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CRITICAL SUCCESS FACTORS IN MINING PROJECTS' POST-COMPLETIONPHASE: MODIKWA PLATINUM MINE

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DECLARATION

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ABSTRACT

Mining plays a crucial role in modern society in providing materials and services needed for everyday living such as raw materials, energy, construction, machinery, and water purification. Mining requires capital-intensive investments to ensure long-term sustainability of its operations. Significant amounts of monies are invested to support mining capital projects, but there are high numbers of unsuccessful projects within the project management critical constraints (scope, time, costs, and quality). Inability to meet mining capital projects' objectives impacts investors, employees, government, and communities negatively. This manifests in financial losses to investors, loss of jobs for employees and loss in taxes to governments. It is believed that by learning from previous successful and unsuccessful projects, future mining projects could be managed and delivered more successfully. These lessons could be learnt by conducting post-project reviews which could result in the improvement of both current and future mining projects. This research report was undertaken in order to understand the complexity of a post completion review of a capital mining project at Modikwa Platinum Mine.

According to the feasibility study, the mine was designed to mill 200 000 tonnes of ore per month and later this figure was changed to 240 000 tonnes per month. The mine has not consistently achieved the design milling capacity mostly due to lack of ore from underground. This stemmed from risks such as complex geology, lower than expected commodity prices and the global financial meltdown. These macro and micro factors contributed to the mine not achieving its feasibility outcomes.

The review is conducted using production information, financial information and results from questionnaires and interviews. The mine is located in a challenging socio-economic environment, which adds complexity to the project in terms of stakeholder management. Reviews of successful and unsuccessful mining projects globally and in South Africa through information analysis and interviews indicate a common thread of critical success factors and lessons to be learnt.

DEDICATION

I would like to dedicate this report to my wife, Ntombi Khumalo, who is always supportive. I thank her for understanding for all the nights and weekends that I could not spend with her due to research report work I had to do.

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NOMENCLATURE

3-D	Three dimensions
6E	Six Platinum Group Metal Elements
ASG	Advanced Strike Gully
ARM	African Rainbow Minerals
AMplats	Anglo American Platinum Corporation
BCE	Before Common Era
BIC	Bushveld Inland Complex
CPI	Consumer Price Index
CPA	Community Participation Association
CSF	Critical Success Factor
DMRE	Department of Minerals and Energy
EDC	Ecological Distribution Conflict
EITI	Extractive Industry Transparency Initiative
EJAtlas	Environmental Justice Atlas
ESG	Environmental Social and Governance
EPC	Engineering, Procurement and Construction
EPCM	Engineering, Procurement, Construction and Management
F-GT	Fetakgomo Greater Tubatse
GW	Giga Watts
Implats	Impala Platinum
IMS	Immediately Available for Stoping
IDP	Integrated Development Plan
IRENA	International Renewable Energy Agency
IRUP	Iron Rich Ultramafic Pegmatite
LCOE	Levelised Cost of Electricity
LHD	Load Haul Dump
MIG	Mainstream Inert Grinding
MPM	Modikwa Platinum Mine
NGO	Non-Governmental Organisation
NPC	Non-Profit Company
Oz	Ounces
PGE	Platinum Group Elements
PGM	Platinum Group Metals
PV	Photovoltaics
PCR	Post Closure Review
PMI	Project Management Institute
PMBOK	Project Management Body of Knowledge
SIB	Stay in Business
SLP	Social Labour Plan
T-FM	Tubatse Fetakgomo Municipality
TSF	Tailing Storage Facility
Ktpm	Kilo tonnes per month
UG2	Upper Group Two
US$	United States Dollar

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1 INTRODUCTION

A project is considered a failure when it has not delivered results that were required in line with pre-set expectations. To be evaluated as a success, a mining capital project must be managed and delivered within the set triple constraints of project management namely scope, cost, and time. In addition, it must fulfil the benefits stated in the business case, as documented in the Project Charter, including all adjustments as agreed by the Client. According to Bannerman (2008) the view that failure or success of project failure is embodiment of a perceived situation and stakeholder perception is a superset of the triple constraints of project management.

There have always been project failures in mining since the use of metals on a large scale which started in Mesopotamia around 3 500 BCE, and in Egypt around 3 000 BCE (Silva, 2016). However, what is different today, is the numerous and complex contributing factors that contribute to failures in mining projects.

The development of the Shorehan Nuclear Power Plant, started in 1966 by the Long Lighting Company, is an example of a failure of a massive project. This project started in 1966 with an estimated completion cost of US$75 million. The project was eventually abandoned 23 years later after a loss of more than US$5 billion (Ross and Staw, 1993).

In this study, examples of successful and unsuccessful mining projects are examined, and inferences drawn from outcomes of such studies. Personnel involved in mining capital projects were interviewed to gain an understanding of what determined critical success factors for mining capital projects. A platinum mine in the Eastern Limb of the Bushveld Igneous Complex serves as a case study project for review and analysis of project initiation, planning, execution, monitoring and controlling, and closure to determine how it compared with set project performance criteria stated in the final approved Project Charter. Factors that influenced the outcome of the project are analysed and conclusions are drawn.

Accumulated knowledge steeped in lived experiences plays an important role in the conclusions and insights that emerged from this study. Data captured from an experienced professional engaged with the Modikwa Platinum Mine (MPM) mining project served as the basis from which a diversity of lessons were learnt for future continuous improvement of capital mining projects.

1.1 Research background

South Africa is a mineral-rich country endowed with several of the largest known mineral reserves in the world. According to the Department of Mineral Resources (2017), South Africa has the largest known reserves of Platinum Group Metals (PGMs), manganese ore, chrome ore, and fluorspar. The country also has the second-largest known gold reserves and the sixth-largest coal reserves. In 2018, the mining industry accounted for the largest share of South Africa’s exports (38%). Mining is critical in bringing in foreign currency to pay for the large number of imports (Minerals Council of South Africa, 2019). In 2018, the mining industry employed 456 438 people. This represented 6.4% of private non-agricultural employment and 4.7% of non-agricultural employment overall (Mineral Council of South Africa, 2019). Hence, the mining industry plays a crucial role in the economy through the creation of employment and contributing revenues, in the form of taxes, to government.

1.1.1 Project failure in mining

In recent times, mining has confronted cyclic economic constraints such as declining metal prices and exchange rates. With many shallow mineral deposits already mined out, companies are looking to expand existing mines or to develop new mines to bring higher value to shareholders by either moving from opencast to underground or greenfield projects. Some shallow deposits extends vertically to considerable depth and thus have the potential to make transition from open pit mining to underground mining. Worldwide, there are few mines that have the potential to make the transition, or such transition has already been made, such as

Kanowna Bell in Western Australia, Grasberg in Indonesia, Chiquicamata in Chile and Sunrise Dam in Western Australia (Chung et al, 2016). Most mining companies do not have the project management and implementation capacity to manage these projects in-house. Therefore, they seek to procure the services of independent contractors or Engineering, Procurement and Construction (EPC) or Engineering, Procurement, Construction and Management (EPCM), and the responsibility for project management is outsourced. Just as with any project, once the execution has started, there is a race against time with significant invested funds at stake. Time delays become the project's most prominent enemy (KPMG, 2013). These delays will impact on the mining company's long-term operational strategies and key performance areas, consequently impacting on financial performance, job creation, and creation of shareholder value.

1.1.2 Examples of project failure in mining

It is estimated that, globally, more than four out of five capital mining projects were not delivered within the triple constraints' mandates (scope, costs, time), by an average deviation of 43% (Kuvshinikov et al, 2017).

Failure in mining projects is a global phenomenon, and the South African mining industry experiences similar impacts or effects. In 2012, Exxaro wrote off US$543 million on the Mayoko project in the Democratic Republic of Congo (DRC), after failing to secure a rail framework and a port memorandum with the DRC government. The key question was "were project management standards and guidelines such as PMBOK well implemented before the project execution?" Similarly, Gold Fields struggled, for over a decade, to make South Deep Mine profitable after acquiring it for US$1.5 billion in 2006 (Mckay, 2018).

There is macro as well as micro factors that have contributed to the failures of many big capital mining projects globally. Numerous mining projects have failed, resulting in losses of about R26 billions of US dollars and employment opportunities as indicated below.

According to Schneider (2017), the following mega mining projects have failed since 2011:

- **Conga Mine Project.** The US$5 billion Conga Mine project in Peru was abandoned. In February 2016, Colorado-based Newmont Mining alerted the U.S. Securities and Exchange Commission that it was shelving the US$5 billion Conga gold and copper mine project it was developing in the northern Andes of Peru. Social protests over water supply and pollution drove fierce resistance that led to the mine's closure.
- **Pascua-Lama Gold Mine.** An US$8.5 billion Pascua-Lama gold mine in Chile was shut down in 2013 after a decade of protests and unfavourable court rulings over perceived threats to water supplies and glaciers. After spending US$5 billion on the project, the Toronto-based Barrick Gold Corporation suspended work indefinitely on the huge open-pit copper mine on the Chile-Argentina border.
- **Tampakan Copper and Gold Mine.** In 2015 Glencore, one of the world's largest mining companies, pulled out of the development of one of the richest precious metal prospects, the US$5.9 billion Tampakan copper and gold mine on Mindanao island in the Philippines. The mine had been the focus of fierce local conflict for over a decade following a tailings pond disaster at the Marcopper open-pit copper mine on Marinduque Island. A breach in the tailings pond containment wall in March 1996 unleashed millions of tonnes of toxic mud and water, flooding communities and ruining productive fisheries. In April 2017, the Philippines government banned the new open-pit mine.
- **Shell's Arctic drilling campaign.** In September 2015, after spending US$7 billion and asserting that its Chukchi Sea offshore drilling project would yield world-class quantities of oil and natural gas, Royal Dutch Shell pulled out of the Arctic. The reasons for abandoning the project were cited as

fruitless effort to discover commercial quantities of fossil fuels, dangerous Arctic drilling conditions, rising expenses, and civic protest.

As can be seen from this list of failed capital mining and other projects, the rate of failure of capital-intensive projects is a cause for concern. A key objective of this research was to identify and gain an understanding of the critical success factors for capital mining projects in South Africa and how these could be applied to eliminate or reduce failures in mining projects.

1.2 Research motivation

This research set out to contribute to the understanding of factors that influence the success or failure of mining capital projects in South Africa. Complexities in a project are inevitable; they cannot be fully controlled or eliminated, but one can have better understanding of them to ensure better project delivery management. The complexity of projects is increasing as time passes, due to their execution in dynamic environments, having multiple stakeholders with different expectations, and technological challenges characterised by uncertainties (Poveda-Bautista et al., 2018).

Projects have different sets of complexities such as technical complexity, organisational complexity, and environmental complexity. Technical complexity includes goals, scope, tasks, experience, and risks. Organisational complexity includes lack of past work experience, lack of trust for contractors, lack of internal support, number of languages and nationalities involved. Environmental complexity includes the market conditions, location, and stakeholders (Bosch-Rekveldt et al., 2009).

It is upheld that competency in the understanding of project complexity is important to assist mining companies and mining projects companies in devising governance processes, methods, and techniques to eliminate or minimise the chance of failures in their projects. Based on research work and drawing on the global experience of mega mining capital projects, it appears that there are ways to ensure that mining capital projects achieve their set objectives (Kuvshinikov et al., 2017).

Edmondson (2011) mentions that once failure has been detected in projects, it essential to go beyond the obvious and superficial reasons for it to understand the root causes. This requires the disciplined use of sophisticated analysis to ensure the right lessons are learned and the remedies are employed. It is important to ensure that organizations do not just move on after a failure but stop to dig in and discover the wisdom contained in the failure.

It is common for capital mining projects undertaken to sustain or expand mining business to not deliver as per project objectives and within the triple constraints (scope, cost, and time). Further to technical complexities, project execution stages today are further affected by non-technical factors which exposes them to a diversity of constraints or challenges outside the triple constraints stated previously.

1.3 Purpose of the study

The purpose of this study was to investigate and understand the macro and micro factors that contribute to the success of capital mining projects, and to extract the lessons learnt from failures. These could be poor understanding of stakeholder expectations, poor project selection, initiation and planning, execution, monitoring and control or project closure.

MPM has been milling, on average, less than 200 000 tonnes per month against a designed capacity of 240 000 tonnes per month since it was commissioned in 2003 to 2019. Underground operations could not supply enough ore for the plant to operate at its designed capacity. This has resulted in suboptimal unit cost and not achieving bankable feasibility study outcomes. The desired state is that MPM should operate optimally at 240 000 tonnes per month on average with the resultant reduction in both cost per tonne and cost per platinum ounce produced.

The micro factors explored at MPM sought first to understand the gap between the company's strategic objectives, project charter, and the actual project deliverables at closure. Secondly, the analysis evaluated whether the project has met the objectives of the business case, identified areas of further development, and lessons learnt.

1.4 Problem statement

Barber et al (2000) describes a project as scope of work in which human material and financial resources are organized under significant constraints. Projects are fundamental to modern society, with more than one fifth of global gross domestic product being generated from projects. A project collapse often result from cascading failures induced by a single failure.

The assessment of project success differs among stakeholders because of their different motivations to execute the project. A distinction is drawn between hard and soft criteria to assess project success in scientific articles about project assessment. Hard criteria is also called quantifiable assessment criteria and is rather more objective and measurable. Time, cost and performance criteria pertain to the category of hard criteria.

The other approach of project success, namely soft criteria, depends on the perception of the stakeholders involved or affected by it. The soft criteria are often closely connected to the so called human factors and they are subjective and difficult to evaluate, but they constitute an essential part of project success assessment. (Albert et al, 2017).

The success of the project is closely linked to critical success factors. These are defined as elements in the project that are critical to the project achieving its mission or goal. The project can more successful if every team member understand the key success factors. Critical success factors are events or activities needed to make the project successful and they can be measured using key performance areas. Critical success factors are important because they help project managers to facilitate communication between different stakeholders; monitor and control the project scope; identify and allocate resources; and identify and optimize tasks (Pendey, 2022).

According Yarbrough (2021), critical success factor is something an organisation accomplish in order to fulfil its goals. Critical success factors help a team or an organisation on what they should focus at and compare to the goals that are set. These goals are often called deliverables. Different deliverables will have different critical success factors and these factors culminate to qualify the effort as either a success or a failure. Therefore if the deliverable is the goal, a critical success factor is what is needed to fulfil that goal.

Alias et al (2014) defines critical success as inputs to project management practice which can lead directly or indirectly to project success. It encompasses many elements, which have to be synchronised to ensure project delivery on time. The study of project success and critical success factors is often considered as one of the vital ways to improve the effectiveness of project delivery. From a project management perspective, critical success factors are characteristics, conditions or variables that can have a significant impact on the success of the project when properly sustained, maintained or managed.

Gupta et al (2018), indicates that Project Management Institute (PMI) described a project as a temporary endeavour undertaken to create a unique product or some service. Project failure should not only be measured against the iron triangle, namely time, costs and quality, it should also include project life cycle and stakeholder expectations.

A project is considered a failure when it has not delivered parameters that were required in line with pre-set expectations. To be evaluated as a success, a mining capital project must be managed and delivered within the set triple constraints of time, cost and quality. In addition, it must fulfil the benefits stated in the business case, as documented in the project charter, including all adjustments as agreed by stakeholders from conception to closure. According to Bannerman (2008) the view that failure or success of project failure is embodiment of a perceived situation and stakeholder perception is a superset of the triple constraints of project management.

According to Edmondson (2011), a sophisticated understanding of project failure causes, and context will help to avoid the blame game and institute an effective strategy for learning from failure. Although infinite number of things can go wrong in an organisation, mistakes for fall into three broad categories; preventable, complexity related and intelligent. All organisations learn from failure through three essential activities namely detection, analysis and experimentation.

It is in this context that this project report seek to gain a deeper understanding in factors underlying the success or failure of a MPM project. In brief MPM was designed to mill 240 000 tonnes of ore per month or 240 ktpm in short. The two underground shafts have had a combined output of less than this target. The plant has not been milling to capacity mostly due to lack of ore from underground. Therefore, the aim of this research project is to examine underlying factors that affect the production and financial performance of MPM. Furthermore, the performance was compared to initial project objectives to identify improvement opportunities and lessons that could be learnt for future mining projects.

1.5 Research objectives

The objectives of the research were to:

- Identify the main inhibiting factors that contributed to the non-achievement of the outcomes of a bankable feasibility study.
- Document lessons learnt from the MPM project which can be used in future projects.

1.6 Research questions

This project report set out to answer the following questions:

- What are the factors that contributed to the MPM project not achieving its feasibility study estimates?
- What lessons could be learnt about the critical success factors from the MPM project experience?

1.7 Research methods

Žydžiūnaitė (2018) mentions nine basic principles of ethical standards. These are: honesty and integrity, objectivity, carefulness, openness, respect for intellectual property, confidentiality, responsible publication, legality, and human protection. It is important that information taken from internal unpublished reports is presented in a way that will not violate MPM confidentiality and legality requirements. The data for this research was sourced from company reports and personnel. In sourcing data from internal and public company records, questionnaires and interviews the author was careful to observe the nine basic principles of ethical standards.

In-depth interviews with key incumbents were also conducted and questionnaires were administered. Questionnaires were sent to specialist individuals who were involved with the MPM project at all stages from initiation, planning, and execution, to closure.

Information on production and financial statistics obtained from MPM were analysed. Charts and tables presented the data quantitatively. The information obtained from interviews and questionnaires was interpreted, and qualitative deductions made on project management insights were extrapolated to MPM. Mapping of information served to align the analysis of both qualitative and quantitative information gathered during the research study, enhancing the understanding of the underlying factors that led to underperformance at MPM.

1.8 Limitation and delimitation of the study

Like every scientific research, this study was faced with a number of limitations and delimitations. According to Theofanidis and Fountouki (2018), limitations of any particular study concerning potential weaknesses are usually out of the researcher`s control, and are closely associated with the chosen research design, statistical model constraints, funding constraints or other factors. In this respect, a limitation is an imposed restriction which is out of the researcher`s control.

MPM was analysed as a case study. The first limitation is that some of the findings and recommendations of the study cannot be generalised as a reflection of all of circumstances in all underground mines in South Africa or in the world. Secondly, the researcher conducted document research from internal documents which have not been published. This limited the depth of the analysis that could be done on the financial and production information. Thirdly, questionnaires and interviews were also used as methods of collecting data. As a result, no control could be exercised on the accuracy of the information collected from questionnaires and interviews.

Lastly, the MPM project started in 2000 and as a result most of the people who were involved in that project are no longer working for the company or they cannot clearly remember how some of the decisions were taken at that time.

Theofanidis and Fountouki (2018) defines delimitations as, in essence, the limitations consciously set by the authors themselves. Delimitations are concerned with the definitions that the researcher decides to set as the boundaries or limits of their work so that the study`s aim and objectives do not become too impossible to achieve. In this respect it can be argued that delimitations are within the researcher’s control. This study is delimited to focus on the critical success factors for capital mining projects. There are numerous factors that contribute to the success or failure of projects. These factors range from organisational structure and culture within a project’s intensive environment, internal business processes, or the strategy of the business. Hence, the findings of this study cannot be generalised and may only be applicable to external validity to the extent at which the study’s results can be generalised to a larger population or a broader context. This study focuses on a single South African mine as a case study. Therefore, external validity could be achieved by sending out questionnaires to a larger population of participants with diverse exposure to mining project management. The outcomes of such an approach would enhance confidence for generalising the recommendations drawn herein to a wider population of South African mining projects.

1.9 Outline of the report

This project report is laid out to cover the critical elements and academic enquiry. Attention is given to the theoretical background of project management processes and specifics when applied in mining. The case study context for MPM is also presented. Results from questionnaires and interviews are analysed and discussed.

Chapter 1: The introduction covers macro and micro factors that contribute to failures in mining projects. Practical examples of failed or abandoned mining projects are discussed with reasons that led to their failure.

