management of the project.

It is crucial to identify any deviations from the planned schedule or delays promptly. This enables project managers to take immediate corrective measures, such as reallocating resources or adjusting project timelines, to minimize disruptions. Effective monitoring ensures that the project stays on track and achieves its objectives within the defined timeframe and costs.

5.3.3. Data Management and Reporting

Effective data management and reporting systems are crucial for gathering, analysing and sharing information related to project performance. The lack of proper data and reporting feedback mechanisms often causes delayed decisions and poor time management, which can be attributed to contractors' ignorance or lack of attention. The feedback and reporting should also relate to the proper factors that could affect project progress and timelines. An example of this would be a metric reporting system that addresses and evaluates the cost and delivery of material consistently with live and active data. It is critical to have management and reporting structures in place from the start and to install outlines for effective and timely execution of the project. Clear data and transparent information are necessary to avoid misunderstandings and misconceptions. Effective contract and data management procedures ensure transparency and accuracy of information, which, in turn, ensures successful project execution. Transparent reporting enhances accountability and ensures that stakeholders are well-informed about project developments.

A robust data management and reporting system enables evidence-based decision-making (Deductive) and provides stakeholders, including government agencies, local communities, and funding organisations, with a clear understanding of project achievements and challenges in real-time. Transparency in reporting also fosters trust and accountability, contributing to the overall outcome of projects.

5.3.4. Calculation of costs for effective management of projects

The successful rehabilitation of abandoned mines requires careful attention to project scope execution and planning. From the conception stage of a project, the design and administration of a tender should be planned and constructed to be able to effectively have points of checks and balances to ensure that management can immediately flag challenges and delays in the project. This involves accurately calculating costs and effectively managing technical, economic, psychological, and regulatory issues. In South Africa, addressing these issues systematically increases the possibility of achieving effective environmental restoration and long-term sustainability in asbestos rehabilitation projects.

Accurate and effective cost and statistical management is necessary to ensure continuity and timely delivery. A lack of informed decisions and delays often is the resultant of ineffective cost, evaluation and reporting strategies. Precise control of expenditures also ensures that impacts are identified when they do not fall into planned costs and budgets for the project.

It is recommended to add cost and timeline holding points based on the factors that could affect the conditions of the contract and design into the project construction program technical and thematic descriptors for a matrix to ensure clear risk-reduced management and outcomes.

5.3.5. Performance Metrics

Establishing and monitoring key performance indicators (KPIs) is crucial for objectively measuring the success of rehabilitation efforts and ensuring adherence to project objectives. Performance metrics provide a quantitative basis for evaluating project outcomes. The metrics should be based on and fully support the technical and design specifications by considering all factors that could impact the construction programs and timelines. An example would be to ensure that access road construction is fully linked to the key holding points to ensure inspections and confirmations of correct execution and delivery of technical requirements of the scope.

It is essential to align key performance indicators with project deadlines and economic planning to facilitate quick and effective decision-making. It is also crucial to consider stakeholder involvement and feedback when defining the indicators, particularly with financial management, procurement and construction requirements.

Regular assessment of performance metrics is recommended as it informs decision-making processes. It will enable project managers to identify areas of success and areas that may require adjustments and never lack the management of real-time information and data for effective decisions and execution of project requirements. Adapting strategies based on performance metrics enhances overall project effectiveness, helping to optimize resource utilization and possible cost and time savings.

5.3.6. Community and Stakeholder Feedback

It is essential to receive regular feedback from the community and stakeholders to understand their concerns, expectations, and the impacts of rehabilitation efforts. This approach fosters collaboration, and cooperation and ensures that the project takes into account local perspectives, challenges and arising dissatisfactions.

Addressing and providing accurate and honest feedback is crucial for establishing and maintaining community trust, confidence and collaborative engagement. It helps to build good relationships and ensures that the rehabilitation project aligns with the needs and expectations of the local authorities and community structures. Proactive communication and immediate responses foster reliable and trustworthy responses and influence perceptions and outcomes. Addressing concerns contributes to a positive relationship between the project team and the stakeholders, which helps to achieve long-term project goals and deadlines.

