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Challenges and Opportunities for Innovation in the South African Mining Industry

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A research article submitted to the Faculty of Commerce, Law and Management, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Business Administration

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DECLARATION

I, Tshepo Ntlhoiseng, declare that this research article is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration in the Graduate School of Business Administration, University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.



Tshepo Mmeko Phistos Ntlhoiseng

Signed at Mulbarton

On the …05th…….. day of …August…… 2023…..

DEDICATION

This article is devoted to the people who have made a difference in my life. A very special thank you goes out to both of my parents, Josephine and Steven Ntlhoiseng, for their unwavering support and belief in me, which has inspired me to perform even better. My wife, Nthabiseng Ntlhoiseng, for accompanying me on this journey and for showing incredible patience throughout it.

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ABSTRACT

Rising costs, diminishing ore grades, labour conflicts, and low-profit margins are all problems facing South Africa's mining industry. Along with external factors, such as global pressures, domestic factors have hindered the mining industry's economic recovery, leading to the loss of jobs, the closure of mines and the departure of certain international mining corporations. Throughout the country's history, the mining industry in South Africa has been recognised as a critical driver of economic development and job creation. The need to innovate for increased productivity is especially pressing in this sector, as it continues to be a significant source of employment in South Africa.

The study set out to look into the challenges and opportunities for innovation in the South African mining sector. Exploratory, qualitative research was chosen to learn about the mining industry and its innovation potential. This study aimed to examine the gold and platinum mining industry specifically. Eleven interviews with top mining industry executives were undertaken. Thematic analysis was used to delve deeper into the industry's challenges and opportunities for innovation. The study revealed that organisational issues such as change management, stakeholder engagement, and the availability of finances, among others, hinder innovation. External elements, such as mining regulations, inhibit or enable innovations in the mining sector.

Moreover, there are four areas where operational efficiency can be enhanced. According to the findings of this research, energy, transportation, big data, communication, and explosives have been highlighted as areas where innovation opportunities exist. Change management and stakeholder involvement were also identified as crucial areas requiring new solutions for effective operations to foster innovation.

Keywords: Innovation; Challenges; Opportunities; Technology

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1- INTRODUCTION

1.1 Purpose of Study

This research aimed to study the current state of innovation and technology in the South African mining industry and to highlight the challenges and opportunities for innovation in this sector. The research will also provide guidance to the mining companies, executives and technopreneurs working in this sector to assist them in stimulating new approaches to technology and innovation within the industry.

1.2 Research Background

The mining industry in South Africa has long been regarded as a traditional and conservative industry in terms of innovation. It has reached a tipping point due to rising challenges like deteriorating ore grades(Calzada Olvera, 2022). Because of this, the sector finds itself in a difficult situation. Although technology is regarded as an answer to this sector, the overall mining sector culture has been seen as conservative and highly resistant to change (Bartos, 2007).

According to Ntsoelengoe (2019),production-related costs, increased government demands, labour unrest, and global pressures have rendered the sustainability of the South African mining industry under enormous threat. These challenges force the mining industry to look for ways to increase profitability and improve safety and efficiencies to be sustainable. However, since the contribution of the South African mining sector is still significant to the country's economy, the need to improve is essential.

According to Szirmai (2012), a continuously evolving economy leads to economic development, but this mostly happens as a result of direct order caused by the engagement of nations in the race against each other for technology with other countries in technological innovation, living standards, and industrialisation. Therefore, based on the statement from Szirmai (2012), a focus on technology and innovation may be the answer to the declining mining sector in South Africa.

According toGruenhagen & Parker (2020), this solution can be achieved by successfully applying innovative technologies and the utilisation of the following technologies:

- artificial intelligence,
- machine learning,
- industrial internet of things,
- virtual reality,
- drones, and
- autonomous driving

The mining industry's challenges have created a strong need for the use of technology and the need to innovate. The digital innovations being developed are already being implemented globally in several mining operations (Calzada Olvera, 2022). These developments are 3D printing, automated drones, and the Internet of Things. Calzada Olvera (2022) mentioned that implementing these technologies will not only solve the current issues but also assist in transforming mining to be efficient and profitable and enable them to find ways to comply with stricter regulations.

1.2.1 The state of mining in South Africa

Mining in South Africa has proven to be experiencing a decline in economic impact. However, the council of minerals in South Africa stated that the transformation of mining in South Africa could protect most jobs. According to the report, two million household dependents will be impacted by 2030. This has caused an urgent push from this council for the mines to prioritise automating their operations. It is said that "lower commodity prices, fluctuating export demand, escalating operational costs, policy uncertainty, labour unrest, ageing mines, and infrastructure challenges" (Lane et al., 2015) are the biggest challenges responsible for the declining South African economic growth and the competitiveness of its mining industry. Calzada Olvera (2022) mentioned that, apart from technological learning processes, it was due to knowledgeable

suppliers that natural resource industries have become vital in innovation and become knowledge-based sectors.

Over several years, over R500 million has been claimed to have been spent annually on innovation and technology. This was reported by the Mineral Council of South Africa in 2016. The council further said that despite this amount of money invested in the transformation of the mines in South Africa, the industry still sees a decline in margins. However, Dutse (2013) mentioned that the combination of technology and innovation leading to technopreneurship is the known driver of enterprise growth globally. The above statement from the Minerals Council of South Africa, 2019, means that some opportunities still need to be explored. Also, there are challenges to innovation and technology in the mining sector. It is, therefore, clear that investment in technology and innovation is one of many solutions to the declining South Africa's mining industry. However, Pakrad & ., (2012) mentioned that high-technology entrepreneurship is highly suitable for assisting small to medium enterprises to create value and gain a competitive advantage. Hence there is a need to explore further the challenges and opportunities of technology and innovation in South Africa's mining industry as guidance.

1.3 Problem Statement

The mining sector has been an anchor of the South African economy. However, this is no longer the case. A decline in employment and productivity is apparent in the mining sector in South Africa. The mining industry has been considered reluctant to innovate mainly due to its priority to cost reduction initiatives; however, due to its current challenges, it finds itself with little choice but to make innovation a high priority to curb the challenges at hand. Most research has been centred on the need for innovation and technology in this sector. However, there needs to be more research on the challenges and opportunities for innovation in the mining sector.

The results of innovation and technology in some areas of the world in this sector have shown some positive results. The problem identified in this research is that

the mines in South Africa are experiencing a decline in margins. Some mining companies have closed down due to this. According to the Mineral Council of South Africa (2019), this decline is due to weak global conditions and skyrocketing production costs. Some of these challenges are caused by the country's local pressure(Mineral Council Of South Africa, 2019). In 1980, the South African mining sector was reported among the top two of the country's most significant economic contributors (*Mining: A Brief History | Statistics South Africa*, n.d.).

The country's decline is despite a large amount of money invested by the Mineral Council of South Africa as a push to modernise the South African mining sector. This research aimed to study the current state of innovation and technology in the South African mining industry and to highlight the challenges and opportunities for innovation in this sector. The mining sector in South Africa faces more local challenges than its global counterparts, making the country's situation more unique and complex. This was reported by Lane et al. (2015). These authors also mentioned that the country's mining sector has a history of labour unrest, an unclear regulatory environment, ever-growing government demands, poor profitability, and unreliable power sources. There are challenges and opportunities for innovation in the South African mining industry that are unique to this country, hence the importance of this study.

1.4 Research Objectives

The objectives of this research study are:

- To determine the challenges and opportunities for innovation and technology within the mines in South Africa resulting from internal and external factors to the organisation and the South African mining regulations and legislation
- To determine the level of commitment to innovation in the South African mining industry offered by the environment of operations

- To determine the current state of innovation and technology, the adoption and rejection thereof in the South African mining industry

1.5 Research Questions

This research explores and investigates the challenges and opportunities for innovation in the South African mining sector. From this research, the framework of the TOE will be explored, with emphasis on its environmental aspect of it. This framework focuses more on environmental, organisational, and technological factors as these are significant factors and are essential in this framework. The goal of this study is to explore the environmental aspect of the TOE framework and the (Iacovou et al., 1995) theories on pressures that are external and internal to the organisation to provide sound knowledge to this industry as to how the environmental aspect of the South African mining industry and external pressures to the mining companies promotes opportunities for innovation, as well as how it raises challenges. The main research question that this study aims to answer is as follows:

• What are the opportunities and challenges for innovation raised by the environmental aspect of the South African mining industry, which are internal or external to the organisation?

Sub-questions from the primary research questions have been formulated to further explore these challenges and opportunities. These questions were derived from the following reviewed literature:

• Technology- Organization-Environment (TOE) framework.

• Factors influencing organisations' adoption of information technology developments (Iacovou et al., 1995)

The following sub-questions were formulated:

• How does the South African environmental context affect and influence the adoption and implementation of innovative solutions in the mining sector-

- What are opportunities for innovation raised by internal factors and the South African mining environment?

- What are the challenges for innovation raised by internal factors and the South African regulations and legislations?

- What is the state and level of commitment given to innovations in the mining sector?

1.6 Significance of study

South Africa's mining sector faces distinct and complicated issues that set it apart from its global competitors (Lane, Guzek, & Van Antwerpen, 2015). According to Morris M.H & Kuratko D.F (2002), a sustained competitive environment can only be realized by continual innovation and the generation of new ideas. Most South African mining corporations have begun incorporating Fourth Industrial Revolution technologies; nonetheless, many of their initiatives have failed. As a result, it is critical for the South African mining industry to discover new solutions to these difficulties(Zulu et al., 2021). According to the Minerals Council South Africa (2016), modernization of the South African mining industry is estimated to save 200 000 jobs, affecting two million household dependents by 2030.

This research aims to identify the challenges and opportunities for innovation in the South African mining industry. The study will additionally give direction to mining companies, executives, and technopreneurs working in this sector to help them stimulate new approaches to technology and innovation within the industry, as innovation and technology have become critical subjects in the mining industry, which requires stakeholders, particularly decision-makers, to be committed and confident in driving the industry's urgent transformation to address current challenges. In addition, the research sheds light on the legislative role to technology and innovation.

1.7 The focus of the study

The scope of this research is only based on the mining sector in South Africa because of the current challenges faced by this sector. Additionally, the study is limited to a particular mining population. There is a strong need for the drive for technology and innovation to offer a solution to the decline in margins in this sector which are believed to be due to the high input cost, decrease in ore grades, and mining and processing inefficiencies(Pakrad & ., 2012). The focus was on mining companies focusing on Platinum and Gold commodities.

1.8 Assumptions

The following assumptions were made:

• The participants were truthful in their survey responses; and

• The participants were knowledgeable about the industry and understood the questions posed.

1.9 Conclusion

An overview of the scope of the problem to be addressed in this study was provided in this chapter. The current issues experienced in the South African mining industry were discussed. The study intends to study the challenges and opportunities for innovation and technology in this industry, as it is believed that adopting technology and innovation might be the answer for this sector. The motivation for this study was also discussed in the sections above.

2: LITERATURE REVIEW

2.1. Introduction

In this chapter, both the theory behind innovation and technology, as well as its significance within the framework of the sector of mining, are examined and discussed. This chapter also examines the theories presented by relevant sources and discusses the opportunities and challenges for technological innovation and advancement in the mining industry. Finally, this chapter will also discuss the theory behind implementing new technologies.

2.2. Innovation

Given that the idea of innovation serves as the primary focus of this research study, it is of the utmost significance that it be addressed and comprehended. The use of novel concepts, technologies, products, or processes is what the Cambridge dictionary defines as innovation. An example of innovation is a new idea, product, process, or technique that creates value and solves existing problems. Innovation can also be regarded as coming up with a new idea.