Chapter 2: The literature review addresses the theoretical underpinnings of project management processes with a focus on project management disciplines and how these have evolved.

Chapter 3: The research methodology covers the information gathering instruments used in gathering both qualitative and quantitative information. The limitations of the different information gathering instruments are also explained.

Chapter 4: MPM is covered as a case study. Background on MPM is introduced and includes the socio-economic environment where the mine is located, MPM ownership, the geology, and the mine design. These are explained briefly to contextualise the mine.

Chapter 5: The results from interviews, questionnaires from both personnel involved with the MPM project and from project teams with various types and level of experience in underground mining projects in South Africa. Production and financial performance statistics are analysed and discussed. Trends and ratios of both production and financial performance are interpreted to assess the health of the mine.

Chapter 6: Discussions and lessons learned from information drawn from the project management body of knowledge, global research, and practical experience at MPM is drawn together on this chapter.

Chapter 7: This chapter provides a summary of the research report, and concludes all aspects of both the qualitative and quantitative information gathered and its interpretation. Finally, recommendations are made on future improvement opportunities and optimisation at MPM and other mining projects.

2 LITERATURE REVIEW

2.1 Introduction

Chapter 1 sets the scene for this study by outlining the intention to examine capital project failure within the mining industry. Characterised by large capital investments, building project management skills competency to improve execution of mining capital projects is an issue that plagues mining firms and related investors across the globe. The literature review begins by describing generic characteristics of project management before going into specifics pertaining to its application within the mining industry. The chapter concludes with a discussion of some sources of deviations that have and continue to cause the high incidence of failure experienced with capital mining projects.

2.2 Project management phases

According to the Project Management Institute (PMI) (2021), a project can be understood to be a temporary endeavour that is undertaken to create a unique product, service or result. It is a temporary undertaking in that it has a defined beginning and end time, and ideally, defined scope and resources. A project is also unique, in that it is not routine or daily operation, but has specific goals to accomplish. Projects can range from simple to complex and can be managed by one person or multiple teams.

Project management is defined by Watts (2014; p.14), as the application of knowledge, skills, tools and techniques to project activities to meet the project requirements. A project is executed by a team made up of people who do not usually work together, sometimes from different organisations and across multiple geographies. This team is managed by a project manager appointed by the project sponsor. The construction of a mine, bridge, or other infrastructure to enhance or increase productivity into segments and even relief efforts after a disaster are all examples of projects. Each one must be expertly managed to deliver on-time, on-budget and as per required quality.

The project management life cycle could be divided into the following five phases, namely, (1) initiation, (2) planning, (3) execution, (4) monitoring and control and (5) closure. Table 2.1 describes the activities that are carried out in each phase of the project life cycle (Malsam, 2018).

Table 2.1: Project life cycle phases (Malsam, 2018).

Activity	Description
Initiation	In the initiation phase the value of the project as well as its feasibility is determined. Before the project is approved or rejected, a business case backed by a feasibility study is required. The business case provides justification for the project and includes the analysis of return on investment of the project. In the feasibility study the project goals are evaluated, practical considerations as well as timelines and the costs for completion are computed for the whole project. The resources required to complete the project like labour, equipment, materials and utilities are indicated. The feasibility document also recommends whether the project should be pursued.
Planning	On approval, the next step is to assemble a project team to start planning how to manage the project. A written scope statement is compiled encapsulating the project deliverables and objectives. Definition and breakdown of large deliverables into smaller ones, helps with control. Detailed tasks to produce the deliverables are defined; and interdependency of tasks is determined. Task completion durations are determined. Estimation of total project costs is followed by budget formulation. Quality control systems and processes must be defined. Human resources, roles and responsibilities are determined. Stakeholder communication planning guides messaging requirements. Risk identification, risk impacts and risk mitigation measures are determined. Procurement decisions must be guided by work plans. Contract definitions establish contractor roles and responsibilities.
Execution	This is the start of the project. The execution phase is made up of the following detailed processes. Executing the plan entails following the plan that has been created, assigning tasks to team members and the monitoring and managing of progress using project management tools like a project dashboard.

Activity	Description
Monitor and Control	To ensure that the plan is being actualised all aspects must be monitored and adjusted as needed. The following activities are done to ensure that proper monitoring and control is exercised: Reporting - Have a metric to measure project progress and an instrument to deliver this information; Scope - Monitor scope and control changes; Quality - Measure the quality of deliverables and make sure that the planned quality is being met. If not, evaluate how to improve the quality; Schedule - Keep track of delays or blocks that impact the timeline of the project and adjust to stay on track; Costs - Monitor expenses and control cost changes; Risks - Note changes in risks throughout the project and respond accordingly.
Closure	Generally, a project is not over until the project goals and objectives have been met. The last phase of the project is closing it out. This involves ensuring project deliverables are completed as planned. Administration must close out all outstanding contract and operational matters, archive the paperwork and disseminate to relevant parties.

Failure in a project can be predicted by the changes made after the finalisation of a feasibility study (Ferguson, et al., 2011). However, not all activities that are supposed to be conducted before the commencement of the project can be clearly defined. Some may be determined by project gate stage reviews (Murthi, 2002).

According to Anbari, et al. (2008), there is a general belief that project reviews can be beneficial to project management if they are conducted in three steps. First, before commencement, an evaluation should be done to select the project that best suits the overall strategy of the enterprise. Secondly, there should be an ongoing evaluation (monitoring and controlling phase) of the project throughout its life cycle. Lastly, during the closing phase of the project, a post-project assessment or audit should be conducted to measure the success of the project in terms of its original and modified scope and objectives.

Murthi (2002), emphasised that a post-project review must not be used to apportion blame, but rather to identify areas for improvement and lessons learnt. Areas where the project excelled and areas for improvement must both be identified. In addition, areas where failures have been experienced must be identified and a decision made on a plan of action to correct this and to avoid it in future projects.

A schedule of project reviews identifies deliverables which have been produced at each phase and determines the extent to which the project has met objectives set for that phase. The outcome of the review is used to determine transition along the project stages and to detect errors that must be corrected.

2.3 Mining project processes

Mining produces three types of mined commodities; (1) metals, (2) industrial minerals and (3) fuels that all countries find essential for maintaining and improving their standard of living. Mining in simple terms involves breaking apart in-situ minerals and hauling the broken materials out of the mine.

Mining projects are brought into execution by following a well-defined and structured project management life cycle and processes. According to Ovalle (2020), the mining processes followed in the development of a mine as described in this report, can be described as a sequenced series of activities as presented in Table 2.2.

Table 2.2: Mining processes (Ovalle, 2020).

Process	Description
Prospecting and Surveying	The first stage in the mining process; it entails the identification of a possible geological target where a particular mineral could be found. There are two methods of surveying or prospecting for minerals and these are direct and indirect methods. Direct methods are used when the sole focus for examination is to locate deposits found near or on the surface. These include visual examination via microscopic study or video prospecting. Indirect methods are applied on deposits deeper in the earth. These include radiometric, seismic or magnetic surveys.
Exploration	This stage involves the collection of core samples for the purpose of evaluating the grade and density of the deposit. Diamond drills are used to obtain the samples. A geological model is compiled as a representation of the orebody. Modifying factors like costs, commodity prices, recoveries and legislator requirements are applied to a mineral resource model with the end result being the mineral reserve. At this stage a decision is made as to whether the project would be economically viable or if it should be abandoned.
Mine Design and Mine Planning	If the project is found to be economically viable the design and planning stage begins. This calls for technical studies to determine if the project is safe, socially responsible, environmentally friendly and economically viable. The mining method would either be for surface mining or underground

Process	Description
	mining, depending on which mining method is technically and economically viable.
Development	This stage requires the establishment of access to the ore, acquiring equipment, labour, material and other utilities required to extract the ore from the orebody.
Production	Once the mining method has been determined, access to the orebody and infrastructure is in place, then production of the ore commences. Mined ore is processed at the processing plant and then sold as finished product or a concentrate or the ore is sold as a raw or unprocessed product.
Closure and Rehabilitation	The final stage in the life cycle of a mine is closure and rehabilitation. The objective of reclamation and rehabilitation includes minimising negative environmental impacts; ensuring public health and safety; protecting and preserving water quality; establishment of new landform and vegetation; removal of waste and hazardous material; and land stabilisation and prevention of erosion. At the conclusion of each stage of the above-mentioned six stages a project review exercise is conducted.

2.4 Post-closure review

This report reviews the MPM as a case study and uses the project post-closure review (PCR) to capture pertinent insight into project management dynamics for complex mining projects. This process is also referred to as post-project review (PPR) or post-project evaluation and defined as a formal review of projects examining the lessons which may be learnt and used to the benefit of future projects. According to Choudhary (2019), post-project review is one of the most important and common approaches to capturing project knowledge.

In mining, the PPR is also referred to as a PCR and allows multidisciplinary teams to critique a project to determine both positive and negative aspects. PPR may even realise cost savings or optimisation of future projects. If done diligently, the lessons learnt in post-project reviews not only provide valuable insights which can help ongoing projects, but they also prove critical to the successful planning of future projects (Llyas et al, 2014). According to Anbari et al (2008), if post-project completion review is done properly and consistently, it will have a positive impact on the development of the learning process within the organisation and its long-term competitive position.

The outcome is the capture of tacit knowledge as learning points to improve the planning and execution of future projects. Learning from a project failure can play a key role in planning and monitoring of future projects to ensure long-term success of any organisation for continuous improvement (Edmondson, 2011). Specifically, such a review assesses the project results against the set project goals with a main focus on quality, scope, cost, and time. According to Dogaru and Dogaru (2015), the PCR serves to:

- Identify techniques and approaches that worked and devise steps to ensure that the new knowledge can be harnessed in the future;
- Evaluate the performance of the project manager and his team;
- Assess final deliverables against initial baselines; and
- Align the current project with the company's strategy.

Choudhary (2019) stated that a PPR is a process through which an organisation looks at the project process retrospectively with a view of learning from activities carried out, to avoid mistakes in the future and to learn from successes and failures. A good time to start thinking of conducting a PCR on a project is shortly after the project has been delivered and when most of the problems have been ironed out, i.e. after the execution stage. However, to adequately assess the quality of the implementation and complete this process, one needs to wait long enough for the changes caused by the project to truly take effect. Where possible, at least one full business cycle must pass before conducting the PCR.

Briscoe, Baccineli and Chambless (2000) recommended that the agenda for the review meeting should be sent at least two weeks before the time to allow the participants to prepare well for the meeting. Several processes are recommended when conducting the PCR. These processes are outlined as follows (Mind Tools Team, 2008):

- **Conduct a gap analysis.** Review the project charter to evaluate how closely the project matches the original objectives. If there are gaps in the deliverables how will those be closed?

- **Determine whether the project goals were achieved.** Is the deliverable functioning as expected? Are error rates low enough and is the system fit for purpose? Is the system functioning well and, in a way that will adjust smoothly to future operations demands?

- **Determine the satisfaction of stakeholders**. Were the stakeholders' needs met? If key stakeholders are not satisfied, how should this be addressed?

- **Determine the project costs and benefits**. What were the final costs? What will it cost to operate the solution? What will it cost to support the solution in future? How does the cost compare with benefits achieved? If the project has not delivered a large enough return, how could this be improved?

- **Identify areas for further development**. Have all the expected benefits been achieved? If not, what is needed to achieve them? Could making further changes deliver even more value?

- **Identify lessons learnt.** How well were the project deliverables assessed and how well were the scopes and costs assessed? What went wrong, why did these things go wrong and how could these problems be avoided the next time? What could be learnt from what went well?

- **Report findings and recommendations**. What was learned from the review? Is corrective action required to achieve the benefits needed? What lessons have been learned that could be carried forward to the next project?

There are many approaches to conducting post-project completion reviews. According to Choudhary (2019) the following methods could be used:

- PPR as knowledge management technique.
- PPR could also be used as part of the project management process. This entails doing PPR in phases, i.e. during the lifetime of the project and also at the end of the project. A key learning point of this approach is that PPR should be adopted as part of the project evaluation mechanism for defining success criteria and for improving project control, quality assurance, change management and risk assessment.
- Systematic approach: This involves the use of cognitive mapping and systems dynamics in carrying out PPR. Mapping identifies feedback loops which affect the success of projects. There are arguments that traditional lessons learnt systems obstruct the examination of deep messy reasons for project failures or problems.

2.5 Project success

The most appropriate criteria for judging project success are analysing the project objectives. The degree to which these objectives have been met, determines the success or failure of a project (De Wit, 1998). Others go further and define the achievement of project goals in the short, medium, and long term. Taherdoost and Keshavarzsaleh (2016) describe project success as multi-layered including meeting scope, cost, time, and quality objectives in the short, medium, and long term such as achieving commercial success and gaining market share, meeting technical specifications, functional performance, and matching tangible and intangible outcomes as well as developing tools, techniques, products, and markets.

Project success may include more than delivering a project on time, on budget and with set quality as judged by the client. It may include realised benefits and stakeholder acceptance or satisfaction. The community view of project success is especially important in the South African context where communities expect to see job creation, community involvement and community development from mining projects (Koelmans, 2004). Ideally, all stakeholders should give feedback or their assessment on post-closure review and not just to the client.

The requirement of each stakeholder group will differ and therefore their perception of what constitutes success will vary. In this report, project success is evaluated as per the client goals which are generally based on the triple constrains of time, scope, and costs.

2.6 Critical success factors

In any project there are critical factors that must be managed well for it to succeed. Project success factors are defined as those essential outcomes that must go well to ensure success for the business, project manager and/or organisation. They therefore represent those managerial or enterprise areas that must be given special and continual attention to bring high performance in both current and future operating activities (Taherdoost and Keshavarzsaleh, 2016).

There are varied views in attempts to define critical success factors (CSF), also known as key result areas (KRA). Rockart (1982) defines CSF as the few key areas of activity in which favourable results are absolutely necessary for a particular manager to reach his or her goal. If the results in these areas are not adequate, the organisation's efforts for the period will be less than desired.

Although there is no absolute rule, it is recommended that the CSF be limited to five or less aspects in a project. This helps to ensure that each CSF has maximum impact and gives clear direction on priorities to other elements of the project or business.

According to an extensive study on project management conducted by Spalek (2005), there are numerous factors that determine the success of a project. Some of these factors are listed in Table 2.3 where groups of factors having substantial, large, medium, small, and even negligible influences on the success of a project are indicated.

Table 2.3 Critical success factors (Spalek, 2005, Exhibit 4).

Influence on the project success				
Substantial	**Large**	**Medium**	**Small**	**Negligible**
Formal establishing of Project Manager	Experience of the Project Manager	Common tools & techniques for the entire project	IT support for scheduling	The change in the company environment
Project goal clearly set	Effective communication procedures	Tools & techniques for budget control	Steering Committee competencies	
Project Manager's competencies	Competencies of the project team	Project Team experience	Change of the strategy of the company	
Establishing project team	Adequate management style of Project Manager	Resistance of people to the project	Steering Committee members fluctuation	
High authority of the Project Manager	Monitoring and change control in Project	Budget significantly decreased during realization phase	Frequent changes in schedule	
Top Management support	Motivation of the Project Team	Tools & techniques for schedule control	The same Steering Committee in planning & execution phase	
	Motivation of the Project Manager	Client involvement	IT support for budgeting	
	Risk Management	Significant changes in project goal	Periodical reports to the Steering Committee	
	Periodical reports to Project Manager	Periodical meetings of the project team	Too "narrow/ tough" schedule	
	Different types of interest people involved in the project	Resistance to the project of client staff	Periodical meeting of the Steering Committee	
	Ad-hoc project team meetings	Project Team staff fluctuation	Budget significantly increased during realization phase	
	Bottlenecks in information flow	The same Project Team in planning & execution phase		
	The same project manager in the project planning and execution phases	Budget estimated in details during planning phase		
	Recognized client's needs	Human resources fluctuation in project		
	Resources estimation and planning for the execution phase	Periodical reports to Project team		
		Periodical reports to the client		
		Establishing the Steering Committee		
		Project final date established based on detail schedule and effort calculations		
		Member of the board in the Steering Committee		
		IT tools & techniques for the entire project		
		Client staff fluctuation		

2.7 Project failure

Any project that does not achieve the three variables of time, cost and quality concurrently can be considered a failure (Chami, 2013). According to Ferguson, et al. (2011), a mine development project is defined as a failed project if it has one of the following attributes:

- It failed to attract project financing in the five years after completion of the feasibility study;
- The project ceases within five years of completion of the feasibility study;

- The project is deferred, or production is suspended within five years of completion of the feasibility study; and
- The company is subjected to external administration within five years of completion of the feasibility study.

2.8 Macro factors behind project management complexity in mining projects

Mining projects are typically high value investments with multifaceted input, output, and process implications. This section examines typical sources of project management complexity that haunt mining projects.

2.8.1 Stakeholder resistance

All over the world, well organised and influential local environmental activist and opposition campaigns have formed to safeguard land, water, and other natural resources. Such groups often clash with the developers of mining projects, leading to some projects being cancelled or construction being halted altogether (Schneider, 2017).

Mining projects present a variety of social risks at national, regional, and local level. These include but are not limited to loss of traditional livelihoods; exposure to communicable diseases; resettlement, and in-migration (for large and new mining developments). They impose pressure on local health and education services; have negative gender impacts, rising food, land, and local transportation prices; deterioration of governance, human rights abuse; conflict resulting from poor access to mining related jobs and rents.

In a study conducted by the World Bank into failures of mining projects caused by social rejection or resistance towards the projects, the following aspects leading to failure of projects were identified at the different stages of the project cycle (Post, 2009):

- **Identification:** Limited consultation, inadequate stakeholder mapping and incomplete social analysis.
- **Preparation:** Social inputs not incorporated into the DNA of the project.
- **Appraisal:** Treating social inputs as a hurdle to overcome rather than an opportunity to enhance a project's impacts and sustainability.
- **Negotiation or approval:** Not including a social development specialist in designing government commitments under the project.
- **Implementation:** Failure to build adaptability into the project's design which may be necessary to respond to emerging social issues.
- **Evaluation:** Absence of or insufficient participatory monitoring, evaluation, and social accountability mechanism.

The emergence of Asian economies like China and India since early 2000 has resulted in steady and rising demand for natural resources worldwide. Also, since the last decade speculative trading with hedge funds have provoked investment booms accelerating mining investments in many parts of the world. Industrial technological advances are making reserves accessible that were previously not economically viable. Companies have been able to excavate and extract mineral reserves in a wide diversity of geological conditions resulting in encroachment into areas that are ecologically and sometimes socially vulnerable (Muradian et al., 2012).

Mining projects are generally in areas inhabited by indigenous or non-indigenous communities who suffer the burdens of pollution; lack of access to basic resources due to unequal distribution of power and income; social inequalities of ethnicity, caste, class, and gender. All these factors could lead to the formation of Ecological Distribution Conflict (EDC). The term EDC was coined by Martinez-Alier and O`Connor, (1996), to describe social conflicts born from unfair access to natural resources and unjust burden of pollution. EDCs are a form of collective claim against environmental injustice. For instance, a mine may be polluting a river, yet this damage is not valued in the market and these impacts are not compensated (Bebbington et al., 2008).

An important finding by some authors like Bebbington (1996) and Escobar (1995), is that many movements create, recover, or reaffirm a development path that rejects mining, but at the same time propose an alternative development model or alternative developments. In other cases, communities adapt and accept the offers of the mining company largely in the form of corporate social responsibility programmes and other ameliorations. Conde (2016) mentions four factors that contribute to the emergence of resistance to mining projects. These are, first, clash of metabolism between subsistence and extraction economy. Communities are likely to resist when they perceive a threat to their health and livelihood. Secondly, lack of participation or representation of local communities living near mining projects and their lack of rights to effectively decide their own development path. Many local communities aspire to determine what happens to their land, wanting to receive visibility and recognition of heritage or ownership rights.