5.3.7. Integrated Rehabilitation Strategies

Developing and implementing integrated rehabilitation strategies that address environmental SDGs, support health, and economic aspects and is essential. These strategies should be tailored to the unique challenges posed by asbestos mines and development locally by considering the factors that influence the project progress and successful construction timelines. The strategies should include all the integration elements to support and help manage contracts and tender outcomes with the support of legislation and contract requirements.

Collaboration with government and official agencies can provide new and fresh approaches to address project challenges and issues. However, many causes of delays in time and construction are often overlooked, and project challenges are not recorded and added to adaptive future strategies.

Both the employer and the appointed contractor can benefit from the lessons learned and better use of data management strategies for improved rehabilitation results. Therefore, it is recommended to incorporate a lessons-learned session and procedure into the contractual requirements, followed by an official report compiling all the challenges and recommendations. This report could help provide possible recommendations and factorial themes for other projects going forward by reviewing all the data and project information. Adaptive management should be based on real-time data management by using deductive and factual project management of factors identified.

5.3.8. Political Influences

Project managers need to stay abreast of political agendas and be aware of possible changes and influenced project timelines, resource requirements, and compliance criteria. This requires a high degree of flexibility and adaptability; project programs and plans may need to be adjusted to meet new legal and regulatory standards on the move in affected areas.

Some areas where asbestos rehabilitations are scheduled have many historical and related issues due to the impacts that asbestos had on communities and the expectations from local dynamics before. The demographics of the rehabilitation areas are susceptible to pressure from communities and need political intervention at any time. The importance of political recognition is cardinal and a high level of focus needs to be placed on collaboration and social acceptance. It is recommended that accurate and in-depth surveys by investigating areas that are marked for rehabilitation and get the real perceptions and feel of the community attitudes and perceptions to ensure proper stakeholder engagement and communication before the project starts. It is also important to do timely information-sharing initiatives regarding the project and the scope with stakeholders and affected parties.

It is recommended that stakeholder engagement with all affected parties be made at very early stages even before implementation or tender stage to determine which parties need to be considered and impacted by the projects. Accurate information collection of the Traditional and Local infrastructure is advised to ensure that all the leadership and local influences are identified and known.

The DMRE and government agencies involved need to be directly involved and correctly engaged at all levels to ensure a multi-tier communication structure and to provide clarity and transparency based on all platforms to evaluate and prioritise planning and scoping for the projects.

5.3.9. Policy and Regulatory Reforms

It is important to advocate for and actively participate in policy and regulatory reforms that strengthen the legal framework governing rehabilitation. It is advised that to ensure that all regulations are clear and well executed it is recommended that all evolving environmental and health standards be communicated with all contractors through the introduction of training and educational programs in the tender process and scoping. The contract and tender data must ensure compliance and accurate synchronisation with that of the Department of Mineral Resources and Energy (DMRE) and the Council for Mineral Sciences and Technology (MINTEK) by ensuring strict participation with all standards and policies regarding the rehabilitation of asbestos mines. This will include policy changes and new regulatory requirements. It is recommended that information and training workshops on all technical, regulatory and Legislative requirements be held regularly to ensure clear and transparent procedures. The experience and feedback sessions from projects should inform if any changes should develop and be considered to enhance policies and procedures for rehabilitation projects, including factors that caused challenges and include technical matters.

5.3.10. Technological Advancements:

It is important to establish sustainable funding models that ensure consistent and reliable financial streams for rehabilitation projects. Public-private partnerships, environmental funds, and innovative financing mechanisms can secure resources for long-term initiatives. Develop new technological methods to approach rehabilitation projects and design. It is recommended that new technologies and methods be at the forefront of all planning and scoping on rehabilitations to possibly save time and cost.

5.3.11. Stakeholder Engagement Enhancement

Establish transparent platforms for stakeholder engagement. Collaborate with local communities, government bodies, and industry stakeholders for inclusive decision-making and effective implementation of rehabilitation plans.

5.3.12. Sustainable Funding Models

Let's develop sustainable funding models for rehabilitation projects that could implement and apply some of the suggestions and recommendations in this report. We can use public-private partnerships, environmental funds, government initiatives, and innovative financing mechanisms to secure resources for long-term initiatives. By considering the factors and findings in this report more effective and sustainable solutions can be developed to improve the maximising of rehabilitation projects and provide a more perfect future and outcome for communities including environmental recovery and restoration locally and globally. It is suggested that by considering and designing sustainable solutions for the end-use of rehabilitated areas, funding and direct financial investment could be attracted from other stakeholders and investment partners. This would include adding new concepts and sustainable rehabilitation models from innovative design and out-of-the-box thinking processes to creatively find viable and economical outcomes for post-closure.