2.2.1 Types of Innovations

According to Kahn (2018), although "innovation" is already familiar, many modern businesses still struggle to grasp its meaning. Because of this misunderstanding, what innovation entails has resulted in poor decision-making by organisations and individuals. It is also a potential reason why many businesses perceive innovation as unattainable (Kuratko et al., 2014). One must first understand that innovation is not only a result but also a process and attitude to successfully implement innovation and reap its benefits.

Kahn (2018) further mentioned that innovation could be an outcome, process, or mindset. The following is Kahn (2018)’s description of these three innovations:

- Innovation as an outcome emphasises the desired output, including product, process, marketing, business model, supply chain, and organisational innovation. This covers both an overall innovation process as well as a process for the development of new products.
- When discussing innovation as a process, we refer to how innovation should be organised for outcomes to be realised.
- The concept of innovation as a mindset refers to the internalisation of innovation by individual company members, which is the process by which innovation is instilled and imprinted, in addition to forming a supportive organisational culture that enables innovation to flourish.

If one has such an understanding, one may describe the required components, factors, and language surrounding the phrase. This enables one to make better judgements, enabling innovation and increasing one's likelihood of success.

2.2.2 Reasons organisations fail at innovations

The successful adoption of corporate innovation continues to be reasonably complex for most businesses. However, corporate innovation is frequently recommended as a feasible method for maintaining outstanding performance in today's firms (Kuratko et al., 2014). According to Kuratko et al. (2014), the staggering speed at which new technologies are being conceived, implemented, and improved could be one of the factors contributing to this ongoing struggle. Because innovation is dictating how business is done on every level, the 21st century will see a rise in the importance of entrepreneurship (Kuratko, 2009).

According to Kuratko et al. (2014), there are numerous reasons for dissatisfaction with corporate innovation programmes. However, a recent study on business entrepreneurship/innovation illustrates at least four essential implementation issues that most corporations must recognise or address effectively. The four difficulties identified by Kuratko et al. (2014) are as follows:

(1) Understanding what type of innovation is being sought- Senior management's misunderstanding of the company's innovation needs is a significant obstacle to establishing a corporate innovation programme. Senior managers sometimes believe everyone understands corporate innovation without fully understanding it.

(2) coordinating managerial roles- Once the type of innovation is chosen, a second obstacle to corporate innovation implementation is a lack of managerial coordination across all levels of the organisation, which is needed for an innovation strategy to operate and become a sustaining part of the company (Kuratko et al., 2005)

(3) effectively using operating controls- Operating controls not working with corporate innovation performance drivers is a third obstacle to corporate innovation plan execution.

(4) properly training and preparing individuals- Corporate innovation strategies must be taught to employees for success. Knowing what corporate innovation requires of people allows decision analysis.

Kuratko et al. (2014) further mentioned that proper recognition and response to these four difficulties might distinguish firms capable of implementing a successful corporate innovation strategy from those unable to.

2.2.3 Innovation in Mining

The significance of innovation in the mining industry in addressing the issues faced by the industry should not be overstated (Sánchez & Hartlieb, n.d.). It is generally accepted that technological breakthroughs directly contribute to long-term economic advantage. They are especially crucial in the mining industry, which faces diminishing resource access and urgently needs innovative solutions to remain sustainable and competitive (Ediriweera & Wiewiora, 2021). Because of its difficulties, the mining industry has made pursuing innovation one of its top priorities.

Because mines need more authority to set their prices, there is little potential for product differentiation and innovation in the mining environment. As a result, the primary area of attention in this business is the development of new processing methods (Calzada Olvera, 2022). The consequences of this led to developments in the mining industry, the primary goals of which were to reduce costs and ensure compliance with laws. It is evident that most firms, mining being no exception, have a decent chance of being lucrative and remaining sustainable if they instil a culture that supports innovation. This holds regardless of the industry. Even though the mining industry has a reputation for being resistant to change, it is clear that the sector needs to do more to foster innovation and technology to meet the problems it is currently facing.

To ensure the mines continue to be profitable and viable, it is essential to note that new technology initiatives have concentrated on increasing productivity, lowering costs, reducing waste, and preserving an environmentally pleasant working environment. According to Ediriweera & Wiewiora (2021), the theory of the spread of innovation highlights and explains that the stages of acceptance and implementation of innovation are as follows respectively:

- understanding and recognising the opportunity for innovation
- persuasion (favourable or unfavourable attitude towards the innovation),
- the decision to accept or discard the innovation,
- implementation (being able to use innovation to reach company goals), and
- confirmation (backing up or rejecting the use of adoption).

2.3. The TOE framework

According to Chiu et al. (2017), the Technology-organization-environment (TOE) framework is ideal for characterising the problems of accepting and implementing innovation and the opportunities that enable innovation adoption at both the corporate and industry levels. Because environmental, organisational, and

technical elements are the most important, this framework emphasises them more. This is because these three types of factors are the most significant overall.

The technologies now in use and readily available on the market constitute the technical factors (Baker, 2012). Oliveira & Martins (2010) state that organisational factors speak more to the organisation's internal formal and informal processes. The researchers provided this definition. They are one-of-a-kind to each company or organisation. The aspects of the environment in which the organisation operates or functions are called environmental factors. According to the TOE framework, all of these elements explain the obstacles associated with the acceptance and implementation of innovation and the opportunities to enable innovation adoption at the corporate and industry levels. This framework is relevant for this research study because it will be used as a base to understand challenges in innovation adoption and enablers of innovation adoption at both the company and industry levels. As a result, this framework is vital to this research because it is relevant to this research study.

2.4. Challenges and barriers to technology adoption

The "Company of the Future Technology" is a significant basis and facilitator of the "Mine of the Future endeavour," as stated by (Bryant, 2015). In addition, Bryant (2015) noted that technological attention should be directed towards producing value rather than reducing costs, which is primarily the case in the mining business. However, according to the technology-organization-environment framework, one of the obstacles to adopting technology is related to technological issues. According to Ramilo & Embi (2014), the inadequate application of technology to existing processes, the lack of access to data, and worries regarding network connection are all examples of technical hurdles that might impede the implementation and acceptance of innovation. The mining industry is the one that is most likely to suffer from this (Gao et al., 2019).

When looking at the organisational factor in the theory of expected utility framework, the most studied obstacles to the acceptance of innovation are considered to be risk aversion, the size of the organisation, a lack of trust between

members of the organisation, an absence of readiness on the part of the company to accept, and information discrepancies. (Pereira Cabral et al., 2020)

Regulations and the push for high health and safety standards are of the utmost importance, as is well-known worldwide. My experience suggests this is especially the case in the mining industry. This is supported by Gao et al. (2019), who investigated environmental issues and found that health and safety standards, environmental concerns, and government laws are possible obstacles to technological innovation. However, these findings are primarily from industries other than mining; as a result, it is essential to obtain first-hand proof of these issues in the context of South Africa's mining industry.

2.5. Opportunities and enablers for technology and innovation

Implementing innovations and technologies in the mining business is more complex than in other industries, mainly because the industry requires significant financial inputs. However, the erratic and unpredictable behaviour of commodity prices is not helping the situation. For this reason, it is of the utmost importance to acquire a deeper grasp of and first-hand experience regarding the considerable potential and facilitators for adopting technology and innovation in this business. According to the majority of the research that has been conducted on the topic of innovation, there are two primary sources of opportunity for innovation: demand and technology.

Regarding technological factors, Pietrobelli et al. (2018) identified three sources of technological opportunities: advancements in scientific understanding, technological advancements generated outside the industry by other value chain firms, and feedback from the technology itself.

According to the research carried out by Wisdom et al. (2014), the following organisational characteristics are the primary drivers of technological advancement and innovative thought:

- social climate and structure

- organisational norms and values
- leadership that promotes innovation
- readiness for change absorptive capacity, and
- keeping contact with those responsible for innovation and consultants in that regard

All of those above are obvious in their respective fields. However, at the environmental level, the critical enablers for innovation and technology are making relations with information sources that are outside of your organisation (Fukugawa, 2006), the growth and demand of mining supply to meet the rising demand (Stubrin, 2018), and knowledgeable suppliers within the supply chain environment or background and legislation on sustainability (Pietrobelli et al., 2018); (Amadi-Echendu et al., 2011).

2.6. Conclusion

The relevant literature review that will help in deriving solutions to the study questions is presented in this chapter. In this chapter, we looked at the adoption theories of innovation and technology and the challenges and opportunities for innovation and technology. The goal of this chapter was to provide a foundation for the research topic that will be covered in the next chapter. This research explores the opportunities and constraints for innovation in the South African mining sector.

3: RESEARCH METHODOLOGY

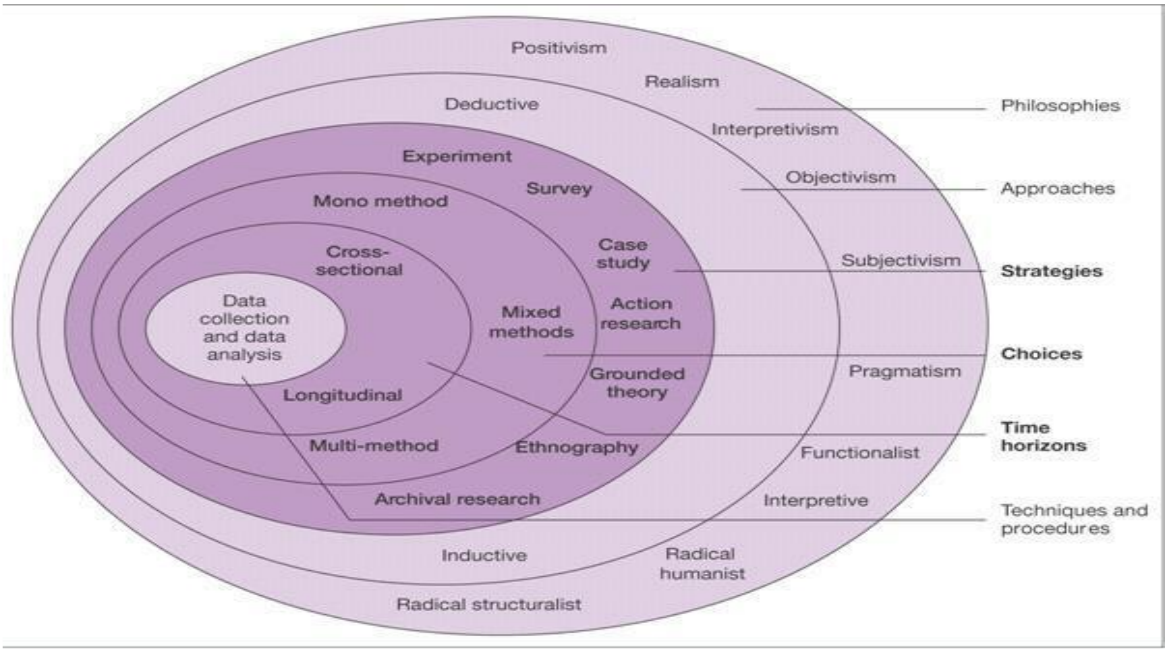
3.1 Introduction

In this chapter, the research methodology and design intended to be followed in the study to answer the research questions intending to highlight the challenges and opportunities for innovation will be discussed in detail. According to Zamrodah (2016), when research focuses on the 'what' question, similar to the questions raised in this study, the recommendation is that the study needs to be conducted as exploratory research as it provides flexibility and the capacity to receive comprehensive responses to the stated research question. From this recommendation and the nature of this research, an inductive, exploratory study will be followed to find in-detail answers to the research questions.

Soiferman (2010) suggests that qualitative research methods are more suitable to get in-depth research knowledge. Therefore, qualitative research will be conducted to pinpoint the companies' challenges and opportunities for innovation in their respective organisations

3.2 The research onion

The research strategy that was followed in this study followed the research onion illustrated in Saunders et al. (2007). This onion shows the stages that should be covered by the research when developing a research strategy. According to Bryman A et al. (2012), the notion that any study design in a wide range of settings can be conducted utilising the research onion makes this a helpful technique. The figure below shows the research onion developed by Saunders.