Thirdly, monetary compensation due to land or resource losses are common claims that motivate resistance to mining projects. A quantitative and qualitative analysis of mining conflicts in Peru indicated that conflicts originate due to people's sense of grievance regarding previous and supposedly unfair land agreements. High company profits incentivise communities to claim the fulfilment of promises by the mining company as well as a greater share of these profits and compensation for their lost assets and livelihoods (Conde, 2016).

Fourthly, the distrust many communities have of the mining companies and the government can also be a source of increased confrontation. A crucial factor that allows for resistance to emerge and expand is the extra local alliance made by communities and local non-governmental organisations (NGO). It is often through the dissemination of information across regional and even international networks that communities learn about the impacts that mining can cause and react before the operation starts (Conde, 2016).

Resistance to mining projects often emerges in remote resource frontiers with a lack of effective presence of the state. When the population lacks institutionalised means to channel their demands or for social or political actors to represent them, then the main path for them to organise is mobilisation and protest.

According to Vittor (2014), many communities do decide to accept mining activity, signing agreements with companies and government. However, increasing number of communities and indigenous people are expressing their opposition to mining through their own initiatives or those of their local government.

For example, Peru has seen a number of neighbourhood referendum processes in the past decade; in Tambogrande in 2002, Ayabaca, and Huancabamba in 2007, and Islay in 2009. These communities decided against mining activities that go against their way of life and direction of development. In referendums in the provinces of Candarave and Tarata in 2008, the communities voiced their opposition against the use of water resources for mining activities. In 2012, the community of Kañaris also held a referendum on a mining project (Vittor, 2014).

In 2009, Embera indigenous and Afro-descendent communities in Colombia's Chocó held a referendum and opposed the mining project of the Muriel Mining Corporation. In July 2013, the inhabitants of the town of Piedras in Tolima, Colombia, declared themselves in opposition to all mining activities in their territory (Vittor, 2014).

Clearly the above-mentioned events indicate that there is growing trend to resist mining projects for alleged or perceived environmental and social reasons. As a result of increasing civil resistance, numerous mining projects have had to be abandoned resulting in millions of dollars in losses for investors.

2.8.2 Rising alternatives

It has long been a tenet of resource economics that if a material`s price should increase due to scarcity or some other factor, then high prices will stimulate increased exploration and thereby increase supply as well as encourage the development of a suitable substitute. A classic example is that of cobalt use in batteries in the 1970s. When a civil war in the DRC caused a sharp decrease in the cobalt supply, scientists at General Motors Research Laboratories and elsewhere developed excellent magnets that used no cobalt (Graedel, 2013).

Recently there has been a larger focus to explore and replace materials with renewable materials. Progress has been made in finding substitutes for fossil fuel, precious stones and building materials.

2.8.2.1 Renewable energy

One of the reasons for the recent struggles of fossil fuel projects has been that the cost of renewable energy has dropped so low that solar, wind and other renewables are seen as less expensive to build relative to fossil fuel energy (Schneider, 2017). These alternatives have lured potential investors away from traditional fossil fuel-based energy projects (see Figure 2.1). Mining projects within the energy sector have also fallen prey to the attractiveness of these modern energy projects.

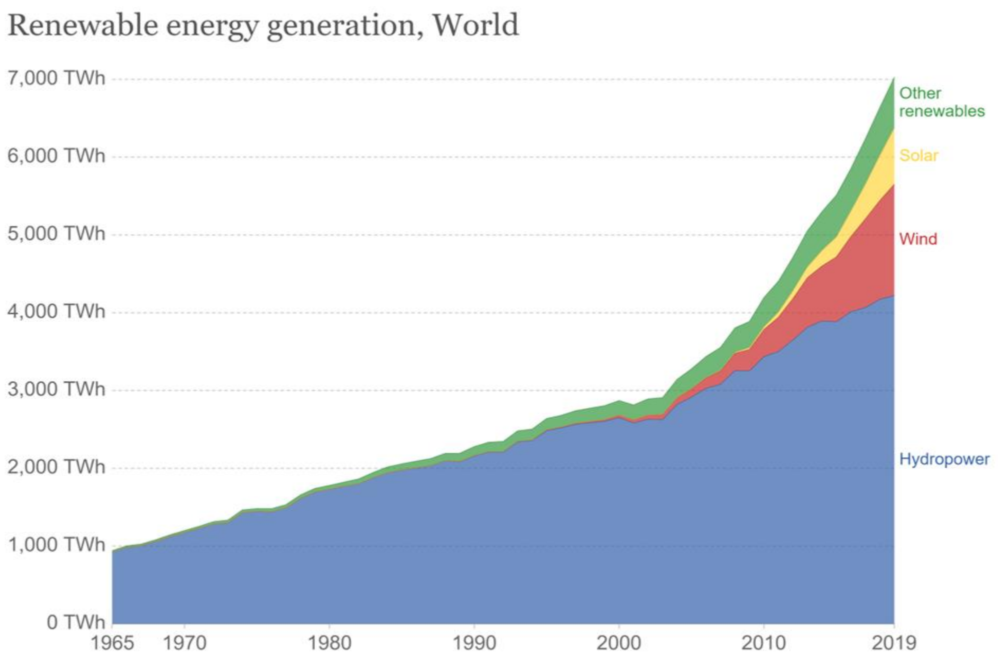

Figure 2.1: Renewable energy generation globally (IRENA, 2018).

Figure 2.1 indicates the growing trend in renewable energy generation globally. More and more fossil fuel producing companies and countries have set themselves targets to reduce the production and use of fossil fuel. Cheaper alternatives are not only restricted to energy generation. There has been some development in finding cheaper alternatives in diamond, concrete, and other resources.

2.8.2.2 Precious stones

According to Kliest (2020) in the diamond mining industry alternatives to mined diamonds are now a commercially attractive alternative in the market. Synthetic diamond, also referred to as laboratory-grown diamond, laboratory-created diamond, or cultured diamond; is a diamond made of the same material as natural diamonds. Synthetic diamonds are different from both natural diamonds, created by a geological process, and imitation, made of non-diamond material. Synthetic diamonds or laboratory-manufactured diamonds are being marketed to clients who prefer synthetic diamonds to mined diamonds.

For example, cubic zirconia came to the diamond market in the 1970s. It ranks 8.25 to 8.5 in terms of hardness on the Mohs scale. It is very brilliant and has a high dispersion. This is an imitation of a diamond and generally less expensive (Kliest, 2020).

Moissanite was originally discovered in its natural form (from a meteor) in 1893. Because of its rarity, most moissanite engagement rings use a lab-grown form of the material. This practice started in the 1990s. It is a hard material, measuring 9.25 on Mohs scale. Visually it may be difficult for an untrained eye to tell the difference between a moissanite and a natural diamond. The synthetic version of moissanite is near colourless and significantly less expensive than diamonds and therefore serve as an alternative to natural diamonds (Kliest, 2020).

Thirdly, laboratory-grown diamonds have actually been around since the 1950s but have only recently became popular for engagement rings. In the manufacturing process, each diamond goes through its own way and its own pattern. The colour, the clarity and the size will all differ from diamond to diamond. In terms of price, on average a laboratory grown diamond costs 20-30% less than a mined diamond, depending on the colour, cut, clarity and carat (Kliest, 2020). Table 2.4 below compares the price, durability and other qualities of a natural diamond and its substitutes.

Table 2.4: Comparing diamonds at a glance (Kleist, 2020).

	Price	Durability (Rating on Mohs Scale)	Brilliance (Refractive Index)	Sustainability and Ethics	Cool factor
Mined Diamond	Most Expensive	10	2.42	Can be questionable	Classic
Lab-Grown Diamond	About 30% less than Mined Diamonds	10	2.42	Favorable	Trendy
Moissanite	Less Than $1000	9.25	2.65 to 2.69	Satisfactory	Lesser Known
Cubic Zirconia	Cheapest of all	8.25 to 8.5	2.17	Satisfactory	Out of style

2.8.2.3 Alternatives in building material

Concrete is a mixture of cement, gravel, sand, water, and a range of aggregates. With about 10 billion tonnes of concrete produced every year, it is the most consumed substance in the world, second to water **(**Specifyconcrete.org, 2019). It is also the world's most widely used material for construction. From bridges to large buildings, concrete forms the very foundations of our infrastructure. Over 70% of the world population live in a concrete structure. The concrete industry has found some sustainable and eco-friendly alternatives to concrete. Some of these are **(**Specifyconcrete.org, 2019):

- Green concrete: an eco-friendly concrete that is manufactured using waste and residual material from different industries and requires less energy for its production.

- Ashcrete-flyash: a by-product of combustion of coal which was previously discarded in the landfill but is now used to manufacture green concrete.
- Blast furnace slag: a glassy granular material produced by quenching molten iron slag from the blast furnace into water or steam. This material is used to replace a portion of Portland cement in concrete manufacturing.
- Micro silica: an ultra-fine powder which is a by-product of ferrosilicon alloy and silicon production from the condensation of silicon dioxide. It can displace about 7-12% of cement in concrete.
- Some aggregate alternatives include paper, fibre, waste plastic, post-consumer glass and concrete debris.

2.8.3 Ecological risks

With global warming causing climate change in the world, more and more natural disasters are contributing to projects being discontinued or halted (Schneider, 2017). In addition, mining is seen as a 'dirty' industry, which is destructive to the environment. These perceptions make mining projects an easy target for environmental activists.

At the early stages of economic development, environmental degradation increases with rising per capita income. However, after a certain level of per capita income, environmental degradation decreases. It is hypothesised that negative impacts of economic growth on the environmental quality may decrease through efficient infrastructure and energy-saving technologies. Theoretically, there are three main channels through which economic growth can affect environmental degradation. These are: (1) the scale effect, (2) composition effect and (3) technique effect (Zübeyde et al., 2020).

The scale effect implies that more production needs more material which creates a higher level of economic activity, more waste and pollution. The composition effect implies that patterns of material used in the production process and the level of throughput are dependent on sectorial structure of the economy. For instance, Zübeyde et al., (2020), mentions that if the production process does not need intensive use of materials, there will be less pollution, such as the service sector. In this case, the composition effect reduces the level of material input and pollution. Furthermore, if the structural change is large enough, the composition effect may offset the scale effect of economic growth. The concept implies that sophisticated clean manufacturing technologies create less material-intensive goods and less pollution.

The scale of trade globalisation appears to outweigh its compositions and the technique effect. This means that output produced from obsolete technologies creates more environmental degradation.

2.8.4 Government policies

Constant changes in government, especially in developing and politically unstable countries, usually lead to changes in mineral or mining policy. These changes sometimes result in increased commercial or financial risks, which could ultimately cause a project to be halted or abandoned (Schneider, 2017).

From the research conducted by Busse and Gröning (2011), there is strong evidence that heightened expectations from resource extraction may foster rent-seeking and corruption among the population. From a policy perspective, the results are highly relevant to many resource-rich countries, in particular developing countries. Since the effects are of sizeable dimensions these countries may pursue an unfavourable trajectory of worsening corruption levels. Corruption in government could lead to ever-changing government policies as wayward intentions come to bear on institutional structures influencing changes in mineral exploitation or taxation laws.

Any efforts to mitigate resource curse effects depends on policymakers in the countries concerned. Given the large amounts of money involved, however, it is questionable how to persuade them to change their behaviour. While increased transparency of the money spent by other national and international investors could help, initiatives in this area have so far been slow in gathering momentum. More and more countries have reached the compliant status of the extractive industry transparency initiative (EITI). This intervention, launched in June 2003, is generally considered a success story, given the large number of resource-dependent governments that have committed to it and the vast support it has received from donors, non-governmental organisations, and extractive industry companies (Rustad et al., 2016).

2.8.5 Civil protest

Communities have become more demanding in expectations to benefit from projects in their communities. Sometimes the demands may be so unreasonable that the investors may decide to halt or abandon the project (Schneider, 2017).

Despite the global economic uncertainties, mining has experienced an unprecedented period of growth. The rise in mineral prices and advancements in technology have rendered orebody discoveries previously considered too expensive and risky, now potentially profitable. The expansion of mining activities to new areas has brought about a wave of local protest around the globe, mobilising indigenous populations and environmentalists as well as homeowners (Dahlberg-Grundberg & Örestig, 2016).

Environmental conflicts are social conflicts over the environment that manifest through mobilisation by individuals or groups in response to perceived environmental threats with detrimental social impacts. With about 3100 cases registered by April 2020, the Environmental Justice Atlas database (EJAtlas) has become the largest global inventory of environmental conflicts that also documents the claims and actions of involved environmental defenders (Scheidel et al., 2020).

In 11% of cases globally, protestors contributed to the halt of environmentally destructive and socially conflictive projects. Environmental conflicts can be broadly described as social conflicts related to the environment. A prevalent argument has been that environmental conflicts are largely due to poverty or resource scarcity which can be demand and supply induced, or structural. This implies that the occurrence and intensity of conflicts would increase as resources become scarcer or if resources have been overused, depleted, or degraded to a certain threshold (Scheidel et al., 2020).

The study of environmental conflicts sheds light on who has the power to decide about, control, and allocate environmental benefits and burdens, which includes issues of distribution, access rights and the division of labour. Such struggles over the distribution of environmental burdens and benefits are termed ecological distribution conflicts. These conflicts arise over unfair distribution of environmental 'positives' such as clean water and air, or access to fertile land, and 'negatives' such as exposure to pollution as well as risks to health, livelihoods, social and cultural identities (Martinez-Alier et al., 2016).

Among the key actors in civic protests on the environment are those who live off the land. There are communities that defend the natural resources against negative social or ecological impacts because their lives and livelihoods depend on healthy ecosystems or for other directly related social and environmental reasons. In protesting or mobilising against the exploitation of nature, environmental defenders frequently serve a larger purpose of environmental protection in their view (Spiric, 2018).

Environmental conflicts are driven by a range of economic activities related to resource extraction, processing, and waste disposal. Of the 2 743 cases documented in the EJAtlas database, the most frequently reported sectors are the mining sector (21%) of all cases, the fossil energy sector (17%), biomass and land uses (15%) and water management such as dams. According to EJAtlas indigenous people mobilise most frequently against damaging environmental activities, accounting for 41% of documented civic protest on environmental issues **(**Scheidel et al., 2020). Figure 2.2 indicates the number of environmental conflicts registered with EJAtlas and the reported type of environmental conflict.

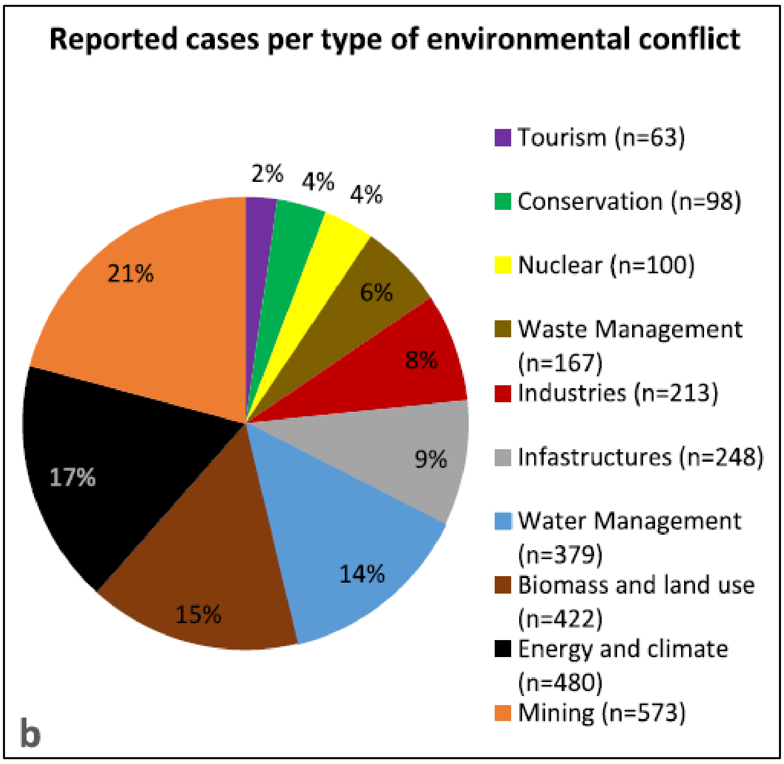

Figure 2.2: Environmental conflicts registered with EJAtlas (EJAtlas, 2020)

It has also been argued that revenue from the mining industry is not income; it is a translation of finite subsoil assets into cash. This transformation should occur at a time when the economy and society can maximise the benefits from the processes and the revenues it generates. It could therefore be argued that under specific circumstances, leaving assets in the ground may be the course of action for a country's development until those circumstances have improved. It should be noted that the country's ecosystem is also vulnerable to resource degradation. One of the most significant risks is the challenge of limited water resources in the country. Access to water is increasingly becoming a key issue (Mills, 2020).

2.8.6 Input cost and commodity price changes

The time lapse between designing big industrial projects and putting them into operation is frequently a decade or more. During this period, market conditions may change drastically. This could lead to some projects no longer being financially viable due to commodity price reduction and input cost increases (Schneider, 2017).

The price volatility of precious metals in times of economic and geopolitical crisis has contributed to the failure of numerous mining projects. Precious metals like gold are used as protection of value in times of economic or geopolitical crisis. Almost all countries in the world are trying to diversify their portfolios by creating resources based economic and foreign exchange reserves, because precious metals do not represent debt and are not devalued by inflation. Extreme indebtedness of Western economies combined with the resumption of emerging economies have destabilised much of the monetary system which was based on the increasingly weakened US dollar. Disposing of dollars in exchange for purchase of gold is especially interesting, as the global crisis increases the price of metals. In the mining industry, uncertainties are derived from two main sources: data variability and unknown future occurrences. Future occurrences include variables like commodity prices, costs, and interest rates (Ardian and Kumral, 2019).

Like oil, precious metals are sensitive to development and emergence of conflicts. However, unlike oil, which is usually the cause of economic crisis, precious metals are more influenced by economic depressions and slowing down or stagnation of growth rates. Precious metals have experienced oscillations during the same periods, suggesting that the same causal forces have increased their economic value (Mionel et al, 2017).

From 1975 through to the end of 2014, precious metal values have increased. From 1979 to 1980 prices registered record values. The two major international crises which impacted other markets were the Iranian Revolution and the Russian invasion of Afghanistan during this time. From 1985 to 1989 was an interval which overlapped several international events. The international sanctions imposed by the United Nations over South Africa because of apartheid represented by far the most important factor that determined the increase in precious metals resource prices, mainly of gold and platinum (Mionel et al, 2017).

South Africa is one of the most important players in the precious minerals market due to its huge reserves. From 2001 to 2006, several events led to steady increase in prices of precious minerals. The terrorist attack on 11 September 2001, the war in Afghanistan since 2001 and the war in Iraq which started in 2003 were some of the global events that have had a material effect on resource prices. The prices of precious metals have doubled in this period. From 2007 to 2013, a period which coincided with the global financial crisis caused by the collapse of lending primarily in the US, led to the collapse of metal prices and curtailment of capital projects in the resource sector. The increase in geopolitical risks along other disruptive factors has resulted in greater volatility in the financial markets (Wade, 2019). Figure 2.3 indicates the trends in the gold and platinum price from 2000 to 2020.