5.3.13. Capacity Building and Education

Investing in capacity-building programs and educational initiatives to empower local communities and stakeholders is advised. The promotion of local environmental awareness and environmental health risk monitoring programs associated with abandoned asbestos mines will foster a sense of ownership and accountability through rehabilitation efforts in communities and areas.

5.4. Future Research Directions

Looking back at previous asbestos mine rehabilitation projects highlights the important lessons learnt about factors that impacted decisions taking into account resources, stakeholders, strategies, planning, and local communities. The challenges found in this report could further some efforts to gain and develop further strategies and plans for other future projects. It is important to consider historical insights, and factors and acknowledge the challenges that these impacts and factors indicated and that many challenges are not always given the priority they require. By identifying both successes and failures it will help develop best practices for rehabilitation. This, in turn, will inform future planning and strategies to help address the causes of past failures and prevent them from occurring again.

Future research could further explore better design, methods and technical specifications to improve the rehabilitation of abandoned mines in South Africa, and further supplement what this study intended to achieve by comprehensive thematic and data analysis through direct and deductive information collected on 32 cases in Asbestos Rehabilitation Projects.

Further investigation and research can be done on the following aspects below:

- Assessing the sustainability of interventions through long-term monitoring of rehabilitated sites and applied technology.
- Conduct research for easier and cost-effective rehabilitation strategies on different types of abandoned mines and improved methods by using specialised and dedicated equipment.
- Develop and design formal training programs for Emerging Small Business managers and owners.
- Models that could be followed to create ownership programs in communities regarding rehabilitated areas and aftercare.

- Plan and design sustainable end-uses into rehabilitation programs to provide possible job opportunities and possibly provide an economically sustainable delivery outcome after rehabilitation.