The research onion (Saunders et al., 2012)

3.3 Research philosophy

The interpretivism philosophy is the organisational complexity and proper awareness of organisational dynamics, social behaviours, and the function of social actors (M. A. Saunders & Lewis, 2019). This research aimed to dig deep and understand the challenges and opportunities for innovation in the South African mining sector. In addition, this philosophy offers a chance to engage with the respondents to understand their experience regarding this matter (Creswell et al., 2007).

3.4 Research Approach

According to Creswell et al. (2007), quantitative, qualitative, and mixed research approaches are the three commonly used research approaches in business studies. The study aims to explore challenges and opportunities for innovation in the South African mining industry. This study will use a qualitative inductive approach to understand and reveal deeper meaning from interview data, which

data analysis will strengthen. This report examines South African mining innovation challenges and opportunities.

3.5 Research Design and Strategy

M. N. K. Saunders et al., n.d. outline seven research methods: action research, experiment, case study, survey, grounded theory, archival research and ethnography. M. A. Saunders & Lewis (2019) list exploratory, descriptive, and explanatory qualitative study design for qualitative research. This study explores the challenges and opportunities for innovation that enable or prevent technology in the South African mining sector. This study adopted a case study research strategy. De Vaus (2014) states that a questionnaire survey is primarily quantitative, whereas focus groups and observations are qualitative.

Aberdeen (2013) suggested utilising a case study research technique to gain a deeper grasp of the case through numerous evidence sources. It was recommended that using a collective case study to obtain insight and knowledge of a situation or phenomenon (Baxter & Jack, n.d.2008). Baxter & Jack (2008) added that the collaborative case study yields trustworthy results. This validates the case study approach since the strategy used collective case study methods to identify crucial barriers and possibilities for innovation in an environment required for appropriate technological innovation acceptance in the South African mining sector.

3.6 Time Horizon

According to M. A. Saunders & Lewis (2019), longitudinal and cross-sectional are the two-time horizons categories. The cross-sectional approach adopted in this study is viewed by Rindfleisch et al. (2008) as a study in which a respondent is given one chance to complete the study. This is mainly due to the limited time allotted for the research study. The cross-sectional approach has the advantage of being pragmatic and cost-effective in various academic and industrial situations and circumstances. However, it is considered prone to standard

method variance, which can be reduced by combining the cross-sectional and longitudinal approaches (Rindfleisch et al., 2008). In practice, this is a challenging and practical issue that leaves the cross-sectional approach suitable on its own. This study used a cross-sectional temporal horizon to meet the university research program's timeframe. However, the constraint of this temporal range is that the data acquired must be extrapolated over just a brief period (Saunders & Lewis, 2019).

3.7 Population

This analysis included all South African platinum and gold mining companies that have implemented or are evaluating technology solutions for at least one equipment or process. Sample the entire mining industry, not the population. The study collected data from specific commodity clusters. The mining operations selected must have implemented or explored a technology innovation or any innovation concept for at least one piece of equipment in their value chain.

3.8 Sample size and sampling method

According to (Dworkin, 2012a), many write-ups suggest that the adequate number of interviews for qualitative research is between 5 and 50 participants. However, Guest et al. (2006) indicate that saturation is the critical guiding principle to determining the sample size. This is when there are no longer new codes coming up during coding. The aim was to collect data from six mining companies from gold and platinum commodities totalling 12. However, eleven interviews were conducted due to the shortage of willing participants

This number is appropriate and falls between the 5 to 50 suggested by (Dworkin, 2012a). Further focus was also placed on the saturation condition as recommendable. The mining operations selected had to have implemented or contemplated a technology innovation or any innovation concept for at least one piece of equipment in their value chain. The potential respondents were reached telephonically and through emails to request their participation and brief them

about the study. The follow-up emails were sent to them, supplying them with more details, consents forms, and interview schedules

3.9 Unit of analysis

The unit of analysis determined the subject of investigation. In a qualitative study, the unit of analysis might range from an individual to a community, according to Creswell et al. (2007). This research focused on South African mining industry decision-makers, experts and specialists who directly or indirectly involved in innovations and technology

3.10 Research and data instrument and procedure

Case studies were the research tools used. The research used interviews as a data collection instrument to guide with primary questions and sub-questions drawn from the literature in Chapter 2. Sanders and Lewis (2018) recommend that the interview guide include questions that answer the research questions from Chapter 1. The case study questions were based on the literature review to answer Chapter 1's research questions. To guarantee consistency, all interviewees used the same framework and questions. Video call interviews collected data. Data was collected from the targeted population via semi-structured interviews. This strategy helps the qualitative method gather high-quality data to address Chapter 1's research questions.

3.11 Data analysis and interpretation

Consent was requested from the respondent to record the audio of the interviews. ATLAS.TI was used to assist with the coding and analysis of data. The coding gave allowance to arrange the data into findings categories that assisted in identifying broad themes coming from the data. The thematic analysis method will be employed after the data analysis process. This coding process was intended to allow arranging the data into findings categories and recognition themes emerging from the data collected.

3.12 Ethical considerations

According to the Wits Business School regulations, there is a pressing need to apply for an ethical clearance certificate from the university. This s to ensure that the research and researcher follow the ethical way to conduct the study. Research ethics is more about how the whole research process, from formulation to analysis, is morally and responsibly carried out (M. A. Saunders & Lewis, 2019). Letters of consent were sent to all respondents. This was to make them aware that their identity would be protected, that taking part in this study is wholly voluntary and that they have the right to withdraw from the study at any time without any consequences.

3.13 Conclusions

In this chapter, the research methodology was discussed in detail. An inductive qualitative study was carried out using a case study as an instrument of data collection. The respondents from South African mining companies focusing on gold and platinum commodities were interviewed. Eleven interviews were conducted, with strict consideration of data saturation.

4: DATA ANALYSIS

4.1 Introduction

This chapter presents and discusses the study's most important findings in light of the study's overarching purpose, which was to inquire into the difficulties and prospects for innovation in the South African mining industry through the use of derived questions. The secondary issue was to what extent the environmental setting in South Africa affects and influences the adoption and implementation of innovative ideas in the mining sector. Eleven semi-structured interviews were done as the primary means of data collection in this qualitative study. Synthesising the data allowed us to classify its many themes and patterns.

4.2 Demographics of the participants

The following table provides information regarding the participants' previous employment as well as the roles they have at present. The purpose of this part is to provide proof that the respondents who were chosen are relevant to the topic at hand. The details of the respondents were categorised according to the mineral commodity and their roles at the time of the survey. The targeted participants are individuals who are now working in the mining business within the gold and platinum commodities or have worked there in the past. The research provides data covering gold and platinum commodities, displaying the perspectives of five organisations from around the mining industry. Due to the availability of the data, the research could examine both the diverse and the unified perspectives held by each commodity.

Participant #	Commodity	Role	Years of industry experience
P1	Platinum	Specialist Underground Mine Modernization	Nine years
P2	Platinum	Underground Mining Technology Implementation Specialist	12 years
P3	Gold	Plant Manager	12 years
P4	Platinum	Specialist Engineer Drilling Automation and Systems	Eight years
P5	Gold	Mine Planning Specialist	11 years
P6	Gold	Senior Geologist	14 years
P7	Gold	Academic and Senior Geologist	Six years
P8	Gold	Programme Manager and Industry Expect	21 years
P9	Platinum and Gold	Group Head of Mining Technical Services and consultant	28 years
P10	Various commodities	Executive and Consultant in Innovation and Sustainability in Mining	26 years
P11	Platinum	Head of New Mining Technology	25 years

4.3 Themes of the study

Theme #	Theme description	Theme codes
Theme 1	Challenges to innovation	• Inability to persuade/convince employees • Lack of stakeholder involvement • Misalignment of needs • Negative perception of technology and innovation • Lack of desire to commit to technology and innovation • Insufficient financial resources • Limited skilled personnel • Complacency towards learning from others • Nearly exhausted mineral deposits • Poor definition of technology and innovation to be adopted • Limited attention given to innovative ideas • Few decision makers who understand technology and innovation • Lack of future focus • Difficulty in balancing health and safety with production • Poor enforcement of health and safety legislation
Theme 2	Opportunities to innovations	• Conducting proper stakeholder engagement • Upscaling and redeploying teams • Employing stricter measures for adherence to health & safety rules • Hire people with the drive for technology and innovation adoption • Implement government incentive programs for innovation • Change the management approach to health and safety issues • Reduce innovative ideas to their projected monetary value Eliminate redundancy and improve operational efficiency

Theme 3	Prioritisation for SHE regulations compliance	• Innovation is key for organisational sustainability. • The commitment of capital investment for SHE regulation compliance • The utilisation of technology to avoid risks to human
Theme 4	Relationship between the operating environment and technology adoption	• Ageing mining environment • Trade union-infested environment • Unfriendly business and regulatory environment • Lack of resilience for technology and innovation adoption • Uncompetitive environment
Theme 5	Role of the legislature in facilitating technology adoption	• Driver and facilitator of technology and innovation adoption • A potential source of red tape and inhibitor of technology and innovation adoption
Theme 6	Dedication to innovation	• The commitment of capital investment for SHE regulation compliance • Technology, innovation, and automation are critical priorities for the future of our mine. • Innovation is critical for organisational sustainability.

4.3.1 Challenges to innovation and technology

The study findings revealed that one of the challenges to improving health and safety standards within the mining environment in South Africa is the need for more convincing employees to adopt innovative technology. According to Participant 1, "*the problem comes in terms of the socialisation between the employer and the employee;* ***how we sell the technology to our teams sometimes is a bit of an issue***".

It was also further revealed that a lack of stakeholder involvement during the innovative technology journey can impede technology and innovation adoption. It was pointed out that the participation of labour/trade unions can help to garner their support early on and avoid having issues with them when they are about to implement innovative technology. The claim is highlighted by Participant 1 in his following statement, "*you have got representative labour unions that sometimes from the organisation side, **we do not take them along the innovative journey;** we leave them behind and then only trying to involve them at the last minute, which causes other problems*".

Furthermore, it was also further revealed that the negative perception of technology and innovation within the mining environment impedes the adoption of technologies that could help improve the performance of the mines. This is because when mining companies in South Africa attempt to introduce these technologies, they may face hostility and resistance from trade unions and employees, as there is a perception that innovative technologies would end up replacing people with machines, eventually resulting in job losses. This is in agreement with the following statement from Participant 1:

> "*And yes, we obviously usually get the **first reaction when you bring in new technologies; there is always hostility**. You know, coming from the fear of people losing their jobs, and I think that's reasonable. But we've done now going forward, especially as we've looked at how technology actually adds value and enhances and makes employee's lives easier instead of trying to replace the employee, we trying to innovate, you know, obviously generate more profits but also have an engaged and a happy employee. So, when we started with the innovation and modernisation journey, **there was a lot of resistance**, and that emanated from the fact that you know, we never took them along. So they would just see those technologies coming into the mine, and they wouldn't know how it will impact the employee's lives the in the long run.*"

This is further supported by Participant 2, who confirms that trade unions and employees of mining organisations are hesitant to accommodate new technologies as they see them as a threat to their relevancy within the mining environment. He further points out that South Africa is a third-world country where most jobs depend on the workforce. Once innovative technologies are

introduced, they bring automation, reducing the workforce required for specific jobs. Naturally, this creates efficiency and productivity from the organisational perspective but creates job losses from the perspective of trade unions and employees. The following statement from Participant 2

> *"We are a third-world country, meaning that **technology and automation innovation is often synonymous with job losses**, so there's often this. **There is hesitation around using technology or introducing technology and innovation in mines** because especially our unions would see that as a threat to their workforce instead of seeing it as an opportunity to rescale and reinvigorate the workforce of the mines. **It is seen as a step towards replacing people with machines**.*"

Participant 3 further points out that the negative perception of innovative technologies in the South African mining environment is a big challenge for new ideas to defeat this. He suggests that to overcome this negative perception, there is a need for a change in the mindset and culture of the South African mining industry. Below is what Participant 3 and Participant 11 had to say:

> "**P3:** *And that's just a little bit. As a result, the **people's mindset becomes the culture is very difficult to change** as well. You know, there are a lot of projects that fail in the mining industry, and **unfortunately, when a project fails, it leaves people negative**, and people never believe. In another [project, there's been a lot of things that people tried; like Copeland in Anglogold, they used to have a project where they took people and then tried a different way of Mining. And then, **when it failed**. The people, you know what happened? **Those who were working in that project were retrenched**. Now, what does that mean to the people?*"

> **P11:** "*Mining and technology are being **perceived as something that is going to reduce jobs**, although a lot of the work that I've done actually shown that it increased the quality of the work as well as the number of jobs. But that is the **perception that is created by the unions by the workforce**, and so on. And unless we don't change that, [they would prefer the mines to] be closed down than trying to adopt technology because every time [technology adoption] is a failure because the people don't want to take on the technology or don't see the benefit for themselves. **Due to this mindset that technology is going to reduce jobs, that is most probably the biggest inhibitor***."