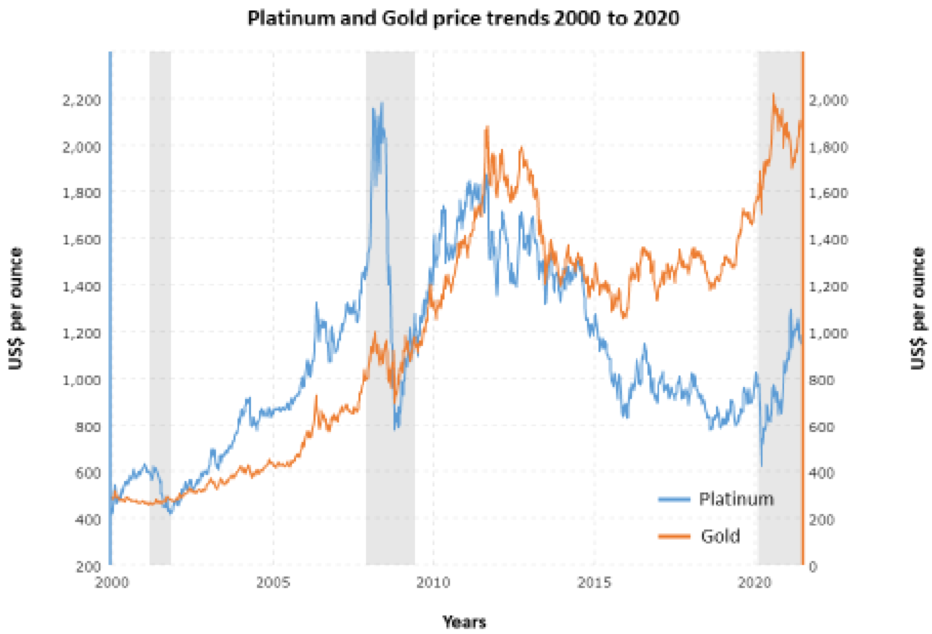

Figure 2.3: Gold vs platinum price trends 2000-2020 (Macrotrends, 2020)

It could therefore be seen that trouble on the world stage and the endeavour by countries to re-configure towards a new international order implies currency war – a war in which oil, precious metals and other commodities are affected. An assessment conducted on 15 mining companies revealed that all companies assessed had to overcome the hurdle of financing their capital projects (Rees, 2016).

In general, it can be said that the above-mentioned macro factors can have material effect on the success or failure of a mining project.

2.9 Micro factors contributing to failures in mining projects

Besides the macro factors which have overarching impact on projects, micro factors are company specific and contribute to mining project dynamics. These factors are usually related to company culture, process, and systems. Some companies use EPCM or EPC companies or have in-house capability and capacity to manage their projects. Generally, companies that have in-house project management resources have set governance, standards, processes, and systems for managing projects. Regardless of the efforts employed to manage projects, mining projects largely fail due to inadequate oversight, processes, and systems.

According to a study done by Standish Group (Pytel, et al., 2014), the top ten reasons causing failure in software development projects, (which could also apply in mining and construction projects) are:

- Incomplete requirements;
- Lack of user involvement;
- Lack of resources;
- Unrealistic expectations;
- Lack of executive support;
- Changing requirements and specifications in the middle of the project;
- Lack of planning;
- Redundancy;
- Inadequate IT management; and
- Illiteracy in technology.

Similar factors have been noted in the construction industry by Pytel et al, (2014). Management theories have identified project strategies as the main missing link in project planning and execution. The implication of this is that despite major strategic investment, a project can still fail. On examining the experiences of project owners, Hjelmbrekke et al. (2015) identified projects' failure to also stem from strategic oversight capability. For one, a project owner may fail to translate the strategy into tangible requirements, or a project team is torn over loyalties to different leadership prevalent in matrix structures. A project with no clear strategic focus or ownership can easily end up as a "motherless child" or failure.

According to Ramirez (2019), mining projects fail or underperform because companies drastically underestimate their complexity or because the complexity does not match the existing capabilities of staff or contractors. Companies often try to compensate for the unexpected complexity of a project by hiring more technical experts instead of filling the gaps in management expertise. Due to this misfit, mining projects are often set up for failure or underperformance from the word go.

South Deep, one of the South African deep level gold mines have been experiencing geology and geotechnical challenges over the last few years. The main shaft was planned at 2760 m deep and a lined diameter of 9 m and included 10 stations. When the main shaft was sunk it intersected an aquifer on 1 May 1996 and the sinking work was delayed for five months (Bevan, 2002).

South Deep was designed and tried a combination of conventional mining; drift and bench. In 2008 all conventional mining was stopped and low profile distress mining started. In 2015 a transition was made from low profile distress mining to high profile distress mining (South Deep, 2017).

The annual gold production output in 2020 was about 258 000 oz. When South Deep was started it was designed to produce about 750 000 to 800 000 oz per year. This has not materialised over the years due to geology and geotechnical challenges that comes with mining at great depths of about 3 km (South Deep, 2017).

2.10 Conclusion

This chapter has detailed scholarly perspective on key concepts identified as important pillars of this research project. The discussion outlined the nature of project management as a discipline before detailing how it is employed in mining contexts. The second part of the review described characteristics specific to high value complex projects with particular emphasis on the macro and micro intricacies that influence performance. Mining projects are complex and long term. Poor understanding and management of project risks is likely to lead to project failure.

With important pillars of the research established, it was necessary to develop a research methodology. Chapter 3 outlines the research methodology followed in this research project.

3 RESEARCH METHODOLODY

3.1 Introduction

The purpose of this chapter is to outline the research methodology adopted for this research project. The research was done using both quantitative and qualitative methods and in some cases a combination of both. The data acquisition instruments used were a combination of questionnaires, interviews, internal and public reports. Statistical methods were used to analyse both the qualitative and quantitative data gathered.

3.2 Justification of research methodology

Williams (2007), defines research as the process of collecting, analysing and interpreting data in order to understand a phenomenon. The three common approaches to conducting research are quantitative, qualitative and mixed method. Researchers typically select the quantitative approach to respond to research questions requiring numerical data, the qualitative approach for research questions requiring textural data, and the mixed approach method for research questions requiring both numerical and textural data.

3.2.1 Quantitative research approach

What constitute a quantitative research approach method involves a numerical or statistical approach to research design. The methodology of a quantitative research maintains assumptions of the empiricist paradigm. The research itself is independent of the researcher. As a result, data is used to objectively measure reality. Quantitative research creates meaning through objectivity. There are three broad classifications of quantitative approach namely, descriptive, experimental, and casual comparative. The descriptive research is a basic research method that examines the situation as it exists in its current state. Descriptive research involves identification of attributes of a particular phenomenon based on an observation basis. Casual comparison involves the exploration of correlation between one or more phenomena (Leedy and Ormond 2001).

3.2.2 Qualitative research approach

Qualitative approach is a holistic approach that involves discovery. Qualitative approach is also described as an unfolding model that occurs in a natural setting that enables the researcher to develop a level of detail from high involvement in the casual experiences. What constitute qualitative research involves purposeful use for describing, explaining, and interpreting collated data. (Williams, 2007). According to Leedey and Ormond (2001), qualitative research is less structured in description because it formulates and builds new theories. Qualitative research can also be described as an effective model that occurs in a natural setting that allows the researcher to develop a level of detail from being highly involved in the actual experience.

3.2.3 Mixed methods approach

With the mixed method approach the researcher incorporates methods of collecting and analysing data from both quantitative and qualitative research approach in a single study. The mixed method approach is an extension rather than a replacement for qualitative and quantitative approach to research. The goal of the research for using the mixed method approach is to draw strength and minimise the weakness of the qualitative and quantitative approach. The mixed method approach provides the researcher with the ability to design a single research study that answers questions about both the complex nature of the phenomenon from participants' point of view and the relationship between measurable variables (Williams, 2007).

The MPM underground mining projects involved complex relationships between the Joint Venture partners, operations teams and the project team. The mixed method approach was chosen in this study in order to understand the existing physical environment and the experiences of the people involved on the project.

3.3 Qualitative data acquisition

Qualitative data acquisition instruments were used to collect qualitative data. Wilkinson and Birmingham (2003) describe research instruments as devices for obtaining information relevant to a research project. The most common methods used for collecting qualitative data are questionnaires, interviews, content analysis, focus groups, observations and research for things that people say and do.

3.4 Use of questionnaire as data collection instruments

In this research project, questionnaires and interviews were the instruments used to collect data and information. There are different types of questions that can be asked in a questionnaire like open-ended questions, closed or multiple choice or ranking questions. An open-ended questions format was chosen as it allows the respondents to express themselves with no restriction compared with the other types of questionnaires. The challenge with open-ended questionnaires is that it makes the analysis process difficult. In this research, 12 open-ended questions were asked (Appendix A).

The purpose of this research was to get information from experienced individuals who were involved in underground mining projects. This research was focused on the personnel involved in underground mining projects and therefore a subgroup of the underground mining personnel population. In order to get a representative sample, stratified sampling was chosen as means of establishing the population. Only individuals who were involved in underground mining projects were targeted to complete the questionnaire. Generally, the following job designations are directly involved in underground mining projects in the South African setup: The Client, Front line labour, Project Administration personnel, Human Resources Managers, Community Development, Project Engineers, Project Readiness Managers, Project Managers and Project Executives

These designations and project team size may vary in some projects depending on the project needs and level of complexity. In this study the questionnaire was sent to all those with the above designations

To maximise the response rate, the questionnaire was sent to personnel involved in projects both internally and externally. The external audience that the questionnaire was sent to was mostly consulting companies. Out of 40 questionnaires, a total of 30 properly completed questionnaires were returned from both internal and external respondents.

The questions were coded to enable easy analysis of the data. The questions were further reduced to numbers to enable quick gathering and presentation in a usable format during analysis. Wilkinson and Birmingham (2003), points out that questionnaires can be used in many situations to gather data and information on a broad range of issues, but they may have the following limitations:

- Asking leading questions when the researcher knows the answer;
- Asking complicated questions by asking one question with a view of harvesting greater yield of information;
- Asking irritating questions like asking the respondent to indicate their age;
- Asking too many open-ended questions.

Asking too many open-ended questions may force the respondent to put more effort in answering the questions and that could also discourage the respondent from completing the questionnaire. The author took the above limitations into consideration in designing the questionnaire. In the total of 12 questions asked, nine were open-ended questions.

3.5 Use of interviews as a data collection instrument

Interviews are not an easy option to use as a data collection instrument. Interviews are far more resource intensive and usually require more time with the respondent than is the case with questionnaires. It has been said that while other instruments focus on the surface elements of what is happening, interviews give the researcher more of an insight into the meaning and significance of what is happening (Denscombe, 1998).

The following are the stages of developing and conducting interviews: draft the interview; pilot the questions; select the interviewees; conduct the interviews and analyse the interview data. (Wilkinson and Birmingham, 2003). There are three models of interviews, namely, unstructured interviews, semi-structured interviews and structured interviews. In this study unstructured structured interviews were conducted

Of the 30 respondents to the questionnaires, only eight were interviewed. The selection criteria for conducting the interviews was the seniority of the position held in a project. As a result, Project Executives, Project Managers and Project Engineers were interviewed. The reason for conducting structured interviews in addition to having filled in a questionnaire was to get more insight and understanding on some of the responses given by Project Managers and Project Engineers in the questionnaire.

Due to Covid-19 restrictions, interviews were conducted online using the Zoom platform. Consent was requested from interviewees to record the discussions and they were informed how the information would be used.

3.6 Use of public reports and unpublished internal documents as data collection instruments

Bhandari (2021) defines quantitative research as the process of collecting and analysing numerical data. It can be used to find data patterns and averages, make predictions, test casual relationships, and generate results to wider populations. Quantitative research methods can be used for descriptive, correlational, or experimental research.

In the study, descriptive statistics were used to investigate the numerical data sourced from internal unpublished reports. Statistical techniques are concerned with the organisation, analysis, interpretation, and presentation of data (Sheard, 2018). Annual production and financial data from 2002 to 2019 was gathered from internal unpublished reports, analysed, and presented as indicated in Figures 4.4 to 4.11.

It can, however, be noted that using quantitative data has both advantages and disadvantages. Some of the advantages of using quantitative research are:

- Replication - repeating the study is possible because of standardised data collection protocols and definition of abstract concepts.

- Direct comparison of results - the study can be reproduced in other cultural settings and results can be compared statistically.

- Large samples - data from large samples can be processed and analysed using reliable and consistent procedures through quantitative data analysis (Bhandari 2021).

Despite the benefits of quantitative research, it is sometimes inadequate for explaining complex research topics. Its limitations are:

- Superficiality - using precise and restrictive operational definitions may inadequately represent complex concept.

- Narrow focus - predetermined variables and measurement procedures can mean that you ignore other relevant observations.

- Structural bias - despite standardised procedures, structural biases can still affect quantitative research. Missing data and imprecise measurements could lead to wrong conclusions.

- Lack of context - quantitative research often uses tools like laboratories that fail to consider historical or cultural context that may affect data collection and results (Bhandari 2021).

3.7 Conclusion

This chapter has detailed scholarly perspective on key processes used in the gathering and collection of information. The advantages and disadvantages of using either qualitative or quantitative information were highlighted. The limitations of the different data collection instruments were also discussed. The research in this report was conducted with the understanding of the limitations of the different information gathering instruments.

The research instruments discussed above were used with respect to the post project completion analysis of MPM. In this regards, Chapter 4 discusses the case study of MPM.

4 CASE STUDY: MODIKWA PLATINUM MINE (MPM)

4.1 Introduction

This chapter aims to provide an overview of community, labour relations, production, and financial performance over the period of 2002 to 2019. This information serves to give insight into the health status of the operations and how financial decisions taken at MPM affected the performance of the mine. This chapter presents the MPM case study context. The data presented serves to set the scene of the context within which the post-project review captured the important experiences and insights of the project team involved.

4.2 General overview

The MPM mine is located in the eastern limb of the Bushveld Igneous Complex (BIC) in South Africa as shown in Figure 4.1. The MPM mine started with development in 2002 and has yet to achieve its planned production of 240 000 tonnes of milled platinum ore per month. The mine is situated about 340 km north-east of Johannesburg and 28 km north of Steelpoort in the Limpopo Province. MPM contributes to the economy of more than 489 000 people in the Fetakgomo-Greater Tubatse Municipality (Tubatse-Fetakgomo Municipality, 2020). Figure 4.2 shows the relative position of Fetakgomo-Greater Tubatse Municipality to other municipalities in the Sekhukhune District.

Exploration in the eastern limb of the BIC started in the mid-1920s with the discovery of the Merensky reef. During the late 1980s, further drilling was undertaken in the area for the Upper Group Two (UG2) reef. Thereafter a feasibility study was completed for the exploitation of the UG2 ore body.

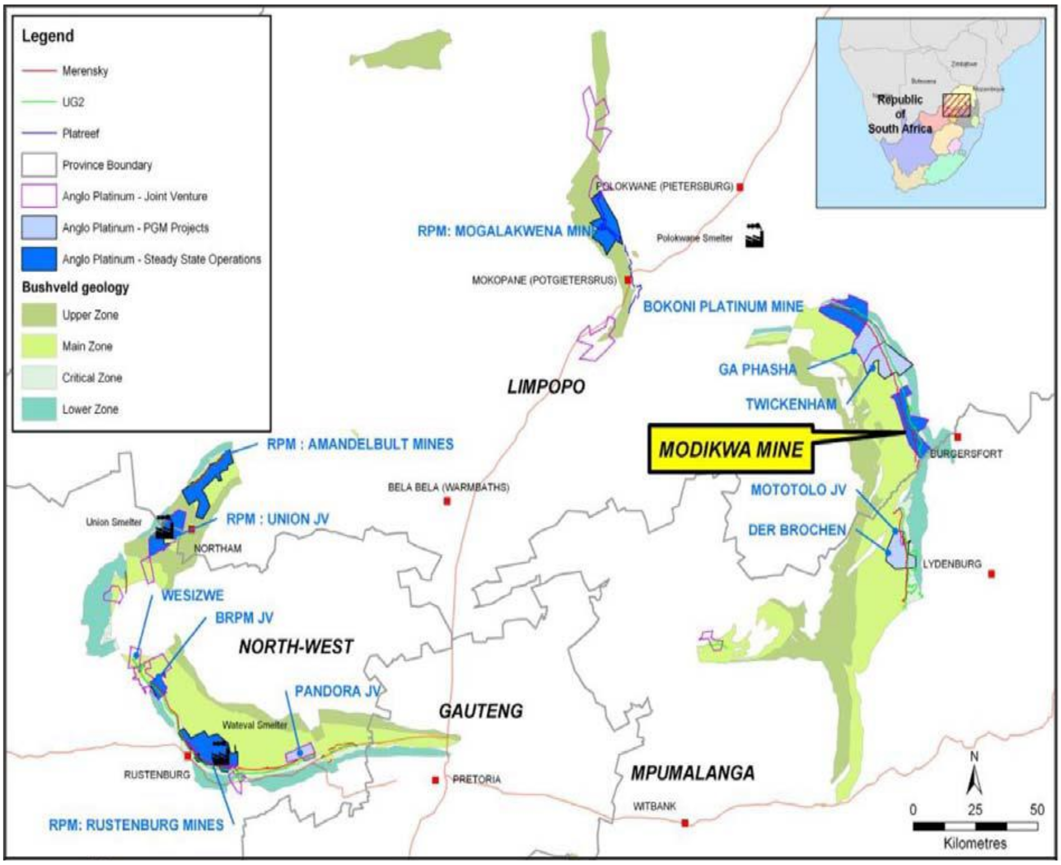

Figure 4.1: Location of mines in the BIC (Modikwa Platinum Mine, 2012).

Figure 4.2: Municipalities in Sekhukhune District (Shai, 2017)

The MPM ownership is a 50/50 joint venture between African Rainbow Minerals (ARM) and Anglo-American Platinum (AMplats). ARM effective stake in MPM is 41.5% through its 83% ownership of the ARM Mining Consortium and the 8.5% is held by the Mampudima and Matimatjatji community companies via their 17% shareholding in the ARM Mining Consortium. The seven communities are legally organised into two Section 21 Non-Profit Companies (NPC) and are represented at the Executive Committee (Exco), the Steering Committee (Steercom) and other governance structures by directors from the NPCs. The seven communities are Matimatjatji and Mampudima. Mampudima is made up of the following six communities:

i. Mamphahane
ii. Sehlaku
iii. Maroga
iv. Mampuru
v. Diphale
vi. Seuwe

The MPM is also managed through a 50/50 joint venture structure between AMplats and ARM. Figure 4.3 indicates MPM's shareholding. The governing body is the Exco and it meets on a quarterly basis. The Exco is composed of equal ARM and AMplats representatives and the NPCs directors are invited to these meetings. The Business Leader or General Manager of MPM reports directly to Exco. The MPM performance review meetings are held by the Steering committee made up of senior employees from both ARM and AMplats on a monthly basis, and the community is represented by NPCs directors. The Exco subcommittees consist of the Audit committee and the Health, Safety, Environment and Community Development.

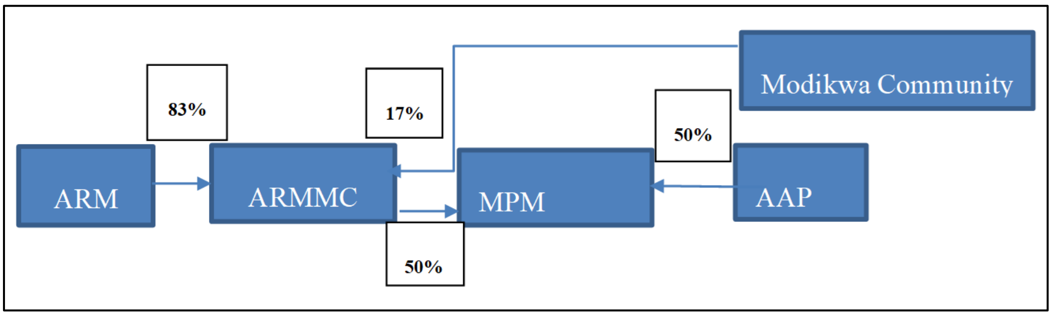

Figure 4.3 MPM shareholding structure (African Rainbow Minerals Platinum, 2020)

The MPM consists of underground workings with three decline shafts and a concentrator plant and was designed to mill 240 000 tonnes per month, which equates to 2.88 million tonnes per year, with annual platinum group metal (PGM) volumes of about 400 000 PGM ounces 6E (African Rainbow Minerals Platinum, 2016). The focus is on the extraction of PGM reserves contained in the narrow tabular UG2 orebody of the Bushveld PGM deposit. The mine comprises of a network of underground workings some 450 metres deep below surface which are accessed through three declined shafts, namely North 1, South 1, and South 2.