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APPENDIX

Appendix 1: Case Studies Cost and time analysis

32 Asbestos Rehabilitation Case Studies Timelines and Costs							
Case Study	Timeline Period Contract	Internal/External Management	Tendered value	Completed Value	Balance (Credit)	cost overrun	Days left on Contract
Case Study 1	2009 - 2010	Internal	ZAR 426,147.00	ZAR 426,147.00	ZAR -	ZAR -	6
Case Study 2	2009 - 2010	Internal	ZAR 4,777,201.00	ZAR 4,798,001.00	ZAR 20,800.00	ZAR 20,800.00	11
Case Study 3	2009 - 2010	Internal	ZAR 5,997,536.00	ZAR 4,798,001.00	ZAR (1,199,535.00)	ZAR (1,199,535.00)	30
Case Study 4	2009 - 2010	Internal	ZAR 2,524,060.00	ZAR 2,524,060.00	ZAR -	ZAR -	7
Excluded as case study	2010 - 2013	Internal	ZAR 47,000.00	ZAR 47,000.00	ZAR -	ZAR -	3
Case Study 5	2010 - 2013	Internal	ZAR 6,533,153.00	ZAR 6,533,153.00	ZAR -	ZAR -	10
Case Study 6	2010 - 2013	Internal	ZAR 4,396,446.00	ZAR 4,396,446.00	ZAR -	ZAR -	19
Case Study 7	2010 - 2013	Internal	ZAR 2,865,362.00	ZAR 2,865,362.00	ZAR -	ZAR -	19
Case Study 8	2010 - 2013	Internal	ZAR 3,432,322.00	ZAR 3,432,322.00	ZAR -	ZAR -	19
Case Study 9	2010 - 2013	Internal	ZAR 2,400,000.00	ZAR 2,400,000.00	ZAR -	ZAR -	0
Case Study 10	2010 - 2013	Internal	ZAR 1,770,933.00	ZAR 1,770,933.00	ZAR -	ZAR -	2
Case Study 11	2010 - 2013	Internal	ZAR 11,526,318.00	ZAR 11,526,318.00	ZAR -	ZAR -	20
Case Study 12	2010 - 2013	Internal	ZAR 2,445,983.00	ZAR 2,445,983.00	ZAR -	ZAR -	4
Case Study 13	2010 - 2013	Internal	ZAR 1,893,012.00	ZAR 1,893,012.00	ZAR -	ZAR -	3
Case Study 14	2010 - 2013	Internal	ZAR 2,032,860.00	ZAR 2,032,860.00	ZAR -	ZAR -	28
Case Study 15	2010 - 2013	Internal	ZAR 7,555,232.00	ZAR 7,555,232.00	ZAR -	ZAR -	29
Case Study 16	2010 - 2013	Internal	ZAR 1,981,125.00	ZAR 1,973,125.00	ZAR (8,000.00)	ZAR (8,000.00)	1
Case Study 17	2010 - 2013	Internal	ZAR 1,807,694.00	ZAR 1,807,694.00	ZAR -	ZAR -	23
Case Study 18	2013 - 2016	Internal	ZAR 3,017,248.00	ZAR 3,017,248.00	ZAR -	ZAR -	1
Case Study 19	2013 - 2016	External Consultants	ZAR 5,574,941.00	ZAR 5,574,991.09	ZAR 50.09	ZAR 50.09	21
Case Study 20	2013 - 2016	External Consultants	ZAR 5,170,908.00	ZAR 3,920,180.51	ZAR (1,250,727.49)	ZAR (1,250,727.49)	18
Case Study 21	2013 - 2016	Internal	ZAR 327,562.00	ZAR 327,562.00	ZAR -	ZAR -	0
Case Study 22	2013 - 2016	Internal	ZAR 1,299,767.00	ZAR 805,113.00	ZAR (494,654.00)	ZAR (494,654.00)	21
Case Study 23	2013 - 2016	Internal	ZAR 6,288,488.00	ZAR 4,617,964.00	ZAR (1,670,524.00)	ZAR (1,670,524.00)	3
Case Study 24	2013 - 2016	External Consultants	ZAR 6,561,648.00	ZAR 5,041,311.00	ZAR (1,520,337.00)	ZAR (1,520,337.00)	-155
Case Study 25	2013 - 2016	Internal	ZAR 7,989,556.00	ZAR 7,989,556.00	ZAR -	ZAR -	56
Case Study 26	2013 - 2016	Internal	ZAR 1,204,274.00	ZAR 918,475.00	ZAR (285,799.00)	ZAR (285,799.00)	-3
Case Study 27	2013 - 2016	External Consultants	ZAR 13,892,518.00	ZAR 9,978,886.00	ZAR (3,913,632.00)	ZAR (3,913,632.00)	50
Case Study 28	2013 - 2016	External Consultants	ZAR 9,958,402.00	ZAR 8,808,345.78	ZAR (1,150,056.22)	ZAR (1,150,056.22)	14
Case Study 29	2013 - 2016	External Consultants	ZAR 21,753,539.00	ZAR 19,564,905.74	ZAR (2,188,633.26)	ZAR (2,188,633.26)	-280
Case Study 30	2016 - 2019	External Consultants	ZAR 4,624,819.00	ZAR 3,304,160.78	ZAR (1,320,658.22)	ZAR (1,320,658.22)	-155
Case Study 31	2016 - 2019	External Consultants	ZAR 45,607,135.08	ZAR 33,699,512.00	ZAR (11,907,623.08)	ZAR (11,907,623.08)	-366
Case Study 32	2016 - 2019	External Consultants	ZAR 4,223,139.00	ZAR 3,839,218.00	ZAR (383,921.00)	ZAR (383,921.00)	-2

On Budget	(green)	Over Time Date/days	(red)
Under Budget	(yellow)	Under Time Date/days	(yellow)
Over Budget	(red)	On Time Date/days	(green)

Appendix 2: Combined factors with all Case Studies

All case studies combined with all factors			
Factor Found	Case Number	Cost Overrun	Time Overrun
Slowness in decision-making processes	Case 24 Case 31	No overruns	Case 31 Case 24
Reworks due to errors during construction	Case 29 Case 30	No overruns	Case 29 Case 30