It was further pointed out that insufficient financial resources to support technology and innovation adoption impede the improvement of health and safety

standards. According to Participant 2, "***capital is always going to be a barrier*** *to any initiative it needs; technology that we wish to bring into the operation or into the organisation needs to be extremely well vetted financially. It needs to make financial sense*". This is also supported by Participant 11, who states, "*I would say the first challenge is obviously capital.* ***Innovation is not cheap.*** *It costs a lot of money*".

Additionally, Participant 7 further highlights that technology and innovation adoption requires financial resources as many considerations, such as labour, power, infrastructure and productivity, are associated with the technology. As such, introducing new technology and innovation can require massive financial resources, which can only be justifiable if they have a corresponding value addition and a significant improvement in the profitability of the mining operations. The following statement from Participant 7 supports this notion:

> "*The problem with technology that now* ***how are you going to pay for it*** *one; two, how are you going to deal with the* ***labour aspect*** *of it? And then three, there's a* ***power factor*** *as well. Uh power has become a major topic in terms of a deep level mining. How are you generating your power? How much are you spending on generating the power to keep the lights on? We know the flows of Eskom, right? So, are we then saying our technological solutions? In terms of the power conundrum, what impact will those have as well? You see what I mean? So, I think, I think most companies fell into.* ***The comfort of saying we've been doing things this way, let's reduce workforce, try to keep costs low. But keep our project's profit margins still going up and production going up at a decent rate.*** *Other than practically transforming the whole sort of operating infrastructure or whatever. So yeah, to answer that first question, I think that this way I'm leaning personally.*"

The study findings further indicated that limited skilled personnel impedes the improvement of health and safety standards. This is because skilled personnel are required to operate the innovative technologies; without them, it would be virtually useless. As such, this lack of skilled personnel presents a significant challenge towards adopting technology and innovation that could potentially improve the health and safety standards within the South African mining industry. Furthermore, training the employees may not always be practical considering the potential high training costs and time requirement needed to make the employees

fully abreast with the innovative technologies. This is supported by Participant 2, who states:

> "*The second barrier is **the skills level in the country** we are talking about. Anything that's innovative or technology based often is quite network and computer intensive and **unfortunately workforce isn't yet at that level** of being able or majority of our workforce is not yet at the level with them, it is* indicated that the South African mining industry is a bit complacent towards learning from others. This suggests that the learning culture within the South African industry is poor, and this, therefore, limits the innovative potential of the industry. According to Participant 3, "*That's another problem for our industry. **We are not learning from each other***".
>
> On the other hand, it was also pointed out that many mines in South Africa have been mined for several years, and most of them are nearly exhausted their mineral deposits. In light of this, there is less motivation for mining organisations to invest in innovative technologies that would be only used for a potentially short space of time. As such, it may not be wise to do so on the mine nearly reaching its limit as the risk involved in doing so may be too great and may not be justifiable given the remaining ore quality. This notion is supported by the following quotations from participants that are shown below:
>
> **P4:** "***The life of mine is just too short or the infrastructure doesn't allow for you to apply innovation** like no disruptive type of innovation and we have those companies that can usually just have [sustained] innovation but they don't implement those things because of the challenges they have in terms of the output we've. The tonnes that will come out or **the quality of tonnes that will come out**, they will just lower the rate and then won't be aligned to your business plan anymore.*"
>
> **P8:** "*So, the other thing that I think is also quite important is a lot of the mines or I don't want to say are dying. But **we've got a very old mines**. So, I think that the biggest thing is one is from, especially from investors and people who want to do new things. **Why would you invest money into something that's nearly dying?***"
>
> **P10:** "*So, I think that many of the junior miners and again not all, but many of them don't care. I think that **many of the junior miners have a 3 or a 5 year life on their mine**. They've, you know, **their goal is to extract as much value as possible** and if there is environmental damage or they don't treat the community properly, they don't care.*"

In addition, it was also indicated that the poor definition of technology and innovation to be adopted is one of the challenges towards improving health and

safety standards within the mining industry in South Africa. This is pointed out to impede the technology and innovation adoption as it is not enough to say that the organisation would adopt innovative technologies without knowing and identifying which technologies add value to the organisational processes. This is highlighted in the following statement from Participant 4:

> "*I think the first challenge is that when we mention innovation and technology,* ***we don't define the type of innovation and technology applicable to [our] mine****. Everyone, when I say technology, I'm thinking of something that is out of the blue that has never been done.*"

4.3.2 Opportunities for innovation

The study findings revealed an opportunity for innovative ideas to gain the support of employees and labour unions by engaging them through the technology and innovation process. This helps the employees and trade unions understand the benefits technology and innovation could bring to the mining environment, particularly their potential to improve health and safety standards. This is supported by Participant 1, who stated, "***we have a lot of work to do in terms of socialisation, how we engage our employees,*** *how we get them excited about their technology, how we get them to be involved and understand the value that the technology brings into the workplace*". Furthermore, engaging both employees and trade unions gives mining organisations the platform to address and dispel the negative perception associated with innovative technologies concerning job losses. In this regard, by explaining how employees would be given new roles within the mining value chain, mining organisations can help address the fears of employees and trade unions.

Moreover, Participant 4 asserts a need for a "*paradigm shift to say that* ***we can still have people managing the process but not doing the work physically themselves****. So, it can also help upskilling process…*". This is also pointed out by Participant 1, who states, "***We upscale, and then we also employ our teams in other areas*** *that enhance and make the technology work even better*". In addition, Participant 11 pointed out that employees should be willing to change

their mindsets and that the management should be able to support the cause as it would not be successful without their blessing. This is highlighted in his following statement:

> **"*the willingness to take people out and change their mindsets*.** *[I had] bought new drills, I wanted to take people out for two weeks to* ***train them on the surface, show them, change their mindset. Make them understand that yeah, it looks the same and it does the same as the old, but it's not the same.*** *This is how you need to treat this technology; that was point blank refused [by the management] and now the technology does not work because people are still using, abusing and [treating] it like the old technology and it doesn't work but that* ***I could have taught them before we even started*****"**.

Given this, Participant 7 also indicated that mining organisations must undergo culture and mindset change towards accommodating technology and innovation in the South African mining industry. As such, Participant 7 goes on to state that mining organisations in South Africa need to highlight and emphasise that:

> "*Machines are not gonna replace [employees],* ***so [the South African mining industry needs] to have a real culture change mindset shift****. To have people to be open to those ideas. A good example is company X. Company X has what they call digital Company X. Company X has done it's so lovely.* ***They've retrained, reskilled. They're looking at now massive amounts of data and improving their productivity, which is what we all want to do so.*****"**

Hence, providing more information to the employees and trade unions and addressing their concerns would go a long way in helping them to understand the role of technology and innovation in the mining environment and how their labour and contribution would still fit in. This would also help align the interests of investors and trade unions, potentially leading to more being achieved in the South African mining industry. According to Participant 11, "*I think there is huge opportunity,* ***if we can get the unions and the labour and the associations and then management and the investors all align*** *that you know we have to spend some money to set up something new*".

It was also noted that introducing technology and innovation should not be hostile. However, it should be a consultative process that engages various stakeholders

to ensure a smooth introduction to avoid negativity against the introduction of technology and innovation in the mining environment. This is highlighted in the following statement from Participant 4:

> "***I think the important thing is how we actually introduce*** *it to them. It mustn't be a hostile introduction because I'm telling you, if I was an operator and* ***someone comes to me with hostility, I'll be extremely negative****. With I don't. First, I don't understand what you're talking about. And I don't see the incentive for me to do what you are saying I must do, and I'm fearful for my job. I don't, I really don't have no reason why I should be doing what you said I must be doing.* ***Hence it goes back to change management, like the way you approach people.*** *You understand who you're talking to and speak the language they understand in a manner they understand.*"

On the other hand, it was also indicated that stricter measures for adherence to health & safety rules present an opportunity to improve the health and safety standards within the South African industry. This is because the lack of health and safety rules enforcement within the South African industry makes other players slacken their commitment to upholding health and safety standards. In this regard, ensuring adequate monitoring and evaluation of the activities of all players in the mining industry would help reinforce those health and safety standards that should not be compromised. The following statement from Participant 2 supports this:

> "*I think we certainly operate better than most other operations or mines, but [there's] certainly still room for improvement, I think. Uh, when it comes to health and safety,* ***it's my personal opinion that it should be very, very strict in terms of the systems around it****. So unfortunately, most of the incidents that do happen is not because of a failure of health and safety systems in place with technologies in place, but rather* ***lack of compliance or rather breaking rules associated*** *with these with these technologies and systems.*"

Furthermore, it was indicated that there is another opportunity for innovation through hiring people with the drive for technology and innovation adoption. This suggests that hiring people with the drive for technology and innovation adoption are more willing and ready to go the extra mile to endure the transition to a new mining environment that embraces technology and innovation. According to

Participant 2, "*I think the* ***newer generation coming into the mining industry****, they certainly are a step change from the older generation to a new, younger, more innovative driven management in operations that are certainly enabling technology*". Moreover, it was further indicated that there is a need for a talent complement in the South African industry that can build on the existing competencies with technology and innovation. This is highlighted by Participant 3, who stated, "*To do this, so you need someone to build on, but that is not happening. So, what I'm saying is that mining jobs are old jobs. That's what I'm saying to you. We need new.* ***We need to test and involve new skills****"*. In addition, new talent in the South African mining industry would help to utilise the untapped innovative ideas whose potential has not yet been realised. According to Participant 5, "*The ideas of innovators, and it's just like it goes to waste and because* ***people don't comprehend what it what it's really offering, and until we have the right people to actually look at talent management and people to look at innovation****, new ideas until we have that right, people in the right positions, it's gonna continue like that. And some of these ideas can be the difference between a mine keeping its doors open or shutting it down*".
Participant 7 further points out that apart from hiring talented individuals willing to adopt technology and innovation, they should also be able to utilise the big data within their mining environment to aid in improving the health and safety standards within the South African mining industry. This is supported by the following statement from Participant 7, who stated, "***Another hindrance to innovation is skilled individuals****. So, your innovation is going to* ***require a big approach towards management and handling and analysis of data***".