The MPM has a concentrator plant with a designed capacity of 240 kilo tonnes per month (ktpm). North 1 and South 1 were the first working clusters to be developed and became operational in February 2000 with original designed capacity of 200 ktpm. This was later optimised to 240 ktpm to match the concentrator plant capacity.

Two replacement projects were undertaken at the mine to maintain a steady production rate. The first project entailed the deepening of the North 1 workings from Level 6 to Level 9 in 2015, thereby establishing three new mining levels. The second project entailed the sinking of South 2 shaft in 2015. The first phase of the project was intended to increase mining flexibility while also contributing to the overall production build-up of the mine (African Rainbow Minerals Platinum, 2016).

4.2.1 Socio-economic environment

There are about 489 900 inhabitants in the Fetakgomo and the Greater Tubatse municipality area as indicated in Table 4.1. This area is plagued with poor infrastructure development. According to the Municipality's integrated development plan (IDP) of 2006-2011, in a period leading to the development of the MPM, to be specific in 1996, there were 35 graduates within its borders. At the same time only 2 000 people matriculated, 2 334 people completed grade 8, while 3 072 people had received no schooling and unemployment in the Tubatse-Fetakgomo municipal area was at 23% (Smith et al, 2008).

The levels of socio-economic development and upliftment have not advanced, despite increases in mining investments in the area. According to Kongolo (2009), socio-economic development in Limpopo province is very poor compared to other provinces. In 2009, the unemployment rate in the province is about 27% which is similar to the Eastern Cape Province it despite being rich in mineral resources.

Water supply and sanitation infrastructure development in the Tubatse-Fetakgomo by 2010 was not matching the growing population and increased mining activities over the years. This resulted in unsustainable development in both water supply and sanitation to the citizens of the Tubatse-Fetakgomo municipality (Monashane, 2011).

Table 4.1 shows the population age distribution and Table 4.2 details the poverty rates in the community. Table 4.3 shows the employment demographics and Table 4.4 shows the population growth statistics. Relatedly, Table 4.5 shows the monthly income by gender.

Table 4.1 Population age distribution in the Tubatse-Fetakgomo Municipality (Tubatse-Fetakgomo Municipality, 2020)

Age - 5 year age groups by Sex for Person Weight, Fetakgomo Tubatse			
	Male	**Female**	**Grand Total**
00-04	26816	27240	54056
05-09	24714	24739	49452
10-14	22774	21192	43966
15-19	32003	28667	60670
20-24	30329	27152	57481
25-29	30051	28938	58989
30-34	22098	23907	46006
35-39	11514	13768	25282
40-44	10130	10409	20539
45-49	7050	9176	16226
50-54	6165	8840	15004
55-59	4890	6247	11137
60-64	4507	5539	10046
65-69	2015	4682	6697
70-74	1460	4823	6282
75-79	845	2650	3495
80-84	401	1732	2134
85+	417	2023	2440
Grand Total	**238179**	**251723**	**489 902**

Table 4.2: Poverty rate in the Tubatse-Fetakgomo Municipality (Tubatse-Fetakgomo Municipality, 2020)

2011 STATSA			2016 community survey	
Municipalities	**Poverty headcount**	**Intensity poverty**	**Poverty headcount**	**Intensity poverty**
Sekhukhune	11.3	41.6	13.6	42.4
Ephraim mogale	10.3	41.0	13.1	41.5
Elias motsoaledi	8.5	41.3	10.9	42.3
Makhuduthamaga	12.2	41.4	15.3	42.5
Fetakgomo	9.6	41.3	14.7	41.5
Tubatse	13.5	42.2	14.2	42.9

Table 4.3: Employment statistics in the Tubatse-Fetakgomo Municipality (Tubatse-Fetakgomo Municipality, 2020)

Gender by Official employment status							
for Person weighted, LIM474: Fetakgomo - LIM475: Greater Tubatse, 15 - 64							
	Employed	Unemployed	Discouraged work-seeker	Other not economically active	Age less than 15 years	Not applicable	Total
Male	38311	25764	5300	50475	-	-	119849
Female	20389	37604	8576	69243	-	-	135811
Total	58700	63367	13877	119717	-	-	255661

Table 4.4: Population growth in the Tubatse-Fetakgomo-Municipality (Tubatse-Fetakgomo Municipality, 2020)

INDICATOR	2011	2015	2020	2025	2030
Population	385 000	430 800	487 400	538 100	579 700
Working age population	236 390	271 400	316 800	360 500	405 800
LF participation rate%	38.4	40	44	48	50
Labour force	90 770	108 560	139 400	173 000	202 900
New jobs	0	10 000	10 000	10 000	5 000
Employment	53 220	63 220	83 220	83 220	88 220
Unemployment rates%	41	42	47	52	56

Table 4.5: Monthly income by gender in the Tubatse-Fetakgomo Municipality (Tubatse-Fetakgomo Municipality, 2020)

Individual monthly income by Gender			
for Person weighted, LIM474: Fetakgomo - LIM475: Greater Tubatse			
	Male	Female	Total
No income	88 965	116 868	205 833
R 1 - R 400	50 444	51 927	102 370
R 401 - R 800	4 270	6 357	10 627
R 801 - R 1 600	16 773	27 723	44 496
R 1 601 - R 3 200	7 756	4 067	11 823
R 3 201 - R 6 400	11 647	3 472	15 120
R 6 401 - R 12 800	6 946	2 785	9 731
R 12 801 - R 25 600	3 221	1 676	4 897
R 25 601 - R 51 200	1 028	313	1 341
R 51 201 - R 102 400	135	38	173
R 102 401 - R 204 800	89	61	150
R 204 801 or more	88	35	123
Unspecified	9 611	10 654	20 265
Not applicable	1 654	817	2 471
Total	202 627	226 792	429 419

More PGM mines are now in operation in the eastern limb of the BIC compared to earlier years. According to Tubatse-Fetakgomo Municipality (2020), the following are mining and smelting operations in the eastern limb of the BIC; Modikwa Platinum Mine (AMplats and ARM JV), Mototolo Platinum Mine (AMplats), Booysendal Platinum Mine (Northam), Bokoni Platinum Mine (AMplats and Atlatsa JV), Phoka Thaba Platinum, Der Brochen Platinum Project, Dwarsrivier Chrome Mine, Sefateng Chrome, Elephant River Granite, Umnotho weSizwe Mooihoek Chrome Mine, Two Rivers Platinum Mine (Impala and ARM JV), Marula Platinum Mine (Impala), Xstrata Thorncliffe Chrome Mine, ASA Metals/Dilokong Chrome Mine, Rhino Minerals Havercroft Mine, Samancor

Chrome Mines, Black Chrome, Tubatse Ferrochrome, Xstrata Alloys Lion Ferrochrome Operation.

Smith, Da Lomba and Anderson (2008) indicated that one of the challenges stifling economic development in the eastern limb of the BIC is the lack of infrastructure development. In particular, the following aspects were identified to be at the core of water supply and spatial development:

- Provision of free basic services;
- Access to municipal services in previously disadvantaged communities;
- Water services (provision and maintenance);
- Solid waste removal;
- Electricity provisioning;
- Transport;
- Roads; and
- Storm water management.

Another challenge in the Fetakgomo-Tubatse municipality has been the growing rate of unemployment. The rate of unemployment has been rising in this area as indicated in Table 4.3.

4.2.1.1 Mining-related social unrest in the bushveld igneous complex on the eastern limb

Stoddard (2018) mentioned that AMplats provided data to Burgersfort, South Africa (Reuters,10 April 2018) indicated that the eastern limb of South Africa`s platinum belt has experienced over 400 incidents of social unrest impacting mining operations since the start of 2016. These statistics paint a picture of an unstable socio-economic environment not conducive to the implementation and maintenance of sustainable mining projects.

The socio-economic environment in the Tubatse-Fetakgomo municipality is challenging in view of the high poverty and unemployment rate and poor water and sanitation infrastructure. These socio-economic challenges contributed to more than 400 community disruptions that have been observed since 2016. Generally during community disruptions employees are prevented from entering the mine and this results in a loss of production. According to Onstard (2007) in one labour strike which lasted for 24 days, MPM lost 150 000 ore tonnes resulting in estimated loss of R120 million. Although supervisors and artisans were used to minimise the impact of the strike by conducting vamping and sweeping operations, the strike still had a severe negative impact on the mine.

Mining companies have been contributing towards social and economic upliftment through many programmes like the Social Labour Plans (SLP) and other public and private partnership programmes like the Lebalelo water scheme.

4.3 Feasibility study

According to, (Modikwa Platinum Mine, 2000): MPM mine started with the company considering the development of a new mining venture in the Eastern Limb of the Bushveld complex with the centre of operation some 25 km north-west of Steelpoort in Mpumalanga. The operation was to mine 200 000 tonnes per month of UG2 platinum ore. The owner was to be fully responsible for all mining activities and for the concentrating operation. The concentrate was to be sold to the smelter. The owner was to provide the necessary regional infrastructure, e.g. roads, power and water for the project.

The ore was to be beneficiated through a single concentrator plant situated centrally to the mining area. A tailings dam was to be constructed in close vicinity to the plant. In siting the operations, every effort was to be made to avoid established communities, building structures and gravesites.

The areas targeted for mining operations spanned approximately 15 km either side of the central concentrator plant. The preferred mining method was to be up/down dip mining. Each mining operation or decline shaft was to typically mine 100 000 tonnes of ore per month, which was to be delivered to the concentrator plant by overland conveyor. Each operation was to typically provide for its own local infrastructure, e.g. water storage dams, compressed air, as well as water, power and road reticulation from the main distribution network. Ore was to be transported from the concentrator by road transport over good quality sealed roads. All other roads on the site that were be used for personnel, materials and equipment transport vehicles were to comprise good of quality sealed and unsealed roads.

4.3.1 Mineral deposit

A new mining venture in the Eastern Limb of the Bushveld Igneous Complex was planned, with the centre of the operation some 25 km north-west of Steelpoort. The operation will mine 200 000 tonnes per month of UG2 platinum ore (Modikwa Platinum Mine, 2000).

4.3.2 Mine product

The mine was to produce concentrate of platanoid minerals, namely platinum, rhodium, palladium, ruthenium, iridium and osmium with gold, copper, nickel and cobalt as by-products in the final concentrate and a by-product of chrome. The estimated reserves for the project were in excess of 120 million tonnes of ore.

4.3.3 Mining method

It was proposed to mine the ore using a twin decline system. This comprised one decline fitted with a conveyor to remove the ore (and waste rock) from four underground mining levels and one decline for diesel powered equipment. The ore was to be transported to the concentrator plant for processing from the southern and northern decline shaft/declines by an overland conveyor.

The areas targeted for mining operations spanned approximately 15 km either side of the central concentrator plant. The preferred mining method was to be up/down dip mining. Each mining operation or decline shaft was to typically mine 100 000 tonnes of ore per month, which was to be delivered to the concentrator plant by overland conveyor. Each operation was to typically provide for its own local infrastructure as stated above.

The concentrator plant was to be a zero effluent discharge plant when operating under normal conditions and was to comprise the following main components: Bunkers, ore stockpile and silos, primary crushers and screens, milling building, flotation building, concentrate thickeners, concentrate handling infrastructure, tailings dam and storm-water dam.

4.3.4 Production rate

The proposed production rate for the underground operations was 200 000 tonnes per month of UG2 ore giving a total annual production of 2 400 000 tonnes per annum with an annual production of approximately 162 000 oz of platinum.

The production rate was changed to 240 000 tonnes per month of UG2 ore giving a total annual production of 2 880 000 tonnes. The change was built in the revised feasibility of mine expansion which ranged from 2005 to 2012. The mining schedule for the period 2005 to 2012 is indicated Figure 4.4.

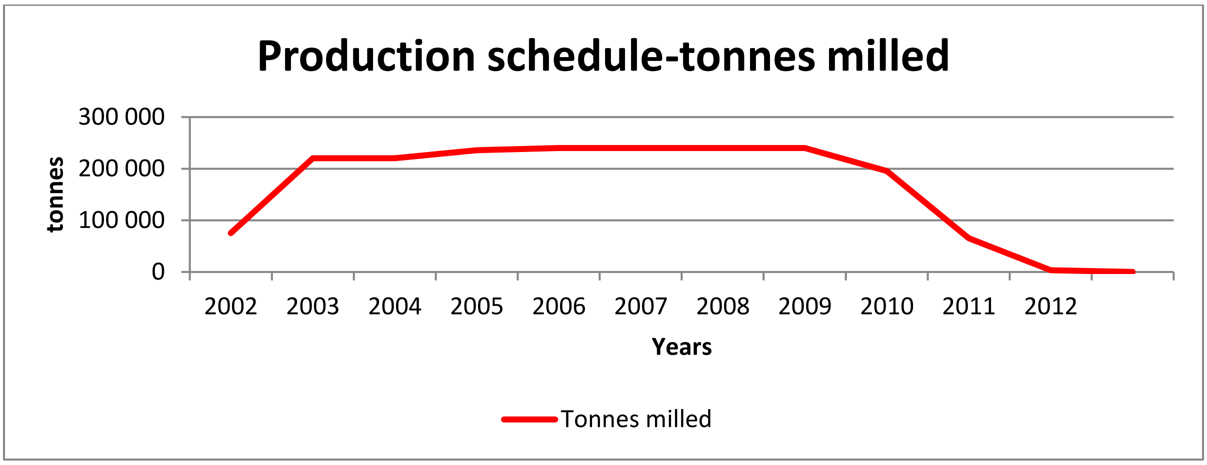

Figure 4.4: Phase 1 production schedule of MPM (Modikwa Platinum Mine, 2000).

4.3.5 Life of mine

The tonnage build up was to take place over a two year period starting in 2000. The mine was thus only to come into full production at the end of the year 2002. It was expected to continue in full production for in excess of 50 years, when phase 1 and phase 2 are taken into account, before production will start to decrease.

4.4 Underground mining projects inherent risks

Underground mining projects have inherent risks as many of the variables that drives profitability are not under full control of the mine. Some of these variables that are outside the control of a mine are metal prices, full understanding of the geology of orebody, socio-economic stability, input cost for critical material like fuel and electricity.

4.4.1 Geology risk

The orebody could be more complex than predicated during the initial delineation. A delicate balance needs to be maintained between over-delineation and under delineation. Sometime a mixture of borehole drilling, aeromagnetic and seismic surveys may be required to gain better understanding of the orebody.

4.4.2 Financial risk

The financial risk in mining projects can be manifested in the achievement of lower than expected commodity prices, higher than predicted inflation, higher than planed input costs for both labour and materials. When the above mentioned risks materialise, mines usually mitigate these risk by reducing stay in business capital. This could lead to an inefficient cycle as older and inefficient equipment do not get replaced leading to poor productivity and high maintenance costs.

Project contingency was modelled using Palisade @Risk Monte Carlo analysis software. The contingency make provision for schedule slippage estimate error and project risk. The contingency output were all based on P90 probability which was considered appropriate risk level for the project.

The global financial assumptions looked at long term metal prices as supplied by different financial institutions. The exchange rate assumptions were drawn from predictions of various financial institutions. The metal prices and the exchange rates were factored in determining the revenue estimates.

4.4.3 Orebody knowledge

4.4.3.1 Geology

The MPM mining lease is underlain by the Main Zone of the BIC. This zone comprises of a layered sequence of differentiated units of chromitite, pyroxenite, norite and anorthosite. The layered sequence strikes North of North West and South of South East and has an average dip of approximately ten degrees towards the west, but steeper blocks have been noted (Modikwa Platinum Mine, 2012).

Platiniferous reefs identified within this area that are of economic interest are the Merensky Reef and the UG2 Reef as well as a number of dunnite pipes such as the Driekop Pipe which was mined in the past. MPM mines the UG2 reef within the

Upper Critical Zone of the eastern limb of the BIC to depths of 50m to 500m below surface (Modikwa Platinum Mine, 2012).

At the MPM, the UG2 reef outcrops on the surface where it is oxidised, and this portion is considered uneconomic to mine. The UG2 is continuous to a depth of 860m below the Leolo mountains at the western boundary of the Mining lease or approximately 550m below the collar elevations of the declines and normally occurs as a solid chromitite, with an approximate thickness of 60cm. In other places the UG2 is potholed. In these potholes the UG2 reef rolls down in the footwall stratigraphy and is either very thin or not developed at all. The potholes are considered unmineable. Gentle undulations of the UG2 reef with amplitude of less than 2m occur throughout the area (Modikwa Platinum Mine, 2012).

Several dykes dissect the area. These dykes are readily recognisable from aeromagnetic images, as well as satellite and orthophotographs. The most prominent dykes occur with a North of North East and South of South West orientation and have little throw or no throw (less than 5m) while thickness of up to 30m may be reached. Faulting occurs mainly along directions parallel to the main dyke orientation. A number of West of North West and East of South East less prominent dykes with thickness up to 5m and maximum throws of 5m also occur. Within the MPM mining lease, most intense faulting has so far been observed in an area on the Southern part of the Mine, known as the South Shaft Gap. The North 1 area is less intensely deformed.

A number of Iron Rich Ultramafic Pegmatite (IRUP) and replacement pegmatite have been observed. Where these occur, the succession has been intruded by the IRUP or replacement pegmatite, as a result of late-stage hydrothermal activity; consequently, the UG2 reef is either completely replaced or highly disrupted.

The first 40 m from surface is considered to be weathered. Within the weathered zone, the rock is more friable and the UG2 reef is considered to be negatively affected by oxidation. The bottom part of the weathered zone, known as the regolith, is associated with the saturated water table. The regolith extends to a maximum of

40 m. The weathered zone and the regolith poses two risks. The one risk is the oxidation of the UG2 reef, which may affect metal content and metallurgical recoveries. For this reason, the ground between the outcrop and the limit of the regolith is not part of the mineral reserves, although it is part of the mineral resource. The second risk associated with the regolith is the possibility of uncontrolled water influx into the mine workings (Modikwa Platinum Mine, 2012).

The risk associated with rigolith had a material effect on the rate of development and subsequently a cover drilling code of practice was introduce in 2003. The purpose of the cover drilling code was to get information of the area ahead of the advancing development end to forewarn development crews of the impending danger. The code of practice entailed drilling 300 m ahead of the advancing development face and this subsequently had adverse effect on the development rate and envisaged in the feasibility study.

An extensive surface drilling programme was conducted at MPM. As part of the surface drilling programme some 30 km of core was produced in 2005, whereas an additional 20 km was produced between 2004 and 2007. A total of 1849 UG2 reef borehole intersections were considered for the compilation of the September 2009 UG2 Reef Geological Resource Model (Modikwa Platinum Mine, 2012).

4.4.3.2 Geophysical surveys

As the development of South 1 decline intersected more geological structures than anticipated, production output fell behind. A decision was taken to further investigate the South 1 area in order to create a better understanding of the orebody. Two methods were used for the additional exploration namely, aeromagnetic survey and seismic survey. The resulting dataset types are complementary. Seismic survey cannot detect dykes with little or no throw, while aeromagnetic survey cannot detect faults with no magnetic material associated with them. Seismic survey detects structures with an offset, the aeromagnetic survey detects dykes with or without offset at the surface.

A 3-D seismic survey was carried out in 2006. The results of the seismic survey indicated the following (Modikwa Platinum Mine, 2012):

- The anticipated north-south trending fault had significantly larger throws than suggested by the widely spaced boreholes.
- Substantial variation in dip and strike of the target UG2 reef were also observed on the up-throw block of the faulting.
- More minor faulting parallel and perpendicular to the main faulting was also observed.
- A large pothole intersected by earlier drilling was confirmed in the west of the survey area.
- Dykes seen in the aeromagnetic survey done in 2003 were traced at the UG2 reef level where they had associated throw.
- Several structures not seen in the aeromagnetic survey were observed in the seismic survey.