Contractor challenges	Case 2 Case 13 Case 15 Case 18 Case 23 Case 24 Case 29 Case 30 Case 31	No overruns	Case 29 Case 30 Case 31 Case 24
Delay in material delivery	Case 24 Case 29 Case 30	No overruns	Case 24 Case 29 Case 30
Community actions and activities	Case 4 Case 11 Case 31	No overruns	Case 31
Shortage of skilled equipment operators	Case 24	No overruns	Case 24
Low productivity level of workers	Case 24 Case 31	No overruns	Case 24 Case 31
Workers risky behaviour on sites as the major causes of construction projects schedule overruns	Case 31	No overruns	Case 31
A lack of project specific experience by project teams	Case 2 Case 24 Case 30	No overruns	Case 24 Case 30
External and organizational decisions in the past	Case 31	No overruns	Case 31
Community resistance	Case 2 Case 4 Case 9 Case 11 Case 31	No overruns	Case 31
Pressure on the project team	Case 24 Case 31	No overruns	Case 24 Case 31
Scope change drive from stakeholders	Case 23 Case 31	No overruns	Case 31

The average overrun percentage was over 25% on all projects.	Case 24 Case 31	No overruns	Case 24 Case 31
Geographical Areas seem to impact on cost overruns.	Case 2 Case 11 Case 17 Case 30 Case 31	No overruns	Case 30 Case 31
Historical trends	Case 2 Case 4 Case 11 Case 15 Case 24 Case 31	No overruns	Case 24 Case 31
And Inflation did not seem to be the cause of the overruns		No overruns	
Incompleteness of estimations	Case 29	No overruns	Case 29
Scope Changes		No overruns	
Inadequate infrastructures	Case 31	No overruns	Case 31
Inadequate estimation due to lack of incentives		No overruns	
Lack of resources	Case 31	No overruns	Case 31
Strategic behaviour	Case 31	No overruns	Case 31
Poor financing and contract management	Case 2 Case 24 Case 31	No overruns	Case 24 Case 31
Bias amongst local officials	Case 4 Case 9 Case 11 Case 15	No overruns	
Cognitive bias of people involved in the project	Case 31	No overruns	Case 31
Cautious attitudes regarding risks	Case 31	No overruns	Case 31
Deliberate cost underestimation or overestimation based on political interests.		No overruns	