The study findings also revealed that there is an opportunity for innovation through the improvement of operational efficiencies and increased production. Moreover, there were four areas in which operational efficiency could be improved: energy, transport, big data, communication and explosives. Firstly, it was pointed out by Participant 7 that there is an opportunity in the mining industry to improve energy cost efficiency. He states that going for renewables in the current energy crisis in South Africa is impractical. But there is an opportunity to

improve the existing energy supply whilst simultaneously ensuring that innovative technologies are being implemented to reduce toxic and hazardous substances from being released into the environment. Participant 7 further states that going for renewable energy is not cheap, but it requires both time and financial investment to succeed. It could, however, be easier and cheaper to focus on the current coal energy generation system to improve its health and safety standards. The following statement from Participant 7 supports this:

> "***in energy there is a] big opportunity [for] cost effective energy*** *that is because renewables are well and good and I really want us to save the environment like the next person; but if we're being real with ourselves,* ***renewables are not cheap****. So, we need innovation in the energy sector to say how can we get cheaper energy: i) for refinery, ii) for operation.*"

Secondly, it was pointed out by Participant 7 that the transport system has to be improved and done away with the use of trucks in the transportation of coal but instead utilise the rail transport system. This is believed to be the only practical way to improve operational efficiency and remove redundancy in the South African mining industry. With the improvement of the transport systems, many mining organisations would benefit from this endeavour in terms of costs and health and safety standards. The following statement from Participant 7 supports this:

> "***Another opportunity in transport****… how you're shipping your coal, right? So, are you moving it by freight or by train? For export market, I know there's going to be either a train or trucks that are going to the port. Most of our mines are inland, right? So, we need innovation there as well because these, for me,* ***these trucks are not helping anyone****. So, you you're going to have to come up with a solution that involves rail, rail infrastructure*".

In addition, Participant 9 further points out that the underground transport system needs to be improved to allow the employees not to waste time moving from one work site to the other. This may also lead to improvement and good performance for the mine in terms of production as the employees would be able to be at the workplace earlier. This is highlighted in the statement from Participant 9, "***we look at transport underground; that's where the mine is still lacking****. Get your workers to their work panel as quickly as possible; so that they can actually start*

working". Thirdly, it was also indicated that big data collection and utilisation in the South African mining industry could present an opportunity to improve processes, leading to improved health and safety standards through continuous improvement. This is consistent with the assertion of Participant 7, who stated:

> "***Another opportunity that is there is now on the data*** *and particularly the collection of data because our mines, a lot has improved, but I think more can be done in collecting like you know data, you can collect data about anything. Anything at all. Movement of your people, movement of your machine, working rate of your machine, deterioration rate of your machine. You can collect ample amounts of data. Yes, yes. But now it's collected, for a purpose. So even in the data space,* ***there's still huge untapped potential for people to come up with innovative solutions because there's some data to problems that we don't know exist now****, problems that are going to exist five years from now. But if we start collecting the data and people start modelling out. We would be able to forecast some of the issues that we're going to have.*"

Fourthly, it was also pointed out that the current underground communication systems in most South African mines are poor and because of this, there is an opportunity to improve it. This improvement in the communication system through the use of 4G/5G technologies or similar would ensure that the underground communication is strong, which could lead to better operational efficiency and improvement in safety as the people underground would be able to communicate efficiently with those on the surface. This underground communication issue is highlighted by Participant 9 in his following statement:

> "*Now turn that around into underground and* ***there's no GPS, there's no communication except by the leaky feeder*** *and maybe right at the workplace. There's no nothing. The only communication [underground] is verbal communication. And so, I think the biggest challenge for innovation is to* ***bring in a communication network*** *like a surface infrastructure where you can actually be able to: First of all, track people to know where they are and that they safe. Unions don't like. And secondly is to track your material, where are they going? Are you? Do you have the right material at the right time at the right place? So that you can actually track it and then be able to make sure that this surveillance is happening on the ground,* ***we can see where safe, unsafe acts are or happening and you can have preventive action around it****. So, for me it's really about moving much faster in the 5G or 4G network underground so that you could actually be able to communicate.*"

Lastly, it was also indicated that the current explosives that are being used underground release toxic gases after being used. This results in the evacuation of the area until it is safe to work again. In this regard, there is an opportunity to improve operational efficiency by reducing evacuation time and allocating more time for productive work whilst simultaneously enhancing health and safety standards. This can be done through innovative ideas aimed at developing non-toxic explosives. This notion is supported by Participant 10, who states:

> "*they've been sort of doing **research into various explosives**. The reason that they are trying to remove various toxic compounds from explosives is because after a blast cycle you have to you now vacate the area for several hours for the toxic fumes to be evacuated before you can send a crew back in. So, there is a health and safety component to what they're doing because they don't want to expose people to these toxic gases. But the underlying reason is that while the crew is hanging around for two hours, they're doing nothing in there being paid. So, there is actually an **operational efficiency** thing. If we are able to, you know, remove the toxicity from the explosives, we're able to get the crew back end faster. And so, the reason that they're doing it is from an operational perspective, even if there's a health and safety element to this. So, what I think you'll see is that many of the innovations and technologies that are being developed will cut across several areas, right, **they will improve cost efficiencies on the mine by reducing an environmental hazard**.*"

4.3.3 Prioritisation for SHE regulations compliance

The study findings generally indicated that most of the mining organisations in South Africa do indeed prioritise compliance with health and safety regulations. Firstly, Participant 2 asserts that innovation is vital for organisational sustainability. Therefore, most mining organisations seeking to remain relevant and operational in the future invest in technology and innovation, prioritising compliance with health and safety regulations. His following statement supports this:

> "*It's quite it's extremely high priority from my corporation we have a variety of commodities that we mine. So, across our business units, technology and **innovation and automation is a key priority to the future of our mine, of our operations.** It's been a priority since our last engagement, which was around 2018 and in our last basically conference, held around September of [that] year, it was noted that **technology and thinking on the innovation is a priority for the sustainability of the company**. So, I would, I would definitely class*

that as an extremely high priority for my company."

Secondly, it was also indicated by Participant 2 that many South African mining organisations do indeed suggest prioritising compliance with health and safety regulations through the continued commitment of their financial resources in this area. He further states that some of these mining organisations also conduct joint ventures with original equipment manufacturers (OEMs) to develop equipment that may improve the health and safety standards to meet and potentially exceed the prescribed health and safety standards. The following statement from Participant 2 supports this:

> "***We consider ourselves innovators when it comes to mining technologies; we do a lot of collaboration with different OEM in terms of bringing new technologies or innovations into the company.*** *So, I would say that it is quite a massive capital investment into innovation and automation. I would not be able to put a random dollar figure to it, but* ***it is certainly a big portion of our capital expenditure on an annual basis****.*"

Furthermore, Participant 6 agrees that many mining organisations prioritise compliance with health and safety regulations by committing financial resources to this cause. He highlights this in his following statement, "***We definitely have invested a lot of time, money and thought*** *in the improvement of health and safety and processes*". Besides, it was also indicated that using technology to avoid human risks is a signal that suggests compliance with health and safety regulations is being observed by mining organisations in South Africa. This is in agreement with the following statement from Participant 9:

> "*Now if you look at, if you look at Company X, if you look at the coal industry,* ***there's a lot of technologies that they are using to assist them specifically around now driverless trucks technology*** *around you know interaction between machine and machine and machine and people. So, one of the things that you have is obviously you got satellites; so, you got GPS. So, you can actually pinpoint every movement of every mining equipment that you have on site so, so that's critical.*"

4.3.4 Relationship between the operating environment and innovation and technology

The study findings suggest a negative relationship between the Mining operating environment in South Africa with innovations and technology adoption. This is highlighted by Participant 4 and Participant 7 in the following statement:

> **P4**: "*No, **I don't think we are doing our research well because we are not put in a corner where if we don't innovate, we won't be profitable**. Like if you go and look in countries like Australia, if they're innovate, the mine will stop because there's literally no one. They are forced to and people they understand that this is how we work, because we have no other option. So, we still have a fall-back plan. We have people and for over 100 years, those people have produced, **so you cannot come and expect the culture of over 100 years to just come to an end without you being creative in managing the change.***"

> **P 7:** "*You need to weigh the pros and cons to say okay, a technological solution; one, **in the long term it might work better for you but then in the short term**, **you might spend too much with little gain**. Most of yeah, **most of these mines did not make provision for advancement in technology because I think most of them do not necessarily expect to live or last long**, right? Especially in the gold sector, some of these mines are dying out. We're looking at life of mine 10 to 15 at most, maybe 20 years now.*"

Secondly, it was also pointed out that the South African mining environment is infested with trade unions with the engraved culture of sticking with the old ways of doing things. This notion is supported by Participant 7, who stated:

> "***The one thing that is hindering them is the fact that trade unions are very much engraved in the culture.** Just as much as they are engraved in South African culture, whether it's private or in government, **trade unions play a major role in how your workforce is going to behave**, how your workforce is going to put pressure on you as an employer. So, in the context, all the mines **came from history where they had a very bloated workforce**. So bloated workforce says now you're employing a lot of people [that are] doing jobs that are kind of vulnerable to technology.*"

Thirdly, it creates an uncompetitive mining environment by refusing to adopt technologies that could improve operational efficiency and health and safety standards. According to Participant 3, "*And because of conditions, **once again***

you will have to develop something that will work for that environment*. And if I'm answering the value chain question,* ***I think the environment is that makes us uncompetitive in terms of gold***".

Fourthly, because there is a negative perception of technology and innovation adoption, it influences the attitude and behaviour of the employees towards technology. This is highlighted by Participant 11, who points out that when technology is introduced within a mining organisation, the moment it fails one time too many, people quickly condemn it without trying to find out why it is failing as they would feel better sticking to their old way of doing things. The following statement from Participant 11 supports this notion:

> "***the third time the machine breakdown on or there's a piece of crap. Let's go back to what we know.*** *And some of these machines break down over and over and over. And* ***you really have to have the resilience*** *to stick to it until if you really believe in it, to make it work.*"

Lastly, the factors above make the South African mining industry an unfriendly business and regulatory environment. The following statement from Participant 10 supports this:

> "*I think the biggest drag on our sector, is the South African public sector is our government led infrastructure and regulations and policies.* ***If there is a business-friendly regulatory environment. If there is efficient infrastructure, whether it's... and the two infrastructures is power and transport****, right. If Transnet, Transnet ports and Eskom worked properly, our industry would double in size. So,* ***I think that we are misleading ourselves if we think that putting some money into innovation is going to fundamentally change the way that our sector works****. When the biggest constraints in our sector have to do with these much larger institutional issues. Now, if you are a company in Finland, if you're a mining company in Finland. You already have an efficient public service. You are able to get your product onto rail and out through a port, right****? Then you need to start looking for incremental and kind of even radical changes in your mining environment because you know the rest of the value chain around Mining is already working pretty efficiently. But when the rest of the value chain is not working efficiently, then it doesn't help to look for a 1% improvement in your in your operation when you can't realise that because the port doesn't work properly.*** *So, you know, should companies be*

investing in innovation? Sure. But I think that there's a lot more value that they can get by putting pressure and continuing to put pressure on government to address its various flaws."