The scale and complexity of the UG2 reef structure in the southern area had not been clearly delineated by borehole control or the aeromagnetic survey data. This was a significant geological risk which was not identified during the feasibility study. During project execution this unidentified geological risk had a significant negative impact on ore production which negatively impacted the project financial returns.

Since the northern area target has a similar dyke swarm to the southern area, this inferred similar faulting associated with these dykes. Community resistance had prevented execution of a seismic survey at North 1. As an intervention, it was recommended that every effort should be made to negotiate with the communities for access to conduct a seismic survey in that area.

The seismic survey information has been of great value in confirming that no mining should take place in the fault zone, which makes up in excess of 50% of the planned area to be mined as indicated by the purple polygon in Figure 4.5. The information obtained from the seismic survey indicated the following (Modikwa Platinum Mine, 2012):

- The main fault throw was larger than originally thought; up to 140m but averaging 100m.
- The main fault is discontinuous, with multiple segments and a complete transfer system at the north.
- There are highly variable dips and strikes on the fault block, especially in the south-west.
- A 25m east-west trending fault can also be seen.
- Displacement is downwards to north; and
- There is a large pothole in the east of the block.

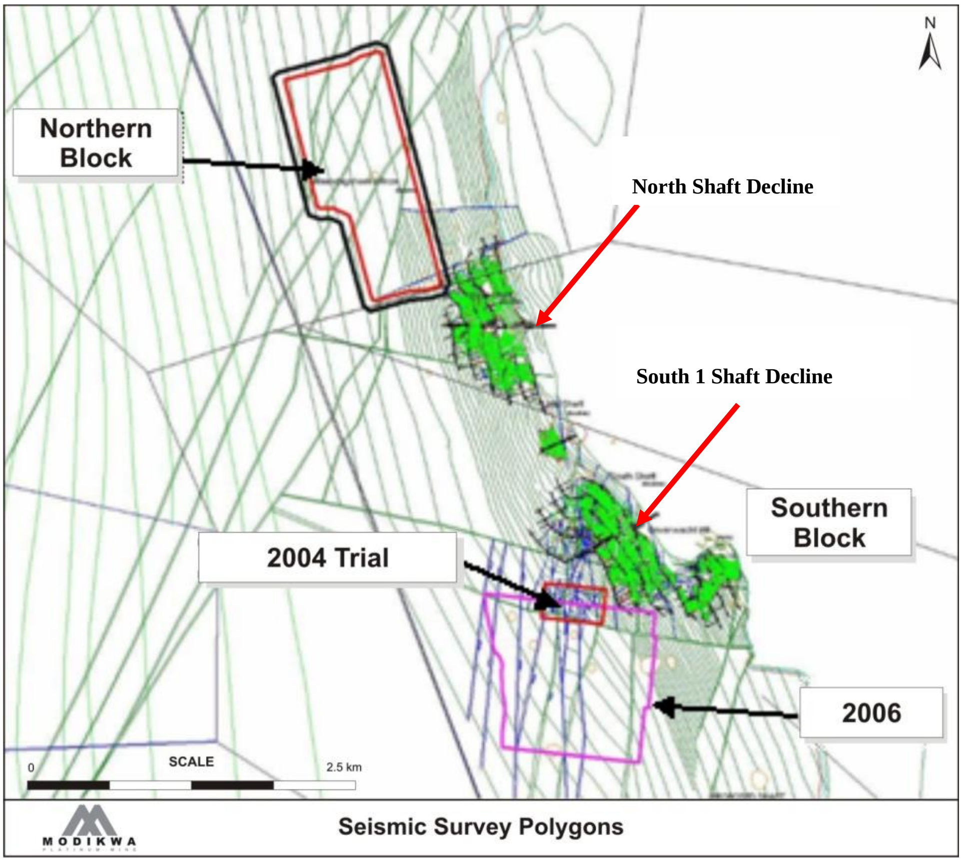

Figure 4.5: Seismic survey polygons of the MPM mining lease area (Modikwa Platinum Mine, 2012).

4.5 Production and financial analysis

This section provides trends in both production and financial performance at the MPM over the period 2002 to 2019. Performance indicators in terms of ratios and factors are calculated to indicate how the mine performed against set targets or design capacity.

4.5.1 Strike development

Mechanised strike development is the key to the health and sustainability of any hybrid mine where access strike development is conducted by mechanised equipment and production is done through conventional mining. Primary development exposes the reserves and creates flexibility in mining. The mechanised strike development as indicated in Figure 4.6, commenced in 2002 during mine development and reached its peak at 11 366m per year in 2003. The mechanised strike development went down sharply to its lowest level of 408m in 2009. It climbed to a peak of 4 215m in 2013, hit another low of 496m in 2015 and reached 3 447m in 2019.

The industry average ranges between 23 m and 29 m per mining crew per month in terms of flat mechanised development over the period 2007 and 2011. MPM achieved an efficiency that ranges from 14 m to 29 m per crew per month over a five-year period as indicated in Table 4.6. This was attributed to having unskilled mining operators who takes time to reach competency levels achieved in mature mining areas like the Western Limb of the Bushveld Igneous Complex. It can be seen that production ramp schedule based on the feasibility study assumptions could not be achieved due to lower than expected labour efficiencies as indicated in Table 4.6.

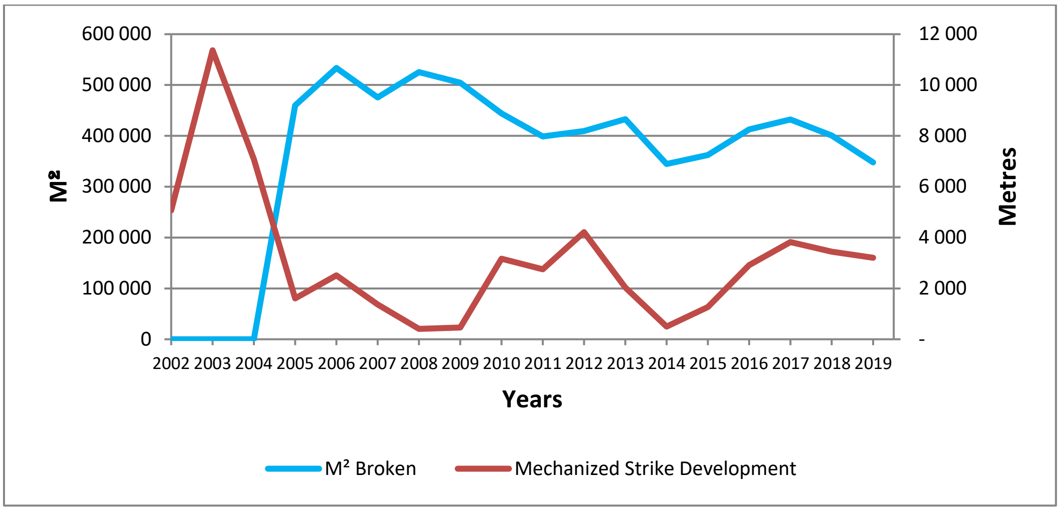

Figure 4.6: The MPM blasted area vs mechanised development metres from 2002 to 2019 (Modikwa Platinum Mine, 2020).

Table 4.6: MPM vs industry efficiencies (Modikwa Platinum Mine, 2020)

Stoping efficiencies						
	Year	2007	2008	2009	2010	2011
Industry Average	M^2/crew/month	374	390	402	358	369
MPM	M^2/crew/month	233	283	340	218	240
Mechanized flat development efficiencies						
	Year	2007	2008	2009	2010	2012
Industry Average	M/crew/month	29	25	28	23	26
MPM	M/crew/month	25	14	21	24	27

4.5.2 Blasted area in the stope

The stope area blasted is measured in metres squared (length and breadth of the excavated area). The strike development is the length of the primary flat development excavated to access the ore reserve. This development excludes primary inclined development like raises or winzes.

A graph of the area of blasted and mechanised development metres is shown in Figure 4.6. The mine reached its annual peak blasted area of 533 527 m² in 2006. It attained its lowest annual blasted area of 344 952 m² in 2014. While there have been years of higher performances since 2006, such as the achievement of 432 891 m² in 2013 and 432 349 m² in 2017, the general trend of annual blasted area has been downwards since 2006.

The industry average ranges between 358 m² and 460 m² per mining crew per month in terms of stope area excavated over the period 2007 and 2011. MPM achieved an efficiency that ranges from 218 m² to 340 m² per crew per month over a five-year period as indicated in Table 4.6. This was attributed to having unskilled mining operators who took time to reach competency levels achieved in mature mining areas like the Western Limb of the Bushveld Igneous Complex. It can be seen that production ramp up schedule based on the feasibility study assumptions could not be achieved due to lower than expected labour efficiencies as indicated in Table 4.6.

4.5.3 Production risk

The Mine may not achieve the set production target due to limited face availability, poor ground conditions, poor machine availability, poor selection of mining method or lack of skill of operators. A slow ramp in development may result in not achieving steady state production at the per production ramp up schedule.

4.5.4 Depletion and replacement ratios

The replacement ratio is the ratio at which new ore reserves are exposed or opened against the depletion ratio. The common logic is that a mine should at least replace what it depleted on a monthly basis to ensure that the equilibrium or mining flexibility is maintained. This means that the depletion ratio should be equal to the replacement ratio when the mine is at steady state.

If more area is depleted than the area exposed above sustained basis, the mine will eventually run out of areas to mine. This could lead to loss of planned revenue due to mining sequence problems, unavailability of workplaces to mine and inefficient use of resources to correct the available ore reserve deficiencies. Figure 4.5 indicates the annual area broken and strike development. There should be a correlation between area mined and strike development. It is expected for strike development to be disproportionately high during the build-up phase of the mine in order to access the initial mineable ore reserve. Only once a mine reaches steady operations, does a replacement ratio calculation apply. If more area is mined but at the same time less development is done, comparatively, the mine will run into a bottleneck situation.

In a conventional mine it takes about 200m of strike development to generate a reserve of 40 000m², which is a 200m by 200m grid from half-level to half-level and between two raise lines. The 40 000m² could further be discounted due to losses (planned and unplanned) to arrive at a realistic extraction rate by taking into consideration pillar dimensions, potholing, faulting, dykes, and other geological and geotechnical features. It is therefore logical to plan that, if for instance a 40 000m² area is mined per month, at least the same amount should be exposed after considering all the losses. Therefore, if losses account for 10 000m² in a block (80% extraction ratio) of ground then technically 50 000m² needs to be exposed to replace 40 000m² of mineable ore.

Theoretically speaking, every square metre (m²) mined reduces the exposed reserves by a certain number of metres. For example, if 200m of strike development generates a reserve of 40 000m², then the replacement rate could be calculated as 40 000m²/m divided by 200m which equates to a replacement ratio of 200 m²/m of strike development. This means that every 1m of strike development generates 200m² of reserves.

Conversely if 200m of strike development generates a reserve of 40 000m², then the inverse replacement ratio could be calculated as 200m divided by 40 000m² which equates to a replacement ratio of 0.005m/m². This means that every 0.005m of strike development generates 1m² of reserves. If a mine extracts 36 000m² per month, it should at least do 180m of strike development per month. If the inverse replacement ratio is lower than the depletion ratio, then the mine could jeopardise its future mining flexibility and this could result in negative financial impact on the business. Figure 4.7 indicates that the MPM performance has been fluctuating over the years in terms of strike development.

It is, however, noteworthy that between periods 2005 to 2010 and 2013 to 2016 mechanised strike development was below the required strike development as determined by the inverse replacement ratio, thus leading to slower than required ore reserve generation and creation of mining panels. During the remaining periods, the actual strike development was above the replacement ratio but not enough to catch up the shortfalls experienced during the periods mentioned above.

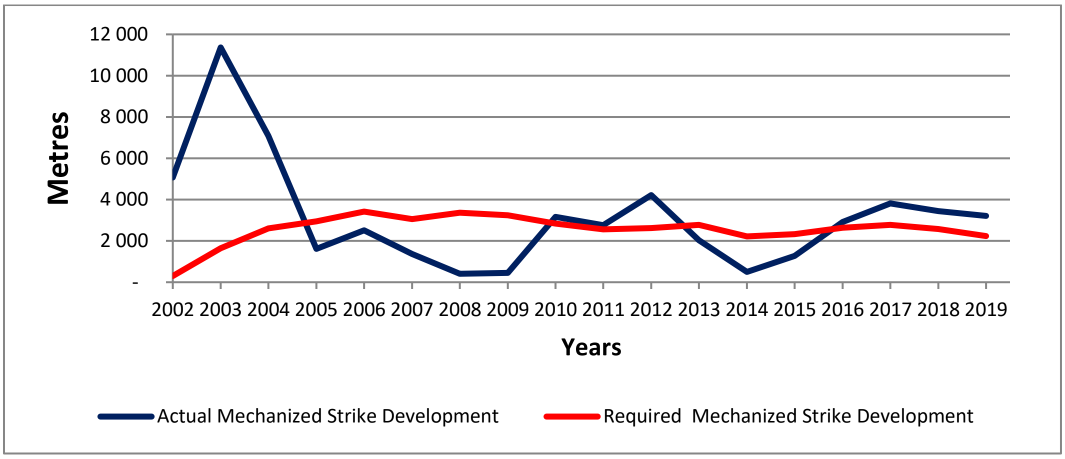

Figure 4.7: The MPM Actual strike development metres versus depletion ratio from 2002 to 2019 (Modikwa Platinum Mine, 2020).

4.5.5 Tonnes milled

The analysis of the production and financial data provides the insight into the trends at the MPM. The concentrator was designed to mill 240 ktpm. Figure 4.8 indicates that the MPM milled less than the design capacity of 2 880 000 tonnes per year. The average tonnes milled per year from 2005 to 2019 is 2 267 194 tonnes against the design capacity of 2 880 000 tonnes per year. This translated to 79% concentrator capacity in relation to its design capacity determined during the feasibility study. The peak of tonnes milled was 2005 and it went down by 26% to 1 911 467 tonnes in 2014. It then increased by 27% from 2014 to 2017 to 2 428 842.

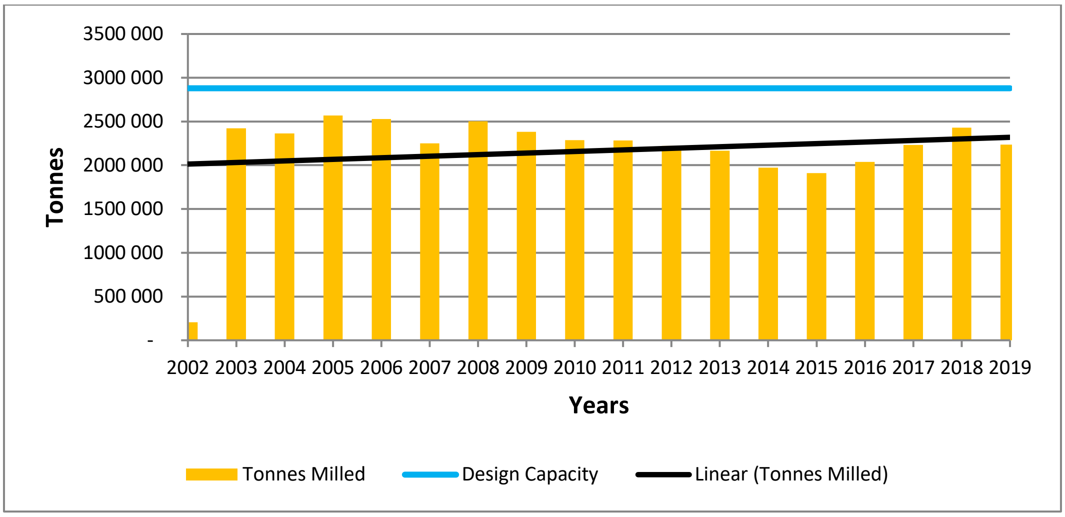

Figure 4.8: The MPM tonnes milled against design milling capacity from 2002 to 2019 (Modikwa Platinum Mine, 2020).

4.5.6 Platinum Group Metals 6E ounces produced

The trend in PGM ounces produced in Figure 4.9 indicated at peak, 357 493 6E ounces were produced in 2006 and this went down by 25% to 266 333 in 2015. The trend also went up by 24% from 2015 to 2018. As expected, the PGM production followed a similar trend to the tonnes milled profile.

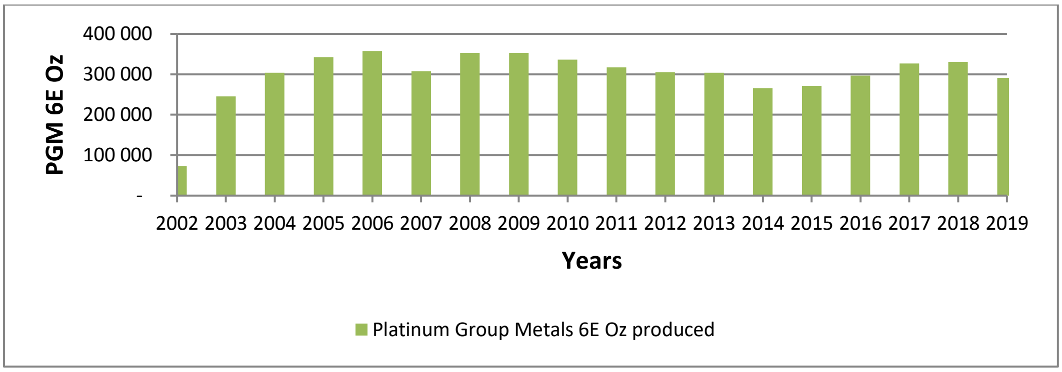

Figure 4.9: The PGM produced from 2002 to 2019 (Modikwa Platinum Mine, 2020).

4.5.7 Rand per tonne milled unit cost

The MPM started with commercial production in 2002. Figure 4.10 indicates that the Rand per tonne milled for the first year was R775/t milled at the mine came into production in 2002. The reason for the high unit cost in 2002 could be the overlap between capital and operational expenditure. The Rand per tonne unit went down to R296/t milled in 2003. If one ignores the unit cost for 2002 as an anomaly, the Rand per tonne cost increased from R296/t in 2003 to R1 456/t milled in 2019. This is an increase of 392% over a period of 16 years.

The high cost per tonne milled rate in 2002 was mainly due to lower tonnes milled as the accumulated ore stockpiled during the mine development phase was milled in 2003. It can be seen that unit costs have been gradually increasing since 2003, with a sharp increase between 2018 and 2019. The tonnes milled and PGM produced in 2019 were 8% and 12% lower than in 2018 respectively.

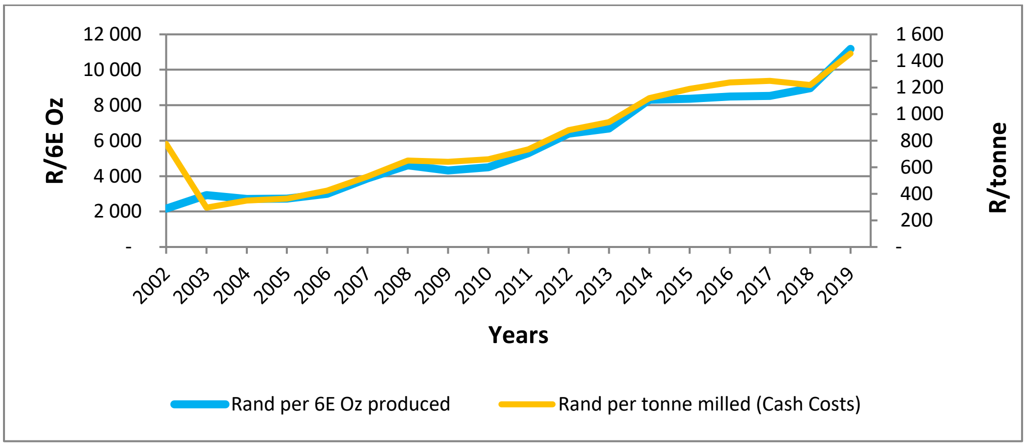

Figure 4.10: The unit costs from 2020 to 2019 (Modikwa Platinum Mine, 2020).