Appendix 3: Project Details and Information for Studies

Case Study Data Capturing and determiniation of costs and timeline details

Case Study	Number	Timeline Period Contract	Province	Title Holder	Tender Award Date	Control Documents	Fixed Price Contract VAT EXC	Remeasurable contract	Internal/External Management	Tendered value	Completed Value	Descrepancy	Management Contract	Construction start	Construction Completed	Project Days Construction	Project Time allowed	cost overrun	Days left per contract
Case Study 1	1	2009 - 2010	Northern Cape	Community	Jan-10	Payment Spreadsheets/reports/minutes and claims/completion certificates/contracts	ZAR 426 147,00		Internal	ZAR 426 147,00	ZAR 426 147,00	ZAR -	Fixed Price	Jan-10	Mar-10	64	70	ZAR -	6
Case Study 2	2	2009 - 2010	Northern Cape	Private	Feb-10	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 4 777 201,00		Internal	ZAR 4 777 201,00	ZAR 4 798 001,00	ZAR 20 800,00	Fixed Price	Feb-10	Apr-10	59	70	ZAR 20 800,00	11
Case Study 3	3	2009 - 2010	Northern Cape	Private	Feb-10	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 5 997 536,00		Internal	ZAR 5 997 536,00	ZAR 4 798 001,00	ZAR (1 199 535,00)	Fixed Price	Feb-10	Jun-10	120	150	ZAR (1 199 535,00)	30
Case Study 4	4	2009 - 2010	Northern Cape	yathemba Municip	Mar-10	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 2 524 060,00		Internal	ZAR 2 524 060,00	ZAR 2 524 060,00	ZAR -	Fixed Price	Jun-10	Nov-10	153	160	ZAR -	7
	5	2010 - 2013	Northern Cape	Kathu Municipal	Mar-14	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 47 000,00		Internal	ZAR 47 000,00	ZAR 47 000,00	ZAR -	Fixed Price	Jan-11	Jan-11	2	5	ZAR -	3
Case Study 5	5	2010 - 2013	Northern Cape	Community	Feb-12	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 6 533 153,00		Internal	ZAR 6 533 153,00	ZAR 6 533 153,00	ZAR -	Fixed Price	Feb-12	May-12	90	100	ZAR -	10
Case Study 6	6	2010 - 2013	Northern Cape	Community	Aug-12	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 4 396 446,00		Internal	ZAR 4 396 446,00	ZAR 4 396 446,00	ZAR -	Fixed Price	Sep-12	Dec-12	91	110	ZAR -	19
Case Study 7	7	2010 - 2013	Northern Cape	Community	Aug-12	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 2 865 362,00		Internal	ZAR 2 865 362,00	ZAR 2 865 362,00	ZAR -	Fixed Price	Sep-12	Dec-12	91	110	ZAR -	19
Case Study 8	8	2010 - 2013	Northern Cape	Community	Aug-12	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 3 432 322,00		Internal	ZAR 3 432 322,00	ZAR 3 432 322,00	ZAR -	Fixed Price	Sep-12	Dec-12	91	110	ZAR -	19
Case Study 9	9	2010 - 2013	Northern Cape	yathemba Municip	Dec-11	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 2 400 000,00		Internal	ZAR 2 400 000,00	ZAR 2 400 000,00	ZAR -	Fixed Price	Jan-11	Apr-11	90	90	ZAR -	0
Case Study 10	10	2010 - 2013	Northern Cape	Community	Sep-12	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 1 770 933,00		Internal	ZAR 1 770 933,00	ZAR 1 770 933,00	ZAR -	Fixed Price	15-Oct-12	12-Dec-12	58	60	ZAR -	2
Case Study 11	11	2010 - 2013	Limpopo	Community	Sep-12	Payment Spreadsheets/reports/minutes and claims/completion certificates	################		Internal	ZAR 11 526 318,00	ZAR 11 526 318,00	ZAR -	Fixed Price	Jan-13	May-13	120	140	ZAR -	20
Case Study 12	12	2010 - 2013	Northern Cape	Community	Sep-11	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 2 445 983,00		Internal	ZAR 2 445 983,00	ZAR 2 445 983,00	ZAR -	Fixed Price	Nov-11	Jan-12	61	65	ZAR -	4
Case Study 13	13	2010 - 2013	Limpopo	ubatse Municipalit	Oct-12	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 1 893 012,00		Internal	ZAR 1 893 012,00	ZAR 1 893 012,00	ZAR -	Fixed Price	Dec-12	Feb-13	62	65	ZAR -	3
Case Study 14	14	2010 - 2013	Northern Cape	Private	Oct-12	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 2 032 860,00		Internal	ZAR 2 032 860,00	ZAR 2 032 860,00	ZAR -	Fixed Price	Dec-12	Feb-13	62	90	ZAR -	28
Case Study 15	15	2010 - 2013	Northern cape	Municipal	Sep-12	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 7 555 232,00		Internal	ZAR 7 555 232,00	ZAR 7 555 232,00	ZAR -	Fixed Price	Oct-12	Dec-12	61	90	ZAR -	29
Case Study 16	16	2010 - 2013	Limpopo	apricorn Municipa	Dec-12	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 1 981 125,00		Internal	ZAR 1 981 125,00	ZAR 1 973 125,00	ZAR (8 000,00)	Fixed Price	Jan-13	Mar-13	59	60	ZAR (8 000,00)	1