4.3.5 Role of the legislature in facilitating technology adoption

The study highlighted that the legislature has a role in facilitating technology adoption in the South African mining industry. It was pointed out that the legislature can be both a driver and facilitator of technology and innovation adoption and an inhibitor. In support of this, Participant 2 states that the:

> "*Laws are put in and when regulations changed, in order to require technologies to be put in it,* ***it makes the implementation much easier****. It's always challenging to try and implement the technology or innovation that's not supported by the DMRE. We often tend to fight against unions around the need for technologies.* ***This is obviously made easier when it is regulated.*** *So, I think with proper regulation it actually does impact stability to introduce new technologies into companies.*"

On the other hand, the legislature can help mining organisations to adopt technology and innovation if they constantly receive some form of punishment for not complying with regulations. In cases where fines are too hefty, it can motivate the mining companies to innovate if they do not want to receive penalties and negative publicity, which would also hate the shareholder value. Given this, Participant 3 states, "*But it's something that can, if taken well, it's something that* ***can help innovate because you keep receiving punishment for the same thing***". Yet still, sometimes, the legislature can push for the mining industry to innovate and adopt certain technologies to allow them to continue operating. The following statement from Participant 9 supports this:

> "*So,* ***the regulator is sometimes pushing it****. So, guys, this is what we would to get into the mines and sometimes the industry is a bit slow to follow. So, in that particular, some mines are ready. But most of the mines will not be able to accommodate the new regulation, so they have to, you know, ask for a bit of leniency from the DMRE that they can actually get themselves ready to do that. And I think the biggest,* ***the biggest stumbling block is that we have is that some of the OEM's that's out there follow their own way of doing things and***

maybe sometimes not listening to, you know what the industry wants them to do."

On the other hand, the legislature can be a potential source of red tape and an inhibitor of technology and innovation adoption. It can create barriers, such as a lengthy approval process that can be both time-consuming and costly. Participant 7, in agreement with this, states that:

> *"It's hugely negatively affecting them…* ***to get anything authorised in this country. One is time-consuming and it's costly.*** *I write application. You name the types of applications that we have. It's very difficult for you to go from project phase conceptual simply because your application is starts at DMR or your application is starts wherever. Another thing for specifically gold and platinum mines, if you're saying you're going to extend some of these mines and try and increase innovation.* ***If you're going to run projects in that, the DMR becomes both an assistant and hurdle, because now the DMR will constantly try and keep monitoring you.***"

Also, Participant 11 further points out that sometimes the legislature can operate with rules established long ago when most technologies and innovations were non-existence. As such, given that some technologies and innovations would improve the ways of doing things in the mining industry value chain, they may not meet the legislature, yet they may be doing it better. According to Participant 11, legislation affecting the South African mining industry states, "*we taking yesterday's, you know, legislation and we apply it on to tomorrow's technology*". In light of this, the legislature can hinder technology and innovation adoption. This is further exacerbated by the fact that technology does not always evolve as fast as technology. Participant 11 additionally supports this notion in his following statement:

> "***They are rules and regulations that were developed over the last 100 years. However, new technology is challenging that.*** *To put it in an example, I've got a tunnel border that cuts a perfectly round tunnel that is self-supporting. You know and that can operate at speed and cut and open up mines much faster. However, if I add all the regulations that they want to force me on my 4-meter belt; that is similar to that of overland belt. Alright. If they put all the support in that they put in a normal drill and blast tunnel because that's all they know.* ***Nobody wants to move and say how do we do it better faster [and] smarter.*** *And accommodate the legislation, it will happen, but it's gonna take so long that you know some of these things might be seen*

> *as not viable before that happens.* ***So, there is a serious need for the legislation to start embracing new technology and see how do we actually get out of that.***"

Besides, Participant 10 argues that the mining industry environment has limited influence on technology and innovation adoption rate. However, it largely relies on where investors are willing to push their financial resources. This suggests that investors will always be willing to take the risk as long as there is an appetising return on investment. But obviously, they cannot just take a risk by investing in technology and innovation in the mining industry if they are other safer and more rewarding alternative industries to invest in. However, the legislature is still limited in facilitating technology and innovation adoption. However, it cannot be the sole cause for the industry's lack of technology and innovation adoption. The following statement from Participant 10 supports this notion:

> "***I think that they are largely irrelevant to innovation****. I think that if you want to explore the regulatory and institutional environment related to innovation. Then you should be, in my view, you should be looking at National Treasury tax code. You should be looking at the various DSI regulatory incentives around innovation, there's a lot of effort that's been put into the development of a South African Start-up Act.* ***So, innovation is driven by money going into risk taking and you need companies to do that. And so, it's the financial regulation, that's the IP regulation; that is of interest when it comes to innovation not the end sector use.***"

4.3.6 Dedication and level of innovation

The study findings revealed that the level of commitment and state of innovation is relatively high in the South African mining industry. This was highlighted by Participant 2 with the following statements:

> *"It's quite* ***it's an extremely high priority*** *for my cooperation we have a variety of commodities that we mine. So across our business units, technology and innovation, and automation are key priorities to the future of our mine, of our operations. It's been a priority since our last engagement, which was around 2018 and in our last"*

> *“We consider **ourselves innovators** when it comes to mining technologies; we do a lot of collaboration with different OEM in terms of bringing new technologies or innovations into the company. **So, I would say that it is quite a massive capital investment into innovation and automation.** I would not be able to put a random dollar figure to it, but it is certainly a big portion of our capital expenditure on an annual basis”*

Furthermore, Participant 6 acknowledges that many mining companies prioritise innovations in health and safety requirements by allocating financial resources to this end. He emphasizes this in the following statement: *"We have certainly **invested a lot of time, money,** and thought in the improvement of health, safety, and processes."*

However, Participant 4 believes that the level of innovation is moderate by the following statement:

> *“I think that this **one is quite neutral** because if you look at most companies and you look at their values, safety is always there in terms of innovation and technologies always there. And if you see the implementation of that innovation, I think it's more at you can see the introduction of the simpler introduction of innovative ways in the administrative side of things compared to the core business of operations of production. It's easy if you go and look at the system to find that people companies have mobile.”*

5: DISCUSSION AND CONCLUSIONS

5.1 Introduction

The objective of this chapter is to provide an interpretation of the findings, a synthesis of those findings, and a description of their relevance to the prior research. This study aimed to investigate the challenges that stand in the way of innovation in the South African mining industry and the opportunities for innovation. In this chapter, we analysed the findings from Chapter 4. We determined whether or not those conclusions are supported by the features and criteria drawn from the theoretical and commercial literature discussed in the literature review. Also, fresh insights will be derived from the findings presented in the previous chapter (Chapter 4).

5.2 Discussion of themes

The following section below aims at discussing the themes generated from the research and linking them to the existing theory

5.2.1 Challenges for Innovation

The study's findings indicated that one of the obstacles to innovation within the mining environment in South Africa is the difficulty of persuading or convincing employees to adopt new solutions and technologies. This was identified as one of the problems for innovation. This demonstrates that the employer and the employees do not always have a good socialisation engagement, which makes it difficult for the employer to convince the employees of the benefits and effectiveness of different and new ideas to the extent that the employees would be willing to adopt innovative solutions. That would be working together to achieve the best results.

There was consensus among most of the participants that communication is an issue between management and employees which most likely poses resistance

to innovative solutions or new technology. Most participants believe an employer must walk the innovation journey with the employees for a successful process. Rogers (1962) highlighted communication as a significant aspect of the innovation process and reaffirmed and emphasised the significance of communication for the technology adoption process. Rogers (1962) viewed communication as an integral part of the process of innovation dissemination. Rogers (1962) defines diffusion as introducing a new invention or technology solution through communication with members within a defined social system. This can take the form of a technological solution or an innovation.

As mentioned by most participants, individuals' mentalities and views about the benefits of technological solutions are considered part of the behavioural shift that is a challenge. Koul & Eydgahi (2018) reported that innovative solutions influence behavioural and social changes; nevertheless, should one’s behaviour not change correspondingly, accepting the new technology will be a struggle.

It was also shown that a lack of stakeholder involvement while developing innovative technologies could hinder the adoption of new technologies and ideas. It was pointed out that getting labour and trade unions involved early on can help to earn their support and avoid having conflicts with them when they are going to use innovative technology or ideas. This is brought to light by Participant 1, who is a seasoned professional in the fields of technological innovation and advancement. In light of this, gaining the support of labour unions could help to make the transition to new technologies more effortless, which, in turn, would contribute to the development of a workplace environment that is productive, efficient, safer and healthier for workers. Most respondents thought that employee participation and engagement were crucial during picking a technological solution and before its execution. Rogers' (1962) confirmed the decision process of innovation, which proposes that employees must have prior knowledge of technological innovations to establish their own opinions regarding technological solutions. As most participants pointed out, the process is

necessary to establish support from all interested parties, including staff as team members.

It was further pointed out that insufficient financial resources to support technology and innovation adoption impede improving processes. This is because for technology and innovation to be implemented within the South African mining industry, financial resources are needed to acquire the technology, train employees and conduct change management in organisational processes to facilitate the transition to the new technology platform. From the study, it is evident that money will always be a barrier to any initiative that has to be taken; the technology that is intended to bring into the operation or the organisation needs to be highly well examined financially before it can be implemented. This must be economically viable. Bryant (2015) supported these sentiments that the cost-cutting initiatives have hampered innovation, which has led to capital restraints and competitive conditions in response to commodity price pressures. As such, financial resources are integral in ensuring that all items needed to transition to an improved workplace environment and new ideas are attained. Ernst and Young (2015) cite this capital conundrum and financial resources as a key threat to the mining industry. Their research reveals that several mining firms have adopted managing capital with monitored disciple and allocation following business financial investment objectives (Ernst and Young, 2015).

On the other hand, it was also pointed out that many mines in South Africa have been mined for several years, and most of them are nearly exhausted their mineral deposits. In light of this, there is less motivation for mining organisations to invest in innovative technologies that would be only used for a potentially short space of time. As such, it may not be wise to do so on the mine nearly reaching its limit as the risk involved in doing so may be too great and may not be justifiable given the remaining ore quality. This notion is supported by the following quotations from participants that are shown below:

Most respondents believe that the mindset and perception of employees and trade unions regarding innovations must be changed. The study revealed that

mining organisation employees and trade union employees resist adopting innovations and technology because they view these innovations as threatening their relevance within the mining industry and a threat to their jobs. Leaders require more work to change this mindset. According to Kuratko et al. (2014), employees must be taught corporate innovation strategies for success. Executives must teach staff about innovation. After assessing the firm's internal work environment, senior managers should analyse if employees understand corporate innovation and entrepreneurial behaviour. It is believed that South Africa is a country that belongs to the third world and that the majority of the jobs there are dependent on human labour. Automation decreases the labour required for specific jobs when new technologies are implemented. From the organisation's point of view, this will naturally lead to increased efficiency and production, but from the point of view of trade unions and employees, this will lead to job losses. As a result, the South African mining environment is hostile and resistant to adopting innovative solutions and technology to keep up with labour demands

5.2.2 Opportunities for Innovation

Most respondents feel that conducting a proper stakeholder engagement needs to be relooked at differently. Three participants, experts in innovation and technology, believe that poor stakeholder engagement and change management process contributes a lot to efficient mining activities, raising an opportunity for an innovative solution to this process. When looking at the organisational factor within the framework of the theory of expected utility, the most common barriers to the adoption of new ideas are thought to be an aversion to risk, the size of the organisation, a lack of trust between members of the organisation, a lack of readiness on the part of the company to accept, and information discrepancies (Pereira Cabral et al., 2020). This highlight from Pereira Cabral et al., (2020) emphasises the importance of change management and stakeholder engagement.

Since it is quite difficult and almost impossible for the mining industry to do product innovation, this industry mostly focuses on process and systems innovation(Olvera, n.d.). However, from the findings, it is clear that the stakeholder engagement processes need innovative ideas to be conducted efficiently. Jayaram et al. (2014) highlight that process innovation entails taking activities to increase production processes' speed, efficiency, and reliability. This, in turn, leads to improvements in product innovation and the quality performance of the product. Hence, improving stakeholder engagement proofs is something to focus on in the mining industry.

It was also highlighted that relevant skills recruitment and detainment is one area that needs improvement to ensure the South African mining industry is friendly and allows for innovation. Most participants felt a need to recruit personnel with knowledge of innovations and technology intentionally. The need to get the right people in the correct positions is vital as innovators' ideas go to waste as people do not comprehend what it is offering. In preparation for the 4IR and implementing innovative technological solutions, most respondents stated that mining businesses must possess skills to lead this intense technology generation. These notions were validated by Sirinanda (2019), who emphasised that mining businesses need dynamic professional technological competencies to comprehend integrating innovative and technological advancements into the mining value chain.

The study findings also revealed an opportunity to improve specific South African mining industry processes by improving operational efficiency. The participants agreed that an urgent need to improve the efficiency and output of the mining industry is necessary. These imperatives were the fundamental impetus for innovations and technology to enhance the mining value chain. Moreover, there were four areas in which improvement is needed, and operational efficiency could be improved, and according to the study, these are energy, transport, big data, communication and explosives. According to Ramilo & Embi (2014), the inadequate application of technology to existing processes, the lack of access to data, and worries regarding network connection are all

examples of technical hurdles that might impede the implementation and acceptance of innovation. Hence, a need for innovative solutions to data and network issues. Among the majority of authors, Ernst and Young (2015) concur with the majority of authors that many mining firms are focusing on innovations that will enable them to pay back their declining productivity and efficiency, which have diminished in recent years as a result of tonnage increases during the commodity boom cycle. The same sentiments are shared with (*MRG_1701_Mavroudis_Eickhoff_170116*, n.d.)

An opportunity exists in the mines industry to develop energy cost efficiency. Improving the existing energy supply whilst simultaneously ensuring that innovative technologies are being implemented to reduce toxic and hazardous substances from being released into the environment seems to be the sought-after solution. Focusing on the current coal energy generation system for improvements is believed to be easier and cheaper. South Africa needs an energy technology innovation revolution to tackle the deep economic and environmental issues that energy poses in today's world. If the country does not take immediate action to improve the conditions for energy innovation, it risks losing investment and experiencing terrible economic conditions. Not only will the mining industry be impacted, but the entire country.

Most participants also highlighted transport underground. The underground transport system needs to be improved to allow the employees not to waste time moving from one work site to the other. This may also lead to an increase in production time. Increased production time would, in turn, yield increased production.

Lastly, the factors above make the South African mining industry an unfriendly business and regulatory environment. This is further exacerbated by the lack of adequate infrastructure, particularly power and transport infrastructure. This makes doing business in South Africa more difficult than in other countries. In this regard, even if mining organisations would like to adopt technology and innovation, the improvements that would be realised would be nearly hopeless,

given that the basic infrastructure is not there. As such, it would not be advisable for them to invest heavily in technology and innovation.

Mining corporations are driven by the necessity of achieving specific benefits tied to their commercial objectives. For example, they might be viewed as services or processes that bring value. These are supported and validated by Iacovou et al. (1995)'s model. The model outlines the benefit perceived, organisational readiness and external pressures that leads firms to embrace innovations

5.2.3 Prioritisation for SHE regulations compliance

According to the study, most mining companies prioritise compliance with health and safety laws in South Africa. Most participants assert that innovation is essential for organisational sustainability; consequently, most mining organisations that wish to remain relevant and operational invest in technology and innovation, placing a premium on compliance with health and safety regulations. The study reveals that the importance of safety compliance has forced many mining companies to partner with OEMs to produce technology that may increase health and safety standards to meet and maybe exceed the mandated health and safety requirements. Bryant (2015) noted that communities affected by mining and regulators from the government are becoming more concerned about the damage caused by mining houses. This has caused the enforcement of stricter regulations requiring mining companies to use environmentally friendly processes, hence the need to innovate. This information was confirmed in theory by Mavroudis and Pierburg (2017), which state that working conditions improve by achieving regulatory criteria and preserving an environment safe for all.

5.2.4 Relationship between the operating environment and innovation and technology adoption

The study results indicate a negative association between the Mining operating environment in South Africa and the use of technology. First, this suggests that

the mining environment in South Africa does not foster or promote the quick adoption of technology and innovation. Secondly, it was mentioned that the mining sector in South Africa is ageing and that most mines have run out of mineral reserves of high quality. As a result, declining ore grades are a prelude to a variety of additional environmental and societal consequences. According to (Prior et al., 2012), falling grades, for example, encourage exploration and increased mine depth or surface extension; more inputs like energy, water, labor, investment) are required for mining and processing increased ore throughput to give a comparable unit of output; and more waste is created. As a result, the majority of mining companies are unwilling to invest and devote resources to such mines, as there is a substantial possibility that this endeavour will not be lucrative.

Second, it was noted that the South African mining environment is plagued with trade unions with a deeply ingrained culture of adhering to outdated practices. The South African mining industry has historically had a bloated workforce. When mining organisations attempt to cut their workforce through technology and innovation to remain lucrative, there is a risk that the business will become unprofitable. This is supported by (Lommerud et al., 2006) who mention that when labour demand is inelastic and unions worry about employment more than wages, trade unions have a legitimate motivation to oppose the introduction of labour-saving technology. They are often opposed by labour unions, who fail to recognise that mining labour dynamics must change and that robots will eventually perform some jobs. In the same way that they are ingrained in South African culture, whether in the private or public sector, trade unions play a significant part in how your workers will act and exert pressure on you as an employer. In this context, all mines originated when the workforce was bloated. The mining industry becomes uncompetitive by refusing to adopt innovations that could potentially increase operating efficiencies and health and safety requirements. This is because labour costs would remain needlessly high by refusing to eliminate redundancy in the mining industry. As a result, South African mines would be unable to compete globally, notably in the gold market. This is supported by Gao et al. (2019), who investigated environmental issues and found

that health and safety standards, environmental concerns, and government laws are possible obstacles to technological innovation. Because there is a negative perception of the adoption of technology and innovation, it affects the attitude and behaviour of employees towards technology.

In conclusion, the causes above contribute to the South African mining industry's hostile business and regulatory climate. The absence of suitable energy and transportation infrastructure also compounds this. It makes conducting business in South Africa somewhat more challenging than in other nations.

5.2.5 Role of the legislature in facilitating innovation and technology adoption

The findings also noted that legislation and regulations could help the South African mining industry to be innovative and use technology. Most participants believe that If technology and innovation are regulated, trade unions may struggle to oppose them. The law can protect mining companies that invest in innovative technology. Legislation may encourage mining companies to adopt technology and innovation by punishing noncompliance and incentivising innovation. Vogel et al. (2019) mentioned the benefits of incentivising innovations. According to Vogel et al. (2019), it is essential to stimulate innovation and sustainability to meet energy and environmental standards. The author mentioned that since innovative technology entails risks in addition to benefits, developers, contractors, and consultants must be incentivized to openly embrace those risks to fulfil society's critical long-term goals for reduced resource consumption and emissions.

The studies also demonstrated that the legislature might create red tape and hinder technology and innovation adoption. It might delay and expense approvals. This may deter investors from technological developments that boost operational efficiency and safety. The legislation can promote or hinder technology and innovation adoption depending on the situation. This is supported by the study by Jiang et al. (2018). Jiang et al. (2018) state that R&D investment directly impacts corporate innovation performance. Secondly, industry regulation

has a detrimental impact on innovation performance, whereas regional regulation has a positive impact on innovation performance, and regional regulation has a negative moderating effect on R&D investment and innovation performance; conversely, industrial regulation has a positive moderating effect.

5.2.6 Dedication and level of innovation

The study findings revealed that the level of commitment and state of innovation is relatively high in the South African mining industry. Most participants have attested to their respective companies' commitment to innovations. Huge capital and resources have been allocated to innovations and new technologies. This is evident primarily in safety and production improvement initiatives. The study also indicates that the state of innovation in the South African mining sector looks promising. These findings are backed up by Hermanus (2017), who mentioned that a coordinated technical innovation program had been launched in South Africa as part of a bigger plan that addresses the social and environmental legacies of mining and spearheads reindustrialization. Co-funding, public-private partnerships, tying R&D to industry, societal needs, and co-planning are success factors. According to Hermanus (2017), the South African mining crisis was handled through a multi-stakeholder initiative called Operation Mining Phakisa, which made an effort to identify and address significant 'constraints to investment in and expansion of the South African mining sector'.

5.3 Answering Research Questions

This study's main research topic was to evaluate the critical challenges and opportunities for innovation in the South African mining industry by looking into both internal and external factors in mining firms. This report set out to answer four research questions using the TOE framework which focuses on Organisational and Environmental factors.

5.3.1 Q1: How does the South African environmental context affect and influence the adoption and implementation of innovative solutions in the mining sector?

Based on the responses from the participants, the following were noted:

- *Due to the ageing mines and low reserves of high-grade minerals, this acts negatively on innovations and technology adoptions as the majority of mining companies are unwilling to invest and devote resources to such mines.*
- *Second, it was noted that the South African mining environment is plagued with trade unions with a deeply ingrained culture of adhering to outdated practices and the habit of opposing changes. This affects innovations and technology adoption negatively.*
- *The shortage of sufficient infrastructure, namely energy and transportation infrastructure. This makes conducting business in South Africa somewhat more challenging than in other nations.*

5.3.2 Q2: What are opportunities for innovation raised by the South African mining environment?

By looking into the research findings, it is evident that most of the innovation issues faced by the mining industry are related to the delivery of internal processes. Areas that were highlighted to raise opportunities for innovation include:

- *Improving stakeholder engagement processes*
- *Operational efficiency improvements, with emphasis to energy, transport, communication/network underground and explosives.*
- *Employing stricter measures for adherence to health & safety rules*
- *Hiring people with the drive for technology and innovation*

5.3.3 Q3: What are the challenges for innovation raised by the South African mining environment?

Similar to research question 2, the study shows that most of the innovation issues faced by the mining industry are related to the delivery of internal processes, with only a few being environment related. This result was also reached after considering the seniority and experience of the respondents, regarded as experts in innovation and technology. The innovation challenges include:

- *Stakeholder engagement*
- *Employee buy-in*
- *Capital availability*
- *Change management processes*
- *Organisational readiness*
- *Depleting mine resources*

5.3.4 Q4: What is the state and level of commitment given to innovations in the mining sector?

The study findings revealed that the level of commitment and state of innovation is relatively high in the South African mining industry. There has been a couple of programmes initiated to develop and grow the initiatives targeted to improve this industry

5.4 Investigation limitations

The following factors are emphasised as study limitations:

- The goal was to interview at least twelve individuals, but only eleven were interviewed due to their unavailability. The number of participants in the study, or the sample size, was a drawback. The study was conducted with few platinum and gold mining sector participants, but Dworkin (2012b) deemed the sample size sufficient for qualitative research.

- Among many mines of different commodities in South Africa, the sampled population is relatively small and does not represent the mining industry of South Africa as a whole. Therefore, generalising the results to other commodities may not be appropriate.
- Qualitative research, by its very nature, involves the researcher as a contributing member and conceivably as a driver in the research's path. As a result, the study is subject to the investigator's preconceptions and biases. The interviews were conducted with the researcher's views under control.

5.5 Recommendations

It is recommended that the mining organisation invest in research and development to unlock and develop opportunities for innovation aligned with their business needs. The study mentioned that most innovation initiatives fail at concept face due to not serving the business objective. In addition, strong emphasises should be placed on ensuring that personnel in charge of heading or sponsoring innovations and technology are clued up in this field. It is clear from the findings that a lot can still be done to revive the status of the country’s mining sector. However, it is more on the industry as most findings reveal internal challenges regarding innovations and technology adoption.

5.6 Suggestions for future research

It is suggested that future work must involve measuring the innovation readiness of South African mining firms. More emphasis must be placed on this because money and time will be lost if the climate is not accommodating for innovations.

5.7 Conclusion

The study examined the challenges and opportunities for innovation in the South African mining industry. According to the research, innovation is hindered by organisational issues such as change management, stakeholder engagement, and the availability of finances. External elements, such as mining regulations, inhibit or enable innovations. Moreover, there are four areas where operational efficiency can be enhanced. According to the findings of this research, energy, transportation, big data, communication, and explosives have been highlighted as areas where innovation opportunities exist. Change management and stakeholder involvement were also identified as crucial areas requiring new solutions for effective operations to foster innovation.

REFERENCES

Aberdeen, T. (2013). Yin, R. K. (2009). Case study research: Design and methods (4th Ed.). Thousand Oaks, CA: Sage. *The Canadian Journal of Action Research*, *14*(1), 69–71. https://doi.org/10.33524/CJAR.V14I1.73

Amadi-Echendu, J., Lephauphau, O., Maswanganyi, M., & Mkhize, M. (2011). Case studies of technology roadmapping in mining. *Journal of Engineering and Technology Management - JET-M*, *28*(1–2), 23–32. https://doi.org/10.1016/j.jengtecman.2010.12.002

Baker, J. (2012). *The Technology–Organization–Environment Framework*. 231–245. https://doi.org/10.1007/978-1-4419-6108-2_12

Bartos, P. J. (2007). Is mining a high-tech industry?. Investigations into innovation and productivity advance. *Resources Policy*, *32*(4), 149–158. https://doi.org/10.1016/j.resourpol.2007.07.001

Bryant, P. (2015). The imperative case for innovation in the mining industry. *Mining Engineering*, *67*(10), 39–40.

Bryman A, Becker S, & Ferguson H. (2012). *Understanding research for social policy and social work: themes, methods and approaches*. Policy Press.

Calzada Olvera, B. (2022). Innovation in mining: what are the challenges and opportunities along the value chain for Latin American suppliers? *Mineral Economics*, *35*(1), 35–51. https://doi.org/10.1007/s13563-021-00251-w

Chiu, C.-Y., Chen, S., & Chen, C.-L. (2017). An Integrated Perspective of TOE Framework and Innovation Diffusion in Broadband Mobile Applications Adoption by Enterprises. *International Journal of Management*, *6*(1), 14–39. http://www.ijmess.com

Creswell, J. W., Hanson, W. E., Clark Plano, V. L., & Morales, A. (2007). Qualitative Research Designs: Selection and Implementation. *The*

Counseling Psychologist, *35*(2), 236–264. https://doi.org/10.1177/0011000006287390

Dutse, A. Y. (2013). Technopreneurship and Enterprise Growth in Nigeria: An Exploration into the Latent Role of Microfinance Banks. *IOSR Journal of Business and Management*, *12*(2), 25–32. https://doi.org/10.9790/487x-1222532

Dworkin, S. L. (2012a). Sample size policy for qualitative studies using in-depth interviews. *Archives of Sexual Behavior*, *41*(6), 1319–1320. https://doi.org/10.1007/s10508-012-0016-6

Dworkin, S. L. (2012b). Sample size policy for qualitative studies using in-depth interviews. In *Archives of Sexual Behavior* (Vol. 41, Issue 6, pp. 1319–1320). Springer Science and Business Media, LLC. https://doi.org/10.1007/s10508-012-0016-6

Ediriweera, A., & Wiewiora, A. (2021). Barriers and enablers of technology adoption in the mining industry. *Resources Policy*, *73*, 102188. https://doi.org/10.1016/J.RESOURPOL.2021.102188

Ernst and Young. (2015). *Business risks facing mining and metals 2014–2015.*

Fukugawa, N. (2006). Determining factors in innovation of small firm networks: A case of cross industry groups in Japan. *Small Business Economics*, *27*(2–3), 181–193. https://doi.org/10.1007/s11187-006-0010-2

Gao, S., Hakanen, E., Töytäri, P., & Rajala, R. (2019). Digital Transformation in Asset-intensive Businesses: Lessons learned from the metals and mining industry. *Proceedings of the Annual Hawaii International Conference on System Sciences*, *2019-January*, 4927–4936. https://doi.org/10.24251/hicss.2019.593

Gruenhagen, J. H., & Parker, R. (2020). Factors driving or impeding the diffusion and adoption of innovation in mining: A systematic review of the literature.

Resources Policy, *65*(November 2019), 101540. https://doi.org/10.1016/j.resourpol.2019.101540

Guest, G., Bunce, A., & Johnson, L. (2006). How Many Interviews Are Enough?: An Experiment with Data Saturation and Variability. *Field Methods*, *18*(1), 59–82. https://doi.org/10.1177/1525822X05279903

Hermanus, M. (2017). Mining redesigned - Innovation and technology needs for the future-A South African perspective. In *Journal of the Southern African Institute of Mining and Metallurgy* (Vol. 117, Issue 8, pp. 811–818). South African Institute of Mining and Metallurgy. https://doi.org/10.17159/2411-9717/2017/v117n8a12

Iacovou, C. L., Benbasat, I., & Dexter, A. S. (1995). Electronic Data Interchange and Small Businesses: Adoption and Impact of Technology. . *MIS Quarterly*, 465–485.

Jayaram, J., Oke, A., & Prajogo, D. (2014). The antecedents and consequences of product and process innovation strategy implementation in Australian manufacturing firms. *International Journal of Production Research*, *52*(15), 4424–4439. https://doi.org/10.1080/00207543.2013.849363

Jiang, Z., Wang, Z., & Li, Z. (2018). The effect of mandatory environmental regulation on innovation performance: Evidence from China. *Journal of Cleaner Production*, *203*, 482–491. https://doi.org/10.1016/j.jclepro.2018.08.078

Kahn, K. B. (2018). Understanding innovation. *Business Horizons*, *61*(3), 453–460. https://doi.org/10.1016/j.bushor.2018.01.011

Kuratko, D. F. (2009). The entrepreneurial imperative of the 21st century. *Business Horizons*, *52*(5), 421–428. https://doi.org/10.1016/j.bushor.2009.04.006

Kuratko, D. F., Covin, J. G., & Hornsby, J. S. (2014). Why implementing corporate innovation is so difficult. *Business Horizons*, *57*(5), 647–655. https://doi.org/10.1016/j.bushor.2014.05.007

Kuratko, D. F., Ireland, R. D., Covin, J. G., & Hornsby, J. S. (2005). A Model of Middle–Level Managers' Entrepreneurial Behavior. *Entrepreneurship Theory and Practice*, *29*(6), 699–716.

Lane, A., Guzek, J., & Van Antwerpen, W. (2015). Tough choices facing the South African mining industry. *Journal of the Southern African Institute of Mining and Metallurgy*, *115*(6), 471–479.

Lommerud, K. E., Meland, F., & Straume, O. R. (2006). Globalisation and union opposition to technological change. *Journal of International Economics*, *68*(1), 1–23. https://doi.org/10.1016/j.jinteco.2005.03.002

Mineral Council Of South Africa. (2019). *Facts and Figures | 2018 EDITION*. *September*, 1–47.

Mining: a brief history | Statistics South Africa. (n.d.). Retrieved June 18, 2022, from https://www.statssa.gov.za/?p=9720

MRG_1701_Mavroudis_Eickhoff_170116. (n.d.).

Ntsoelengoe, J. S. (2019). *Factors necessary for effective adoption of modernization in the South African mining industry*. *November*, 1–121.

Oliveira, T., & Martins, M. F. (2010). Information technology adoption models at Firm Level: Review of literature. *4th European Conference on Information Management and Evaluation, ECIME 2010*, *14*(1), 312–322.

Olvera, B. C. (n.d.). *Innovation in mining: what are the challenges and opportunities along the value chain for Latin American suppliers?* https://doi.org/10.1007/s13563-021-00251-w/Published

Pakrad, M., & . R. M. K. (2012). Identifying Effective Factors on Technological Entrepreneurship in Iranian Nanotechnology SMEs. *Information*

Management and Business Review, *4*(8), 461–466. https://doi.org/10.22610/imbr.v4i8.1001

Pereira Cabral, B., Lage de Sousa, F., & Canêdo-Pinheiro, M. (2020). Assessing the impacts of innovation barriers: a qualitative analysis of Brazil's natural resources industry. *Resources Policy*, *68*(February). https://doi.org/10.1016/j.resourpol.2020.101736

Pietrobelli, C., Marin, A., & Olivari, J. (2018). Innovation in mining value chains: New evidence from Latin America. *Resources Policy*, *58*(May), 1–10. https://doi.org/10.1016/j.resourpol.2018.05.010

Prior, T., Giurco, D., Mudd, G., Mason, L., & Behrisch, J. (2012). Resource depletion, peak minerals and the implications for sustainable resource management. *Global Environmental Change*, *22*(3), 577–587. https://doi.org/10.1016/j.gloenvcha.2011.08.009

Ramilo, R., & Embi, M. R. Bin. (2014). Critical analysis of key determinants and barriers to digital innovation adoption among architectural organizations. *Frontiers of Architectural Research*, *3*(4), 431–451. https://doi.org/10.1016/j.foar.2014.06.005

Rindfleisch, A., Malter, A. J., Ganesan, S., & Moorman, C. (2008). Cross-Sectional versus Longitudinal Survey Research: Concepts, Findings, and Guidelines: *Https://Doi.Org/10.1509/Jmkr.45.3.261*, *45*(3), 261–279. https://doi.org/10.1509/JMKR.45.3.261

Rogers, E. M. (1962). *DIFFUSION OF INNOVATIONS Third Edition*.

Sánchez, F., & Hartlieb, P. (n.d.). *Innovation in the Mining Industry: Technological Trends and a Case Study of the Challenges of Disruptive Innovation*. https://doi.org/10.1007/s42461-020-00262-1/Published

Saunders, M. A., & Lewis, P. (2019). Research Methods for Business Students Eights Edition Research Methods for Business Students. In *Research Methods for Business Students*.

www.pearson.com/uk%0Ahttps://www.amazon.com/Research-Methods-for-Business-Students/dp/1292208783/ref=sr_1_2?dchild=1&qid=1614706531&refinements=p_27%3AAdrian+Thornhill+%2F+Philip+Lewis+%2F+Mark+N.+K.+Saunders&s=books&sr=1-2&text=Adrian+Thornhill+%2F+Phili

Saunders, M. N. K., Lewis, P., & Thornhill, A. (n.d.). *Research methods for business students*.

Sirinanda, K. ,. (2019). Skills needed for digital mines. *The Australasian Institute of Mining and Metallurgy Bulletin,*.

Stubrin, L. (2018). Reprint of: Innovation, learning and competence building in the mining industry. The case of knowledge intensive mining suppliers (KIMS) in Chile. *Resources Policy*, *58*(October 2017), 62–70. https://doi.org/10.1016/j.resourpol.2018.09.001

Szirmai, A. (2012). Industrialisation as an engine of growth in developing countries, 1950-2005. *Structural Change and Economic Dynamics*, *23*(4), 406–420. https://doi.org/10.1016/j.strueco.2011.01.005

Vogel, J. A., Lind, H., & Holm, C. (2019). Incentivising innovation in the construction sector: The role of consulting contracts. *Construction Economics and Building*, *19*(2), 181–196. https://doi.org/10.5130/AJCEB.v19i2.6613

Wisdom, J. P., Chor, K. H. B., Hoagwood, K. E., & Horwitz, S. M. (2014). Innovation adoption: A review of theories and constructs. *Administration and Policy in Mental Health and Mental Health Services Research*, *41*(4), 480–502. https://doi.org/10.1007/s10488-013-0486-4

Zamrodah, Y. (2016). *済無No Title No Title No Title*. *15*(2), 1–23.

Zulu, M. S., Pretorius, M. W., & van der Lingen, E. (2021). The strategic competitiveness of the south african mining industry in the age of the fourth

industrial revolution. *South African Journal of Industrial Engineering*, *32*(3), 185–200. https://doi.org/10.7166/32-3-2627