4.5.8 Unit cost changes against Consumer Price Index

In an efficient mining operation real unit cost changes should be closer to Consumer Price Index (CPI) taking inflation into consideration, however nominal cost escalation should be generally flat. Figure 4.11 indicates that the CPI was at its lowest in 2004 at negative 0.68% and reached a peak of 10.04% in 2008 then slowed down to 3.7% in 2019. It is however noteworthy that Rand per tonne unit increases for most years except for few years including the period of 2015 to 2018 where the unit cost escalation was below CPI.

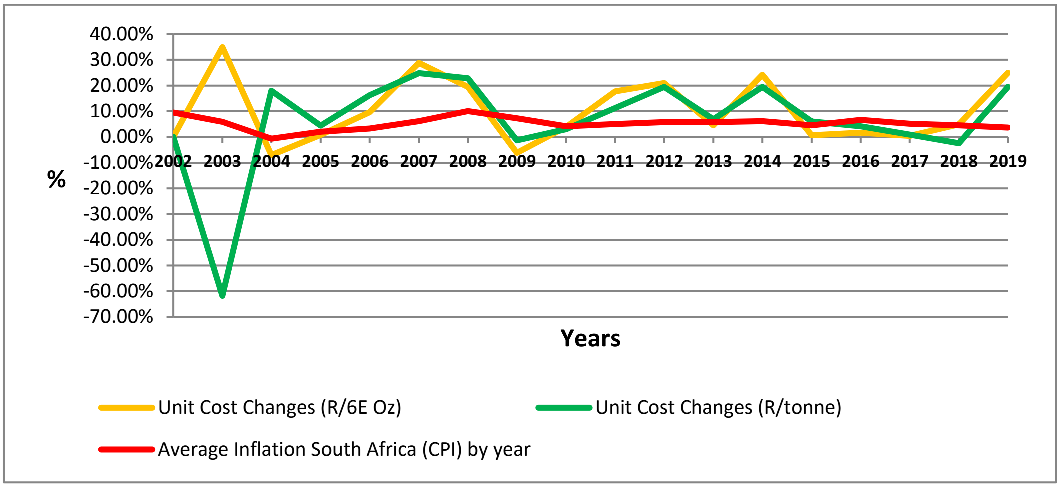

Figure 4.11: Unit cost and CPI changes from 2002 to 2019 (Modikwa Platinum Mine, 2020).

4.5.9 Stay in business costs

Stay in business (SIB) capital expenditure is mostly to sustain current business by spending on replacement of equipment, replacement of major components or refurbishing of equipment. This type of expenditure is essential to keep the operating cost down and to improve equipment engineering availability.

According to Figure 4.12 the SIB capital ranged from R0 to R287 million over the period 2002 to 2019. The expenditure fluctuated from R251 million in 2008 to R82 million in 2015. Although production remain averagely constant, the SIB capital was on a downward trend. The implication could be that major mining equipment was being operated but not replaced at optimal replacement intervals. It is also noteworthy that the MPM experienced double-digit and above inflation unit cost increases during the period 2008 to 2015. This trend could be an indication of reduced stay in business investment. This lack of SIB capital expenditure, meant that new levels were not developed at the required rate, leading to a reduction in mining flexibility and mining production.

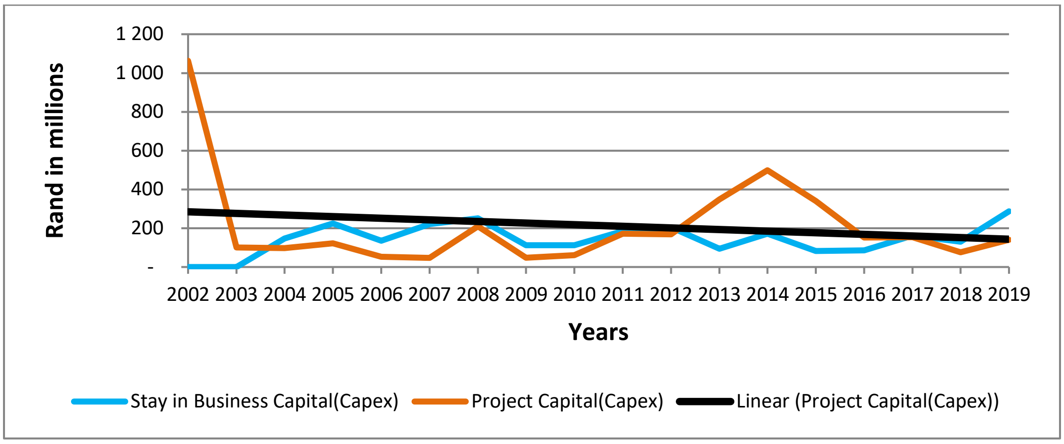

Figure 4.12: The capital expenditure from 2002 to 2019 (Modikwa Platinum Mine, 2020).

4.5.10 Project cost

The mineral reserve depletes as extraction takes place. Depleted reserves need to be replaced to maintain or extend the life of the mine. Additional reserves may also be mined to reduce the unit costs or take advantage of other opportunities in the market. Capital expenditure in an operating mine could either be for reserves expansion, reserve replacement or optimisation.

MPM spent R1 063 million as part of initial capital to establish the mine in 2002. The project capital expenditure continued as the North 1 phase 1 and South 1 deepening and establishing the Merensky board and pillar during the years 2005 to 2008.

In 2009 to 2010 the project capital was cut back following the global economic crisis of 2008. The capital expenditure in Figure 4.12 gradually increased as the deepening of North Shaft and South 1 resumed albeit on a reduced capital expenditure level. In 2014, R499 million capital was approved for the South 2 shaft sinking.

There are three notable phases in Figure 4.12. The mine was developed and constructed from 2002 to 2004. The project capital was R1 063 million in 2002 and went down to R98 million in 2004. The project capital expenditure then gradually increased from R98 million in 2004 to R209 million in 2008. Project Capital decreased from R209 million in 2008 to R47 million in 2009 and then gradually increased to reach a peak of R499 million in 2014. Since 2014 the project capital has been on a downward trend, reaching a low of R76 million in 2018 before rising again in 2019 to reach R141 million.

It can also be noted from the data that although tonnes milled were averagely on an upward trend from 2002 to 2019, capital expenditure was on a downward trend over the same period as indicated by both trend line in Figures 4-8 and 4-12 respectively.

Many mining companies went into major cost reductions in 2008 during the economic downturn which had a negative financial impact on many companies. In order to mitigate the negative impact on financial performance, companies implemented cash preservation initiatives. These cash preservation measures included deferment of capital in new and ongoing projects; shelving of some capital projects; labour reductions and efficiency improvement initiatives.

These cash preservation initiatives had short-term benefits, and long-term negative impacts in many businesses depending on how long they were implemented. At the MPM, capital deferment led to the reduction of shaft deepening and mining fleet replacements capital.

4.6 Conclusion

The main external and internal challenges that the MPM faced in a period from 2002 to 2019 are socio-economic and geological conditions that resulted in a hostile business environment. Inclusive in this period was the 2008 credit crunch.

The socio-economic environment in the Tubatse-Fetakgomo municipality is challenging due to high poverty, high unemployment rate and poor water and sanitation infrastructure. The were 400 community disruptions in 2016 including the labour strike that lasted for 24 days at MPM which resulted in a loss of 150 000 tonnes in production and R120 million in financial losses.

The geological conditions appeared to be more complex on the southern side of the mine. Generally, mining projects are confronted with two main risks namely, 1) lack of sufficient data, and 2) unknown future events. Additional drilling and geophysical surveys needed to be conducted to get a better understanding of the geological conditions on the southern block of the mine.

The information from the production stats indicates that the rate of strike development was in most cases not aligned with the depletion ratio. At times extraction from the stopes increased but strike development was not increased at the same rate, meaning more reserves were depleted and less replenished. If such an environment is allowed to continue for a long time, production will eventually reduce due to limited exposed reserves.

The concentrator plant could not be utilised to its design capacity due to mainly lower production from underground. This could be an indication that the underground mining footprint was not designed or developed optimally to produce enough ground to keep the concentrator fully utilised. This could also mean that other ore sources could be mined like Merensky open pit to fill the concentrator plant to capacity.

It can be noted that unit cost increases were in double-digits and above the CPI for most of the period between 2002 and 2019. This could be a combination of many factors including low production output but high fixed-cost component and low expenditure in SIB.

The project capital expenditure as indicated by the trend line was in downward trend over the period of 2002 and 2019. This condition could lead into a production reduction as reserves get depleted and are not being replaced. This situation could also contribute to high unit costs as mining flexibility reduces, mining efficiencies are reduced followed by unit cost increases.

The MPM actually never recovered from the two aggressive cost-cutting periods that is 2008 to 2009 and 2013 to 2015, through targeting development cost leading to a persistent shortage of mineable ore reserves evident until the present time.

5 RESULTS FROM QUESTIONNAIRES AND INTERVIEWS

5.1 Introduction

This chapter discusses the outcome from interviews and questionnaires from both internal and external project personnel and the responses were found to be equally split between the two categories of respondents. The internal project personnel are those who were directly involved with the MPM project whilst those categorised as external were involved in underground mining projects but in other parts of South Africa. The sample is made up of 30 respondents, twenty of whom are external and ten internal.

The chapter not only presents key findings but also compares data, highlighting experiences that were both common and different across the two groups. This dual approach served to expand insight into what are regarded as critical success factors of mining capital projects but also enriched the diversity of lessons learnt for both successful and unsuccessful underground mining capital projects.

A third aspect of the discussion examines the experiences at MPM, employing the broad-based insights to evaluate the specifics of the case. Data interpreted from production and financial reports from MPM are used to provide granular perceptions of the challenges encountered with this mining project.

Various aspects pertinent to mining projects are at the forefront, with particular attention paid to understanding the influence of local socio-economic conditions on mining project prospects. Lived experience accounts from the interviewee responses provided rich descriptions of the nature of challenges encountered underscoring the overarching impact on mining capital project success. For ease of reference, the internal project external personnel are referred to as group I and the external as group E in the analysis.

5.2 Summary of results

The total sample of questionnaire responses received was 30 out of total of 40. The in-depth interviews were conducted with eight respondents whose designations included Labour Union Representatives, Human Resources Managers, Community Development, Project Engineers, Project Readiness Managers, Project Managers and Project Executives. The clarification interviews were structured questions and were held over a video conferencing platform due to Covid-19 lockdown restrictions on physical person-to-person interaction. The interviews were recorded and transcribed to enable data analysis and interpretation.

5.2.1 Questionnaire results

The questionnaires' data results were broken down to a sample of 30 respondents made up of 21 Group E individuals (External Project Personnel) and 9 from Group I (Internal Project Personnel). Respondents involved in project management but who were not involved in the MPM underground project were named Group E. Respondents involved in underground project management and who were involved in the MPM underground project were named Group I. The sample of respondents had the following characteristics:

- Group I underground mining project experience ranges from four to forty years compared to Group E which had a range of five to twenty-five years in underground mining project experience.

- The combined years of experience in underground mining projects for both group I and E respondents was 523 years made up of 135 years and 388 years from I and E respectively.

- The average years of experience in underground mining projects was 18 and 19 years for groups I and E respectively.

- The 30 respondents had different roles in the project made up of Social and Community Development Manager (2); Labour Union Representative (1); Human Resources Manager (1); Project Geologist (2); Project Accountant (2); Project Readiness Manager (2); Project Engineers (6); Project Managers (8); Project Executives (4); and Project Construction Managers (2). Of the total 30 participants who completed the questionnaire, 28 had university qualifications, one had a college diploma and one had matric.

Group E was involved in 137 underground mining projects, 98 of which met investor objectives and 39 which did not. Group I was involved in 54 underground mining projects, of which 21 met investor objectives and 33 did not. This translates into 72% and 39% underground mining project success rate for groups E and I respectively. Table 5.1 summarises the characteristics of both group I and E.

Table 5.1: Project management teams projects statistics.

	External Project Personnel (E)	Internal Project Personnel (I)	Total/Average
Sample Size	21	9	30
Total years of experience in projects	388	135	523
Mean (Average years of experience)	18	15	17
Number of Successful projects	98	21	119
Number of unsuccessful projects	39	33	72
Total number of underground projects	137	54	191
Success rate	**72%**	**39%**	**62%**

5.3 Critical success factors

The main questions that were asked in the questionnaire of both Groups I and E, were: (1) What were the main contributing factors that made the projects that were successful to be successful? and (2) What were the main contributing factors that made the projects that were not successful to be not successful? The response to question 1 were as follows:

5.3.1 Accurate understanding of the geological, geotechnical and geohydrological conditions of the orebody.

Group E highlighted geology, geotechnical and geo-hydrological factors as one of the most prominent factors that negatively affects most underground mining projects resulting in late delivery and budget overruns. Particular mention was made of the challenges stemming from poor understanding of the orebody and surrounding rock structures. This led to poor project scoping, defining the capital footprint leading to reduced mining footprint, slowdown in production ramp-up, increased underground support and pumping costs.

The MPM project suffered from unexpected complex geology on the south side at South 1 shaft. The initial surface drilling results indicated a gradual undulation of the UG2 reef below level 4. However, when the mining teams physically reached that level, highly disturbed ground conditions were intersected which reduced the rate of advance in strike development. This had a major impact on the project and additional investigation into the geology had to be done with cost escalation and delays in project execution. A seismic survey carried out revealed that there were 'swarm dykes' below level 5 and the area could not be further developed for mining.

Group I responses were similar to those of group E in terms of negative effect that limited understanding of both the geology and hydrogeological features of the orebody. One of the Group E respondents quoted an example from one project, where a high-level estimate was done on the type of secondary support required in strike development. Initial estimation of requirements, costing and scheduling were based on existing ground conditions. When life of mine extension required entry into a new geotechnical zone which was not anticipated, the project's schedule and cost had to be adjusted. The secondary support budgeted for, was for thin lining support (TLS) but the intersected conditions required heavy fibre-crete support (HFS) which was six times more expensive. The fibre-crete also required additional time to install. Personnel had to be trained in its installation and it also required more time to install since it was thicker than the original solution. This resulted in major overruns in both costs and time schedules for the project. A key learning is that adequate time should be spent in pre-feasibility, feasibility, and front-end loading to understand the: (1) geological, (2) geotechnical and (3) hydrogeological conditions in an orebody before a project is implemented. These three factors had a major negative impact on project cost and time estimations, hence impacted on triple constraints. Also, a proper risk management process needs to be undertaken to understand their impact on project deliverables.

A second example made by group E pertained to poor understanding of geohydrological conditions of the orebody and surrounding rock. Poorly understood geohydrological conditions in that particular project led to the intersection of higher volumes of water than expected. This led to increased pumping cost and time delays in the project as the pumping infrastructure was not designed to handle higher volumes of water. In addition, infrastructure redesign was required to adjust infrastructure to accommodate water handling both underground and on the surface.

5.3.2 Front-end loading

Good understanding of the project environment ensures realistic scoping, costing, quality, and scheduling estimates to be computed. Group E highlighted that projects should not be rushed for implementation before sufficient information has been gathered on the physical conditions and in addition more time and effort should be spent in better planning so that execution is seamless. The group further pointed out that the scheduling of project activities underground must take into consideration the sharing of resources like Trackless Mining Machinery or access to a development end with the operational team. This may result in major delays on the project side as priority is generally given to operational activities.

Group I pointed out the danger of global assumptions about technical conditions and efficiencies in a brownfield project as these often result in major deviations between project targets and actual outcomes achieved on the ground. An example was the intersection of poor ground conditions which needed higher support density resulting in increased support cost and time delays due to the additional time required for the additional support. Encountering these unplanned and unknown physical constraints on the ground was demotivating to the executing team on the ground.

Group I indicated that an 85% correct plan is better to have than no plan at all. They further indicated an agreed-to plan should not be changed unless proper change management and control is implemented, and all effects of the changes are evaluated and well understood.

5.3.3 Appointment of a competent and experienced project team

Group I mentioned that there were constant changes in the core project team members, and this had a negative effect on sustaining strong project momentum. New team members take time to get on board and acclimatise to a new environment, which negatively affected the efficiency of the project team. The turnover on the project team was higher than 5% which is higher than the norm of about 5% in the mining industry.

The local community had a limited number of experienced underground operators. Inexperienced front-line local labour had to be used due to demands from local communities. Due to regulatory requirements like the social labour plan (SLP) commitments, it is sometimes difficult to bring expert technical skills to both greenfield and brownfield projects. The SLP might require extensive use of local labour or training of local labour to meet project human resourcing requirements. Newly trained labour may take time to reach the required level of competency, and this results in poor quality workmanship, cost, and time overruns.

Group E emphasised the importance of appointing people with the best skills for the project to succeed. They further indicated that team members not adding value to the project and not aligned to the project team goals should be disciplined promptly. This group further pointed out that operators and other front-line workers should be given an opportunity to give input to the project as they have years of practical experience in performing different operational activities.

5.3.4 Change management

Group I pointed out that change management is critical especially in a brownfield project. There was little cooperation between the operational team and the project team since their objectives and goals were not aligned. The operational teams were not giving prompt attention to the project team on matters that affected the success of the project teams, such as commitment to make a certain piece of equipment or development end available to the project team. This non-alignment of goals and a lack of an Operational Readiness Plan resulted in delays on the project implementation plan.

Group I felt that the goals or objectives of both the operational and project teams were not aligned to ensure achievement of the main objectives of the organisation. Group I felt that proper change management was not done to align the goals of both the operational and the project teams.

Group I pointed out that implementing a project in brownfield environment was three times more difficult than in a green-field environment. Group E also mentioned that when implementing a project in a brownfield project, the project scheduling requires a scheduler who is experienced in underground logistics. They mentioned that proper change management on shared resources like mining equipment and ground handling facilities is critical. These sentiments were with respect to replacement projects, namely the deepening of the North 1 workings from Level 6 to Level 9 and the sinking of South 2 shaft.

5.3.5 Support of the project from top management

The active involvement and support of senior management in a project is crucial. The project environment is dynamic and sometimes major decisions need to be made in response to unexpected events. Delays in making those decisions could result in major delays and cost increases for the project. Group I stated that change of scope often took too long to be approved by senior management. Meanwhile, costs continued to accumulate whilst work was suspended and awaiting change of scope confirmations. For instance, contractor claims on time delay costs and the front-line teams were negatively affected as they stood idle awaiting decisions by senior management. Group I believed that if senior management could have been more actively involved in the project, high-level decisions would have been made promptly thereby reducing time delays in the project and minimising the cost of delays.

Group E highlighted that setting up an efficient project steering team where senior management is represented, is an effective way to draw in practical senior management support for projects. Project steering committee meetings must be held at regular intervals and be well attended by relevant personnel. This ensures strong positive momentum of progression for a project. Group E highlighted the importance of Senior Management taking an interest in the project from the start and not only when things go wrong. They mentioned that the project team got motivated when senior management in both EPCM and the client took active interest in the project. Group E further indicated that a proper project governance structure with Senior Management support is a precursor to project success. Senior Management needs to appoint a Project Sponsor, who will in turn appoint a competent Project Manager. It is the Project Manager’s role to appoint Project Teams who are competent in terms of skills and experience.

5.3.6 Pre and sustained engagement with all stakeholders - employees, communities, and regulators

Group I pointed out that community disruptions and labour strikes resulted in unplanned delays in the project. According to MarketWatch (2007), there was a labour strike lasting more than three weeks in 2007. The cited reason for the strike was the wage gap between black and white miners, transport subsidies and continuous working operations arrangements. In 2012 another protected wage dispute strike lasted three weeks (ARM News, 2012). Group I indicated that one of the factors that contributed to labour disruptions was lack of properly defined structures of engagement and communication. There were instances where personnel from JV partners would communicate and make promises to labour union representatives and the mine would not be privy to those discussions. Group I pointed out that in the early stages of the mine, the labour union representatives did not fully understand their mandate and powers at the mine. The union acted as if they were running the mine, whilst their legal role was to consult with management in their role of protecting workers` rights. Most of the mine employees were working on a mine for the first time in their lives and it took time for them to understand what the mine expected from them.