Case Study 17	17	2010 - 2013	Limpopo	ubatse Municipalit	Jan-13	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 1 807 694,00		Internal	ZAR 1 807 694,00	ZAR 1 807 694,00	ZAR -	Fixed Price	Feb-13	10-Mar-13	37	60	ZAR -	23
Case Study 18	18	2013 - 2016	Northern Cape	Kuruman	Jan-13	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 3 017 248,00		Internal	ZAR 3 017 248,00	ZAR 3 017 248,00	ZAR -	Fixed Price	Feb-13	Apr-13	59	60	ZAR -	1
Case Study 19	19	2013 - 2016	Limpopo	pricorn Municipal	Feb-14	Payment Spreadsheets/reports/minutes and claims/completion certificates		ZAR 5 574 941,00	External Consultants	ZAR 5 574 941,00	ZAR 5 574 991,09	ZAR 50,09	Remeasurable	24-Mar-14	19-Sep-14	179	200	ZAR 50,09	21
Case Study 20	20	2013 - 2016	Limpopo	pricorn Municipal	Feb-14	Payment Spreadsheets/reports/minutes and claims/completion certificates		ZAR 5 170 908,00	External Consultants	ZAR 5 170 908,00	ZAR 3 920 180,51	ZAR (1 250 727,49)	Remeasurable	31-Mar-14	20-Aug-14	142	160	ZAR (1 250 727,49)	18
Case Study 21	21	2013 - 2016	WesternCape	sikisiki municipali	Feb-14	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 327 562,00		Internal	ZAR 327 562,00	ZAR 327 562,00	ZAR -	Remeasurable	Mar-14	Apr-14	31	31	ZAR -	0
Case Study 22	22	2013 - 2016	KZN	meroy Municipali	Jan-15	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 1 299 767,00		Internal	ZAR 1 299 767,00	ZAR 805 113,00	ZAR (494 654,00)	Remeasurable	10-Feb-15	20-Apr-15	69	90	ZAR (494 654,00)	21
Case Study 23	23	2013 - 2016	Limpopo	Lebokwagomo	Dec-14	Payment Spreadsheets/reports/minutes and claims/completion certificates		ZAR 6 288 488,00	Internal	ZAR 6 288 488,00	ZAR 4 617 964,00	ZAR (1 670 524,00)	Remeasurable	10-Jan-15	10-Aug-15	212	215	ZAR (1 670 524,00)	3
Case Study 24	24	2013 - 2016	Limpopo	Lebokwagomo	Jan-15	Payment Spreadsheets/reports/minutes and claims/completion certificates		ZAR 6 561 648,00	External Consultants	ZAR 6 561 648,00	ZAR 5 041 311,00	ZAR (1 520 337,00)	Remeasurable	Feb-15	Apr-16	425	270	ZAR (1 520 337,00)	-155
Case Study 25	25	2013 - 2016	KZN	meroy Municipali	Jun-15	Payment Spreadsheets/reports/minutes and claims/completion certificates		ZAR 7 989 556,00	Internal	ZAR 7 989 556,00		ZAR (7 989 556,00)	Remeasurable	Jul-15	Mar-16	244	300	ZAR (7 989 556,00)	56
Case Study 26	26	2013 - 2016	Limpopo	Lebokwagomo	Sep-15	Payment Spreadsheets/reports/minutes and claims/completion certificates	ZAR 1 204 274,00		Internal	ZAR 1 204 274,00	ZAR 918 475,00	ZAR (285 799,00)	Remeasurable	Oct-15	Feb-16	123	120	ZAR (285 799,00)	-3
Case Study 27	27	2013 - 2016	Northern Cape	Siyathemba	Feb-15	Payment Spreadsheets/reports/minutes and claims/completion certificates		ZAR 13 892 518,00	External Consultants	ZAR 13 892 518,00	ZAR 9 978 886,00	ZAR (3 913 632,00)	Remeasurable	May-15	Nov-16	550	600	ZAR (3 913 632,00)	50
Case Study 28	28	2013 - 2016	Northern Cape	Siyathemba	Aug-15	Payment Spreadsheets/reports/minutes and claims/completion certificates		ZAR 9 958 402,00	External Consultants	ZAR 9 958 402,00	ZAR 8 808 345,78	ZAR (1 150 056,22)	Remeasurable	Oct-15	Oct-16	366	380	ZAR (1 150 056,22)	14
Case Study 29	29	2013 - 2016	Northern Cape	Community	Jul-15	Payment Spreadsheets/reports/minutes and claims/completion certificates		ZAR 21 753 539,00	External Consultants	ZAR 21 753 539,00	ZAR 19 564 905,74	ZAR (2 188 633,26)	Remeasurable	Aug-15	Jun-17	670	390	ZAR (2 188 633,26)	-280
Case Study 30	30	2016 - 2019	Limpopo	Mafefe Capricorn	Dec-15	Payment Spreadsheets/reports/minutes and claims/completion certificates		ZAR 4 624 819,00	External Consultants	ZAR 4 624 819,00	ZAR 3 304 160,78	ZAR (1 320 658,22)	Remeasurable	Jan-16	Mar-17	425	270	ZAR (1 320 658,22)	-155
Case Study 31	31	2016 - 2019	Limpopo	ubatse Municipalit	Dec-15	Payment Spreadsheets/reports/minutes and claims/completion certificates		ZAR 45 607 135,08	External Consultants	ZAR 45 607 135,08	ZAR 33 699 512,00	ZAR (11 907 623,08)	Remeasurable	Jan-17	Feb-19	761	395	ZAR (11 907 623,08)	-366
Case Study 32	32	2016 - 2019	Limpopo	ubatse Municipalit	May-18	Payment Spreadsheets/reports/minutes and claims/completion certificates		ZAR 4 223 139,00	External Consultants	ZAR 4 223 139,00	ZAR 3 839 218,00	ZAR (383 921,00)	Remeasurable	Sep-18	Jan-19	122	120	ZAR (383 921,00)	-2