Group I also indicated that MPM was one of the first major underground mines in the area and as a result very few of the employees had mining experience. It is believed that the production ramp-up schedule was unrealistic for an inexperienced labour force with no prior mining experience. The failure by labour to deliver the required output led to strained employer-employee relationships and resulted in poor productivity at the mine.

Group I indicated that the main cause of the disruptions by the communities was the demands for employment of local people and local contractors even if they did not have the necessary skills required for the project execution. As indicated earlier, the surrounding communities did not have any prior mining work experience and as a result the required technical services could not be readily supplied by the surrounding communities. Most of the companies that supplied products and services were from outside the community and this resulted in resentment and conflicts between the community and the mine. The community felt that the mine made promises to develop and empower their communities, but in the communities' view the mine did not deliver on those promises.

Group I also indicated that traditional authorities' structures were also not well understood as to whom the mine should be engaging with and who had the legal mandate and authority to negotiate on behalf of the community. Lack of clarity in this arena led to numerous self- appointed structures and the majority were pursuing their self-interests and not the general welfare of the bigger community. It was also pointed out that there was communication and engagement between representatives of JV and communities where promises were made without the mines' involvement. This also strained the relationship between the mine and the communities when promises made were not fulfilled.

Group I pointed out that broad-based and well-orchestrated engagement with the diversity of multi-layered and often intertwined stakeholders is one of the most important activities when managing a mining project. A structured programme for managing key interfaces must be proactively defined and rigorously implemented before, during and even after a project. The engagement and alignment of all stakeholders prior to project implementation could have reduced some of the labour and community disruptions that were experienced. Group I pointed out that in South Africa one of the most important factors for successful execution of mining project work is the involvement of the local community. Aspects such as community upliftment in terms of job creation, local enterprise development, local supplier development, local infrastructure development and general community involvement are opportunities to build and maintain positive relations.

Group E highlighted that proactive consultation involving all formal and recognised structures was good practice to embrace. There are government and non-governmental organisations that can assist such as labour representatives; regulators such as the Department of Minerals and Energy (DMRE) and Community Participation Associations (CPA). Failure to actively and transparently involve all relevant stakeholders often results in constant disruptions of the project. Group E mentioned that they had witnessed numerous delays and disruptions on projects in many mining regions across South Africa due to community disruptions. They further mentioned that in one project there were major delays in the project since they had to first train local labour on project activities before the project could continue. Table 5.2 summarises the critical success factors as highlighted by the MPM project team.

Table 5.2: Critical success factors highlighted by the MPM project team.

1. Good understanding of the geological, the geotechnical and geohydrological conditions of the orebody
2. Front-end loading
3. Appointment of competent project team
4. Change management
5. Support of the project from top management
6. Pre-engagement with all stakeholders, especially, employees, communities and regulators

5.4 Other critical success factors

Group I mentioned the importance of having direct involvement of management throughout a project. It was highlighted that in many instances the project team will hand over a project, but the operational team will take longer than expected to bring the operation to steady state due to a poor handover process. There should be transition management personnel included in the project team to ensure a smooth transfer from project to operations, i.e. an operational readiness team. The advantage of practical operational team involvement is that their oversight will give guide on practical realities like the layout of the mine and ensure that the realistic targets are done.

It was highlighted that in some instances a project team may design a mine with certain output parameters, only to find that the expected throughput is not achievable. This may be due to a variety of reasons known to or even caused by disengaged operational teams. Issues such as constrained mining footprint, poor quality support in ore-passes resulting in sidewall scaling were proffered as lived experience examples. Such factors are detrimental to projects. Group I respondents emphasised the implications, lamenting that an underground mining project undertaken at an existing and active operation is “three” times harder.

Group E raised the issue of transparency in sharing information with relevant stakeholders. Project information must be shared with the investors and senior management from prefeasibility right to closure. Being transparent about good and bad events and outcomes as they occur, makes it easier for all stakeholders to make the right decisions and to make them promptly, based on correct information. It was emphasised that project team members should not be kept in the dark about the challenges that the project might be experiencing.

Additional viewpoints from Group E were related to processes like following guidelines from PMI, PMBOK and other project management processes that the investor or the service provider has in-house. They indicated that operational teams should also be trained in PMBOK even for just the fundamentals of project management.

Further to the critical success factors supported by both respondent groups, some distinctive cautionary observations were captured. These are factors that were identified as obstacles to project success.

5.4.1 Establishment of project teams

It was highlighted that in-depth project management skills are invaluable ingredients for a successful project team. Practical operating experience adds great value to projects ensuring that the final product meets the required specifications in terms of quality and usability. Examples were made where implemented mining projects are not delivering the required volumes. Ore passes that have been scaled prematurely; mining footprints that cannot produce the designed volumes due to constraints and poor logistics. It is critical that project team members should have practical work experience in the work required.

Related to this, there is tangible and intangible value in competent leadership capable of coordinating and creating a conducive working environment. Leadership should be conscious of managing the morale of the project team to ensure continuity and stability in the team. At the same time the project leader supports the team by networking effectively with all stakeholders.

5.4.2 Knowledge management

The feedback pointed to a wealth of accumulated knowledge that must contribute to ensuring successful underground mining projects. However, the weakness in the whole system is that this knowledge is not properly captured and shared with relevant stakeholders. Typically, when a new project is started, the feasibility work is often rushed with no time allocated to review previous similar projects as part of the project planning.

The result is that similar mistakes are made across different mine projects. Wide consultation with a diverse community of subject matter experts should be carried out before the project is initiated. Frequent ongoing consultation and collaborative interaction with specialist focus may also ensure mapping and compliance with a trajectory for greater success in outcomes.

5.4.3 Relationship management

The issue with relationships was the need for more focus on building positive working relationships that could endure even during turbulent times in the project life. It was pointed out that project leadership should be actively involved in aligning and managing investor expectations on the project’s progress and outcomes. It was further pointed out that community expectations should be proactively and cohesively managed in a way that is specific to the project dynamics. This entails giving the project leadership a measure of freedom or latitude to manage community expectations without having to revert to the project owner in case of minor challenges developing during the implementation of the project.

5.4.4 Effective project management

Just as the soft issues need to be proactively and continuously managed, so too do the processes and disciplines for project management itself. In some instances, this could mean breaking the activities into hourly tasks ensuring closer monitoring at the lowest level. The project team should have the right level of authority to make decisions and changes in areas within the scope of a project. Such level of freedom could enhance productivity and achievement of the project's goals.

Overlapping activities should be given proactive consideration and should be well planned and coordinated over time. The procurement and delivery of long lead-time items, critical and high value items should be well planned to avoid major delays in a project.

Table 5-3 summarises the additional factors highlighted by the discussion in this section. Although not critical success factors, these factors could be a barrier to a mining capital projects success if not executed well.

Table 5.3: Obstacles to success highlighted by MPM project team.

1. Establishment and management of teams
2. Knowledge management
3. Relationship management
4. Effective project management

5.5 Conclusion

It can be concluded from findings that underground mining projects are complex technically, organisationally and in other ways. Geological and geohydrological conditions were listed as some of the common high risks in most underground mining projects. The other risks which are organisational included project leadership, project team competence, support from management and front-end loading. Socio-economic factors also had a negative impact on the MPM due to high unemployment and poverty rates in the area. It is also noteworthy that the challenges experienced at MPM were not unique to the mine or to South Africa. Risk management is essential from initiation to closure. Project Risk Management is a key to project success.

6 DISCUSSIONS

6.1 Introduction

This chapter discusses the main inhibiting factors that contributed to the non-achievement of the outcomes of a bankable feasibility study of MPM project. Furthermore it documents the lesson learnt from the review of the MPM project as they emanate the literature review, review of the feasibility study and questionnaire and interviews.

6.2 Macro factors that affected the MPM project in relation to the feasibility study expected outcomes

In modern day society, more and more communities are demanding that they should directly benefit from projects exploiting heritage-linked natural resources. Sometimes the demands may be so unreasonable that the investors may decide to halt or abandon the project. In some cases, the socio-economic environment could be rendered unstable to such an extent that viable mining activities cannot be conducted.

Mining commodity prices are cyclical in their nature. When a low-price commodity cycle intersects with increasing input costs, that usually results in temporary halting of certain operational activities, deferment of capital expenditure and/or severe reduction in operating costs. Low metal prices impacted the MPM project. As was seen in the production and financial analysis in Section 4.3, capital deferment lead to delay in infrastructure development and reduction in business capital expenditure. The medium- to long-term impact was reduction in production due to lack of flexibility and an increase in maintenance costs as old equipment was used beyond their economic life. The cost cutting measures taken to mitigate the compounded influence of reduced commodity prices and increased input costs wielded medium- and long-term negative effects on the viability of the MPM project.

6.3 Micro factors that affected the MPM project in relation to the feasibility study expected outcomes.

Internal factors are equally influential on mining project outcomes. Aspects such as company culture, business processes and systems set the climate within which projects occur. Some mining houses have both the capacity and capability to conduct big mining projects in-house. Some mining companies choose to use external contractors to execute projects. Common forms of contracting are through EPCM or EPC arrangements. There could also be a mixture of both forms. Whatever form of contracting is employed, mining projects do fail to meet investor requirements due to many businesses' internal processes and systems. It is evident from the information obtained from the questionnaires, interviews, financial and production analysis that were many micro factors that affected the MPM project as discussed below.

Firstly, inadequate understanding of geological conditions of the orebody mainly contributed to a bigger portion of the MPM project reserves not being developed due to complex geological features which were not anticipated during the feasibility study. This has lead to underperformance in relation to the expected feasibility plan outcomes.

Secondly, inadequate front-end loading of underground activities resulted in project delays as sharing of resources and facilities between the project team and the operations resulted in less than planned resources being allocated to the project. Practical constraints prevalent in a brownfield project were not taken into consideration in scheduling project activities underground. Project scheduling for an underground project required practical mining experience and project scheduling experience. This was a deficiency in the project as highlighted by Group I.

Thirdly, failure to institute adequate change management processes in aligning the goals of the project team and the operational team lead to project delays. Both teams were focused on delivering their individual targets and consequently ended competing for resources between themselves.

In the absence of proper change management, the teams sharing common goals could end working against each other with the result that the project gets delayed. Group I indicated that operational team delayed in handing over development ends to the project team and the agreed schedules for sharing common facilities and trackless mining machines were not adhered. Both production targets and incentives of both teams needed to be aligned to focus both teams on achieving short- and long-term goals. Group I indicated that the operational team was more focused on achieving its operational objectives and gave very little support to the project team.

Fourthly, the project team received inadequate support from senior management. Both Group E and Group I indicated the importance of the interest and support of senior management in a project. Group I further indicated that there were delays in the project because decisions by senior management were not made promptly. In any project there are unplanned for or not anticipated events which require prompt decisions to keep the project on track. Delays in making major decisions resulted in the project team being idle and some valuable skills were lost as they sought alternative opportunities outside the project due to frustration on the lack of progress.

Fifthly, there was lack of adequate consultation with all relevant stakeholders. Effective stakeholder engagement is essential to avoid unnecessary disruption of projects. There has been a growing trend in communities especially in the developing world to want to be actively involved in projects implemented in their communities. Failure to engage and align communities before and during project execution has resulted in many mining projects being delayed or abandoned and this was the MPM project. Group I mentioned that there were several project delays due to community disruptions. The community was demanding employment of local labour in most positions and also demanding that local business owners should be given opportunities in the mine development projects. A point in case is that there were over 400 community related disruption in 2006 reported.

Mining projects are capital intensive, complex and long term in nature. Poor understanding and inadequate management of project risks posed by both macro and micro factors are likely to lead to project failure. In post project reviews it important to document lessons learnt to improve on future projects management while taking cognisance of both macro and micro project environments.

6.4 Lessons learnt

The following lessons emerge from the MPM project:

a. When conducting an underground feasibility study, it is imperative that geological, geotechnical, and hydrogeological conditions are well investigated and understood to the highest possible confidence level. These factors were the most commonly cited challenges that have led to many unsuccessful underground mining projects.

b. A good understanding and design of the capability of the mining method, underground and surface infrastructure capability is critical. If front-end loading is executed with due discipline, aspects such as mining method capacity, underground infrastructure capacity and surface infrastructure can be well understood. As a result, it becomes easier to design systems and processes capable of delivering to optimal capacity in a sustainable way.

c. Engaging openly and effectively with all stakeholders before and during project execution is crucial. This is more important in developing countries like South Africa where unemployment and poverty rates are high. These conditions contribute to social instability leading to high and unrealistic philanthropic expectations on rent-seeking activity. Unstable socio-economic environments could lead to disruption of mining projects by communities as they demand more employment and business opportunities.

d. It is also important to build strong management-labour relations to avoid illegal strikes and other labour relations disruption. Compliance with local laws in terms of community and labour relations should not be done grudgingly but instead looked at as an opportunity to create a stable and sustainable community and labour environment.

e. Brownfield projects are inherently complex by nature as they require different teams with different specialities to cooperate. Usually, the operational team is focused and measured on tonnage throughput and the project team is focused and measured on compliance to a project plan. If the goals of the different teams are not aligned, this could lead to unhealthy competition for resources, resulting in the failure of the project. When a brownfield project is conducted a change management process should be conducted where goals and targets are aligned to ensure that both the operational and the project team achieve the business goals.

f. This is critical especially when unexpected events like low metal prices affect the business. Top management support is required in taking a strategic or long-term view to see the project through turbulent times. Experience has shown that more long-term damage is done to a project by opting for short-term gains. Capital deferral should not be done to an extent that results in long-term damage to the business. Mining is a long-term business, as a result consistent investment in SIB capital throughout the mining cycles is important. Due to lack of SIB capital development at Modikwa, new mining levels were not sunk in time to maintain production levels.

6.5 Conclusion

It can be concluded that with any underground mining project there are multiple factors that can affect the success or failure of such a project. Macro factors can be mitigated to a certain extent, but the micro factors are generally within the control of the companies involved in the project. With this said, the next chapter provides an overall summary of this project report and answers to research questions.

7 CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

This chapter draws conclusions from the analysed MPM case study, literature insights as well as the responses captured through questionnaires and interviews. The lessons learnt and recommendations will also be covered in this chapter.

7.2 Report conclusion

The extensive surface drilling done during the feasibility study to understand the orebody was used in designing the mine with a throughput of 200 ktpm. Although extensive surface exploration drilling and aeromagnetic surveys were conducted, the information was not enough to identify and understand the geological complexity on the southern part of the mine.

Originally the mine was designed for a throughput of 200 ktpm and later increased to 240 ktpm as it was believed the mine could be optimised to reach those levels. The optimisation opportunities and processes were not clearly outlined in the study nor how they were going to be achieved.

The additional geological information was acquired through seismic and aeromagnetic survey. The interpretation of this technical data indicated that the area below level 4 could not be economically mined due to a dyke swarm and other complex geological structures. As a result, the mine could not sustainably produce at 240 ktpm although the infrastructure and other resources were geared for 240 ktpm.

Metal prices are cyclical and low metal prices throttle mining company activity. The economic meltdown in 2008 crashed metal prices significantly. This resulted in reduction in capital expenditure or deferment of capital projects at MPM.

The socio-economic environment in the Tubatse-Fetakgomo area where MPM is located is unstable due to poor infrastructure development and high unemployment rate. The unstable socio-economic environment led to community expectations being unfulfilled and this damaged the relationship between the mines and the surrounding communities. At one stage, MPM could not conduct the seismic survey in the north shaft area because the community refused to give access to that area of the mine. The unstable labour and community environment led to constant disruptions of the mining operations which affected productivity throughput negatively and by extension curtailed financial performance.

Capital deferral or capital reduction are effective mitigation measures implemented when a mine is not achieving its designed throughput. Investment is also delayed when global markets experience lower metal prices; when operating costs escalate exponentially; in the advent of unhealthy labour relations and where constant community disruptions occur. This is standard risk management strategy used by many mining companies to hedge the prospects of runaway losses.

However, these defensive levers are not without their consequences. Capital deferment can lead to increased working cost as infrastructure and major equipment is not replaced at optimal replacement intervals. Capital preservation could hamper reserve development necessary to create future resource pipeline and mining flexibility. The constrained immediately available stopes (IMS) with resultant lack of mining flexibility is often a symptom of delayed infrastructure and reserve development.

The high cost per tonne that has prevailed since 2002 could be evidence of a mixture of suboptimal micro factors at play. These include high maintenance costs, inefficient mining operations, high labour costs and many years of capital starvation.

It is clear from gathered information and discussions above that MPM is a complex operation both technically and in terms of relationships. This project was not only affected by inefficient internal processes but was also negatively impacted by external factors. The analysis of the information about the MPM project points to one macro factor and five micro factors that had adverse affected project success. They are:

- Commodity price volatility (macro factor);
- Understanding of geological conditions (micro factor);
- Front-end loading of underground activities (micro factor);
- Change management processes (micro factor);
- Senior management support (micro factor); and
- Relevant stakeholder consultations (micro factor).

The above identified inhibiting macro and micro factors can be stated as having answered the first research objectives as stated in Chapter 1.

The lessons learnt from MPM project is that adequate understanding of the project complexity and the application of project management principles from project conception to post closure review is critical to the success of underground mining projects. In addition to the above macro and micro inhibiting factors the analysis of the project data reveals the following lessons:

- Conduct adequate geological, geotechnical, and hydrogeological studies;
- A good understanding of a mining and related geotechnical knowledge and required infrastructure are important;
- Adequate engage surrounding communities and win their trust;
- Create mutually beneficial employer-employee relations;
- Alignment of goals and targets of all teams involved in a brownfield project is important; and
- Planned SIB targets must be maintained despite changes in the macro environment.

The above can be stated as lessons emanating from the study as well as adequately responding to the second research question as posed in Chapter 1.

7.3 Recommendations

The following actions are recommended to ensure that MPM achieves the designed capacity in the long term.

- Firstly, conduct a technical and economic review on what the current mine infrastructure (mining layout and equipment) can achieve sustainably in the short to medium term;

- Secondly, assess what will be required (technically and financially) to move the operations from short-term sustainable throughput to original design capacity of 240 ktpm or higher;

- Thirdly, review and understand the activities and services that need to continue or cease to match the current mining infrastructure capacity and capability;

- Fourthly, conduct a risk assessment (technical, financial, social) on the impact of continuing with or ceasing identified activities and generate risk mitigation measures for the identified risks; and

- Lastly, apply the identified critical success factors and follow best practice in project management in putting together a plan to address the above-mentioned recommendations.

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APPENDIX A

Title of Research Proposal:

Critical Success of Mining projects post completion phase: (Underground Mining Projects)

Interview questions:

Interviewee:

Position:

Year of experience in mining project:

Role on the Underground Mining Projects:

Other Greenfield or brownfield Mining Projects involved in:

1. In how many underground mine development projects have you been involved?

2. What was your role in these projects?

3. How many of the projects that you were involved in met most or all the investor objectives in terms of project delivery on time, in quality and within cost?

4. How many of the projects that you were involved in did not meet most or all the investor objectives in terms of project delivery on time, in quality and within cost?

5. What were the main contributing factors that made the projects that were successful, to be successful?

6. What were the main contributing factors that made the projects that were not successful not to be successful?

7. With the information you have now what could have been done differently on those projects that were not successful.

8. With the body of knowledge now available in Project Management discipline and lessons learnt from other failed mining projects, how could the Mining industry capitalize on this knowledge?

9. What other general factors do you believe that all stakeholders involved in the development of a Mining Project should be aware of?

10. Any observation that you would like to make about mining projects in general.

11. What are the critical few things that could ensure the success of a mining project?

12. Any other observations insights that you like to share on successful or unsuccessful mining projects?