2009 - 2010	Financial Contract 2009 - 2010
2010 - 2013	Financial Contract 2010 - 2013
2013 - 2016	Financial Contract 2013 - 2016
2016 - 2019	Financial Contract 2016 - 2019

Projects that ran over in Time Or Costs afer capturing data from control sheets and information all case studies

Case Study	No	Timeline Period Contract	Province	Ownership	Tender Award Date	Control Documents	Fixed Price Contract VAT EXC	Remeasurable contract	Internal/External Management	Tendered value	Completed Value	Descrepancy	Management Contract	Construction start	Construction Completed	Project Days Construction	Project Time allowed	cost overrun	Days left per contract
Case Study 24	1	2013 - 2016	Limpopo	Lebokwagomo		Payment Spreadsheets/reports/minutes and claims/completion certificates		ZAR 6 561 648,00	External Consultants	ZAR 6 561 648,00	ZAR 5 041 311,00	ZAR (1 520 337,00)	Remeasurable	Feb-15	Apr-16	425	270	ZAR (1 520 337,00)	-155
Case Study 29	2	2013 - 2016	Northern Cape	Community		Payment Spreadsheets/reports/minutes and claims/completion certificates		ZAR 21 753 539,00	External Consultants	ZAR 21 753 539,00	ZAR 19 564 905,74	ZAR (2 188 633,26)	Remeasurable	Aug-15	Jun-17	670	390	ZAR (2 188 633,26)	-280
Case Study 30	3	2016 - 2019	Limpopo	Mafefe Capricorn		Payment Spreadsheets/reports/minutes and claims/completion certificates		ZAR 4 624 819,00	External Consultants	ZAR 4 624 819,00	ZAR 3 304 160,78	ZAR (1 320 658,22)	Remeasurable	Jan-16	Mar-17	425	270	ZAR (1 320 658,22)	-155
Case Study 31	4	2016 - 2019	Limpopo	ubatse Municipality		Payment Spreadsheets/reports/minutes and claims/completion certificates		ZAR 45 607 135,08	External Consultants	ZAR 45 607 135,08	ZAR 33 699 512,00	ZAR (11 907 623,08)	Remeasurable	Jan-17	Feb-19	761	395	ZAR (11 907 623,08)	-366

Appendix 4: Ethical Clearance Certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

SCHOOL OF MINING ENGINEERING ETHICS COMMITTEE
CONSTITUTED UNDER THE UNIVERSITY HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: EMINN/2022/34**
PROJECT TITLE	Asbestos Rehabilitation Projects in South Africa and Community Impacts on Project Overruns
INVESTIGATOR	Reuben Meyerowitz
SCHOOL/DEPARTMENT OF INVESTIGATOR	School of Mining Engineering
DATE CONSIDERED	15 June 2022
DECISION OF THE COMMITTEE	Approved
RISK LEVEL	No RISK
EXPIRY DATE	15 June 2025
ISSUE DATE OF CERTIFICATE	15 June 2022
CHAIRPERSON	(Mr. Huw Thomas Senior Lecturer)

cc: Supervisor: Dr. Ingrid Watson, Mrs. Pontsho Twala

DECLARATION OF INVESTIGATOR

To be completed in duplicate and **ONE COPY** returned to the Chairperson of the School/Department ethics committee.

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

____
Signature

Date _____/_____/_____

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES