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Digital Transformation Opportunities and Challenges in the South African Mining Sector

Ntokozo Mthimkhulu

Supervisor Ayanda Magida

A research report 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 Management in the field of Digital Business

Johannesburg, 2023

ABSTRACT

The sustainability of the South African mining sector is under threat due to multiple factors affecting the sector, these include high production, and labour costs, the decline in global commodities prices, aging infrastructure, plant and equipment, and strict health, safety, and environmental regulations. Most South African mining companies are operating old mines that are reaching their end of life. Therefore, South African mining companies are looking for innovative ways to remain sustainable and competitive.

The purpose of this research was to understand the potential Digital Technologies and Solutions that the South African mining sector can adopt, in addition to explore some of the Drivers and perceived Barriers to their adoption in their mining and operations processes.

A qualitative, exploratory research method was used to conduct the study, and thematic approach analysis was employed to explore the study objective. Nine participants were interviewed from different South African mining companies operating different commodities, and only participants in senior, middle, and junior management roles were selected for this study. Participants' interview responses were recorded, and transcribed, and data analysis using a thematic approach was applied.

Six themes emerged from the data analysis; these themes were composed of twenty-five categories. These categories were identified as drivers and barriers for South African mining companies to adopt potential digital technology and solutions in their mining and operations.

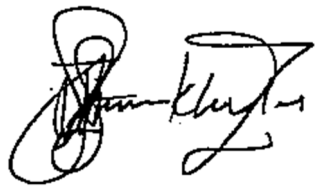
The barriers due to the South African mining sector's complex environment were identified as the reasons for the slow adoption of digital technologies and solutions by the mining sector. The mining sector must adopt digital technologies and solutions that are suitable for their environment.

The recommendations for the South African mining sector to successfully adopt digital technologies and solutions to their mining and operations and suggestion for further studies was presented

DECLARATION

I **Ntokozo Ziphozonke Terrence Mthimkhulu** declare that the research reported in this report is entirely my work, with the exception of the citations and acknowledgments. It is presented as a partial fulfillment of the University of the Witwatersrand, Johannesburg, Master of Management degree requirements in the field of Digital Business. It has never before been submitted to this university or any other university for a degree or examination.

Name: Ntokozo Mthimkhulu



Signature_____

Signed in Centurion **on the** 29 **of** June 2023

DEDICATION

To my mother Nkosingiphile Millicent Buthelezi - MaMthimkhulu, you've been the pillar of my strength, my prayer warrior. I know with no doubt that this Master's degree wouldn't have been possible without your constant prayers. Ngiyabonga Bhungane uNkulunkulu angigcinele wena and this Master's degree is yours.

I would like to importantly dedicate this Master's degree to my late MaMncane – Mbalizethu Nyamazela Mthimkhulu you always believed in me even at my young age. You saw something in me when you bought me envelopes and writing pads to apply for bursaries in order to get to university. It's sad that you never got to see me grow from a little boy from the dusty village of Thokoza - Ulundi into the man I've become. I dedicate this to you and I know you looking down from the heavens smiling to my achievements, may your Soul Rest in Peace. Forever in my heart.

Last but not least, I would like to dedicate this whole Master's degree to the whole entire Mthimkhulu family for all their support and encouragement.

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It appears difficult at first, but it eventually becomes easier. Every path we take has people who either make it easier or difficult for us to get there. My path has been both exciting and difficult. The following people have my deepest gratitude:

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- To my lovely kids, Daddy loves you, this one is for all of you, for allowing Daddy to juggle his school, work and your quality times. Thank you for your understanding. I give this one to you. I believe one day you guys will follow my steps and go even further. Education is key to success; business is life and entrepreneurship is a lifestyle. Study to empower yourself to be self-employed.
- To all my nephews, this one is for all of you, thank you for looking up to me which pushed me to even do better. I want you to know that you never too

old to study. Remember education and business are the biggest lever to financial freedom. Study not only to gather knowledge but to create business ideas that will empower you towards self-employment.

KEYWORDS

i. Digital Transformation
ii. Mining and Processes
iii. Digital Connected Mine
iv. Digital Technology Adoption
v. South African Mining Sector
vi. Digital Technologies and Solutions

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LIST OF ACRONYMS

IoT – Internet of Things

ML – Machine Learning

AI – Artificial Intelligence

OI – Operations Information

IT – Information Technology

4IR – Fourth Industrial Revolution

TOE – Technology Organisational Organizational

CHAPTER 1. INTRODUCTION

1.1 Statement of purpose

The purpose of this qualitative study was to understand the potential *Digital Technologies and Solutions* that the South African mining sector can adopt, in addition to explore some of the *Drivers* and perceived *Barriers* to their adoption in their mining and operations processes.

1.2 Background of the study

Global and South African mining companies are shifting and reconfiguring both their business and operating strategies by adopting new digital technologies and solutions in their mining and operations, this is happening rapidly. The rapid adoption is due to multiple factors that is affecting the mining sector, which includes market volatility, change in commodities demand, search for new resources and reserves, asset lifecycle improvement and extension to achieve operational excellence as well as policy shift (Local and Global) (Sganzerla et al., 2016). Digitalization in the mining processes involves the use of advanced digital technologies and solutions that have edge computing, analytics, and artificial intelligence capabilities to reduce costs, improve business productivity, and transform mining practices (Lazarenko et al., 2021; Elliott Charles, 2017; Vijaykumar et al., 2015).

Therefore, the digital technology selection process plays an important role in the success of the digital transformation process Figure 1.1. Figure 1.1 describes the 10 evaluation criteria that are used when choosing a new technology. Each criteria evaluate specific needs and requirements about the new technology to be adopted in order to determine its features, security, setup and maintenance cost etc. These digital technologies and solutions include but not limited to Sensors, Robotics, Bigdata, Artificial Intelligence (AI), Machine Learning (ML), advanced analytics, cloud computing, digital wearable technology, Internet of Things (IoT), etc. (Lazarenko et al., 2021; Konyukh, 2012).

Figure 1-1 - Technology Selection Criteria



"Source:(*10 Criteria to Evaluate When Choosing a New Technology*, n.d.)

However, the South African mining sector has been slow in its digital technologies and solutions adoption compared to global mining companies and has resulted in less digital transformation in the Sector (Wadula, n.d). South Africa's mining sector must increase its digital transformation by adopting digital technologies and solutions to stay competitive in the global market. This will reduce their production cost and increase production. South Africa's mining sector has recently started increasing its innovation by implementation cutting-edge technologies to improve efficiency of their mining and operations, to manage and improve their safety, health, and risk, while reducing their maintenance and extraction cost (4IR – The Future of Mining in South Africa – Issuu, nd.) .

Therefore, there is a pressing need for digital transformation in the South African mining sector to improve their competitiveness and safety by adopting digital technologies and solutions. For the purpose of the study, mining sector was classified

into two processes levels, management and operational, digital technologies and solutions can be adopted in all these process levels.

1.3 Research problem

South Africa's mining sector plays an important role in the South African economy, they employed 432 866 peoples, contributed R27,2 billion in taxes and R371,0 billion to the country's GDP in 2021 (Facts and Figures - Minerals Council South Africa, 2021; Fedderke & Pirouz, 2002).The sector has been facing a lot of challenges in the recent years, some of the challenges are the need for Safety Improvement, Productivity Increase and Operational Cost Reduction. Adopting digital technologies and solutions in mining and operations will reduce these challenges by streamlining operations work processes and providing greater data insights to drive strategic decisions (Dayo-Olupona et al., 2020).

Mining sector digital maturing is less than 40 percent compared to other industries, e.g., manufacturing, automotive and chemicals, they are in their early stages of digital transformation, this is due to the nature and complexity of their mining and operation processes and its regulations (*Racing Toward a Digital Future in Metals and Mining | BCG*, n.d.). Digital technology adoption has grown interest among both academics and practitioners (Lazarenko et al., 2021). Global mining companies have advanced their progress in their digital transformation compared to South African mining companies. Slow digital transformation by adopting digital technologies and solutions in South Africa mining sector is a serious problem. Theirs is also no trends of digital technologies and solutions adoption and implementation in South Africa mining sector (Barnewold et al., 2020; Barnewold, 2019).

Therefore, for South Africa's mining sector to increase their digital technologies and solutions adoption, there is a need to understand the potential technologies and solutions that the sector can adopt, explore drivers and perceived barriers for their adoption. This will assist the sector with selection and adoption of digital technologies and solutions that are suitable for their environment in order to increase their digital transformation.

1.4 Research questions

1. What are the potential Digital Technologies and Solutions that South African mining sector can adopt in their processes?
2. What are the Drivers for adopting Digital Technologies and Solutions in South African mining sector?
3. What are the Barriers for adopting Digital Technologies and Solutions in South Africa mining sector?

1.5 Rationale

When COVID19 pandemic hit the world, companies that were digitally transformed were able to respond to the challenges that came with lockdown and their employees could work remotely. Digitally transformed companies were able to quickly adjust and set up their systems for their employees to work remotely without interrupting their duties (Ng et al., 2022). Digital transformation has multiple benefits, some of them are production increase, improved business models and customer experience, it is also an enabler for innovation and agility. Therefore, it is crucial for South Africa mining sector to accelerate their digital transformation and by identifying digital technologies and solutions that are unique and compatible to their environment, clearly identify and evaluate drivers while mitigating their barriers.

South African mining companies are under pressure to address their industry challenges and digital transformation has been identified as the solution to some of the sector challenges (World Economic Forum, 2017). Other industries have benefited from digital transformation and mining can implement digital transformation in their operations as well and adopt digital technologies and solutions (*Racing Toward a Digital Future in Metals and Mining | BCG*, n.d.). So, there is a need for digital transformation in the South Africa mining processes value chain. The study will assist in determining the potential digital technologies and solution that South Africa's mining

sector can adopt in their management and operational processes, drivers, and barriers for their adoption (Ediriweera & Wiewiora, 2021).

1.6 Delimitations of the study

Mining and operations processes were divided into leadership, management, and operational process levels for this study. The research and literature review focused only on management and operational process levels, looked at digital technologies and solutions that can be adopted on these levels, identified both drivers and barriers for their adoption.

Leadership process level was excluded from the study, because it only focuses on corporate and governance activities. The study aimed on identifying potential digital technologies and solutions that would have impacts on organisational and personal management, plant and equipment operations and maintenance.

1.7 Definition of terms

Digitization: it is the creation of digital representation of physical objects (Gupta, 2020).

Digitalization: is the enabling processes by leveraging digital technologies and digitized data (Gupta, 2020).

Digital transformation: explains how the adoption of digital technologies has caused a company's or business model's total transformation (Barnewold et al., 2020))

Digital transformation process is an important factor among other factors which that central to the development of the mining sector (Lazarenko et al., 2021).

Digital technologies: are electronic tools, systems, devices, and resources that generate, store or process data (Virlan, 2022).

Integrated platform: Internet of Things platform that provides IoT devices, networking, and network management, handling of information, processing, and analysis, creation of applications, protection, control of access, tracking, event processing, interfacing, and integration (*Industry 4.0 and the Fourth Industrial Revolution Explained*, n.d.).

Artificial intelligence (AI): It is the advanced analysis and logic-based techniques, which includes machine learning, to interpret events, support and automate decisions, and take actions (Definition of Artificial Intelligence (AI) – IT Glossary | Gartner, n.d.; What Is Artificial Intelligence (AI)? | Oracle South Africa, n.d.).

Machine learning (ML): It is an algorithms that are composed of many technologies including deep learning, networks and language processing), it is used in unsupervised and supervised learning, its operation guided by lessons from existing information (Definition of Machine Learning – Gartner Information Technology Glossary, n.d.).

Cloud computing: It is the delivery of multiple services through the Internet, which includes tools, applications for big data storage, servers, database, networking, and software (Frankenfield Jake, 2022) .

Big data management: It's the efficient handling, storage, organization or use of large volumes of structured and unstructured data belonging to an organization (Rossi & Hirama, 2015; Qi & Qi, 2020).

Internet of things Technology is the integration of computer-based digital technologies connected to industrial machines through an interconnected network, for the measurement of parameters, workflow control and automatically collecting data from multiple sensors (Molaei et al., 2020; Liu & Song, 2011).

Automation: is the process of automating a device, a procedure, or a system." Merriam-Webster dictionary.

Remote Operation Centres: is a centralized control room that is situated remotely away from mining operations, it monitors and control several sited, enabled by IoT, Big Data Management, Artificial Intelligence and Integrated Digital Platforms. Remote operating centres enable easy and quick collaboration of resources planning and production planning decisions. It empowers operators to optimally monitor, execute and control operations in multiple sites with less resources (Gallestey et al. 2015; Kauppila et al., 2019).

Robotics: Mining robots are devices with advanced skills to sense and analyze their surroundings. These machines are purposed built robots to perform a specific task which demand effective automation in erratic and changing mining situations (Corke et al., 2008).

Connected worker: Connected worker is the workers that is equipped with digital devices that can remotely communicate and transmit information through IoT to the Remote-Control Centres (The Connected Worker | Deloitte UK, n.d.; adammyatt, 2018).

Smart Sensors: mart sensors are built as IoT components that convert the real-world variable that they are measuring into a digital data stream for transmission to a gateway (Posey Brien, n.d.).

1.8 Assumptions

The research assumed that the slow digital transformation progress in South Africa mining sector was due to the following reasons:

- Available digital technologies and solutions are not suitable for mining sector
- Lack of knowledge on which digital technologies and solutions are suitable for the sector.
- No clear definition and understanding of drivers for their digital technologies and solutions adoption.
- No proper evaluation of barriers for digital technologies and solutions before adoption.
- Digital technologies and solutions have high impact on management and operational mining levels,
- Digital technologies and solutions adoption has less impact on the leadership processes level.

The assumption was that management and operational process levels were similar irrespective of the commodity differences, process value chain required similar digital technologies and solutions to address their challenges.

1.9 Chapter Outline

Below is the outline of how the research problem was addressed:

Chapter two systematically reviewed literature from the academic papers and journals related to the digital technologies and solutions adoption in mining sector and South African mining sector. Systematic literature review offered an overview on this topic. Potential digital technologies and solutions for adoption in mining sector were identified, with their drivers and barriers for adoption in management and operations processes.

This chapter also presented theoretical framework that was needed to be answered. Technology Organization Environment (TOE) framework was used for this study, this theoretical framework is composed of three elements, Technology, Organisation and Environment contexts, these elements influence technology adoption and innovation. TOE framework is the best framework for evaluation of existing and new technology capabilities and limitations, identifications of organisational drivers and barriers for new technology adoption and environmental factors where the new technologies will be adopted (Koul & Eydgahi, n.d.).

Chapter three outlined and detailed the research methodology that was used for the study, what data collection method, instruments, and analysis were used, as well as instruments and procedures for data collection. Limitations and conclusion on how the data collection process methods provided quality and credible information.

The research study's findings are presented in Chapter four in the form of direct and indirect quotations and interpretations of the responses provided by the participants. The interview transcripts were analysed and broken up into pieces to find the themes that will emerge from the study. The emerging themes are each discussed and summarised at the end of the chapter.

The study results for each research question are thoroughly analysed in Chapter 5. Further, the results were investigated and contrasted with the relevant literature.

Chapter six presents the conclusions of the findings from both the research and literature, provides recommendations based on the findings that emerged from the research questions. Prepositions are also evaluated against the study findings to confirm or refute them.

CHAPTER 2. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Introduction

This chapter defines digital transformation within the context of mining sector. The chapter provides consolidated theories from various sources on digital technologies and solution options that mining sector can adopt, their drivers and challenges for their effective adoption. The Technology Organisation and Environment (TOE) model was used for this study, it has been used by several academics to investigate barriers to innovation adoption and facilitators of innovation adoption at both organizational and industry levels. (Baker, 2012a). TOE framework has three major components, technological, organisational, and environmental factors for technologies and solutions adoption. These factors influence the adoption and implementation of digital technologies and solutions (Tornatzky et al., 1990).

Through literature review, the research looked at potential digital technologies and solutions that mining sector can adopt. This further provided in-depth exploration of drivers and challenges for their adoption, i.e., what drives and limits mining sector from adopting some of these digital technologies and solutions in their management and operational processes. The chapter concludes with an in-depth review of the literature on the adoption of digital technologies and solutions, including opportunities and challenges for their adoption. The impact of digital technologies and solutions adoption mining sector is largely unknown to date (Barnewold et al., 2020). There is a strong view that digital technologies and solutions can have a positive impact on management and operational mining processes. Digital transformation by adopting digital technologies and solutions is expected to produce a significant improvement on management and operational mining processes.

There is a link between digital technologies and solutions adoption and improvement in management and operational processes, this study seeks to identify potential available digital technologies and solutions that can be adopted by South Africa mining sector, identify drivers and barriers for their adoption. Answering the above research questions will assist South Africa mining sector to improve and accelerate their digital

transformation which will pave their way towards future digital mining and achieving their Mining 4.0.

2.2 Definition of topic or background discussion

Business environment constantly changes, therefore for businesses to survive in their dynamic and complex business environment, they need to constantly evolve by monitoring and analysing their industry technology trends regularly (Sánchez & Hartlieb, 2020). Knowing latest trends will assist them to match their digital transformation drivers with potential digital technologies and solutions, they will identify barriers that might prevent the adoption of these potential digital technologies and solutions (Barnewold et al., 2020). Mining sector is currently facing multiple industry challenges and changes in their business environment that requires innovation. The sector must search for potential digital technologies and solutions that will facilitate their innovations through digital transformation in their mining and operations processes. Digitalization in mining is defined as the use of digital sensors or systems, and data to reduce cost, maximize production, and modernize mining and operations processes (Khoyutanov et al., 2022). There is no digital transformation without digitalization and digitization, below is the definition of the three digital transformation stages Figure 2.2. Digital transformation is a business model's total transformation as a result of the use of digital technologies and solutions (Barnewold et al., 2020).

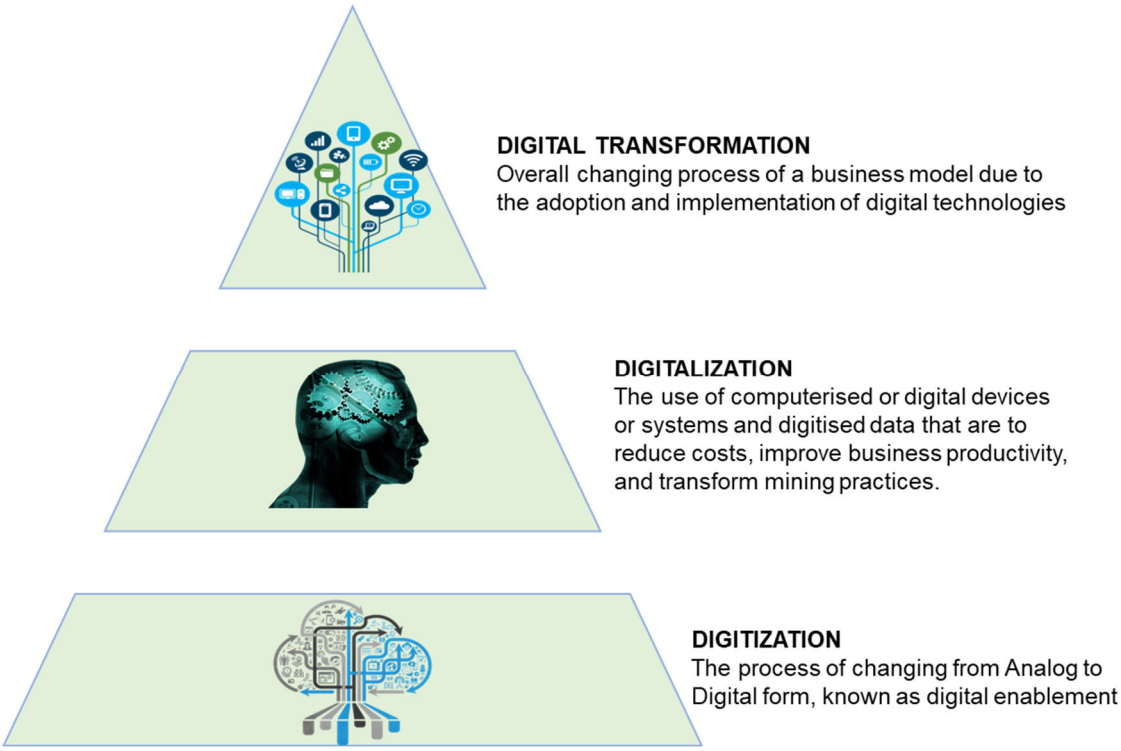


Figure 2-1 - Digital Transformation Process – (Researcher, 2023)

The majority of companies are starting their journeys toward digital transformation in this digitally connected world by adopting latest digital technologies and solutions to improve their management and operational processes. They do this to remain competitive in the market, reduce risk and increase their performances. However, mining sector has difficulty in deciding which digital technologies and solutions to adopt and relevant to their needs and challenges (Lazarenko et al., 2021). Across all industry sectors, companies are facing increased pressure to include digital transformation on their business strategies and embrace digitalization opportunities by adopting latest digital technologies in their operations, mining is feeling this pressure (Lazarenko et al., 2021). Digital transformation is the total business model process change empowered by the implementation of digital technologies and solutions. It is therefore imperative to research about which available potential digital technologies and solutions are in the market that can assist South Africa mining sector on their digital transformation. To also identify drivers and barriers for adoption of these potential digital technologies and solutions in mining management and operational processes. There are no definitive indications of the trends or direction that the South Africa mining

sector is adopting digital technologies and solutions in their mining and operations (Barnewold et al., 2020). Hence there is a need for this research.

2.3 What are the potential Digital Technologies and Solutions that South African mining sector can adopt in their processes?

An organizational-level theory called the TOE framework describes how three key elements of an organization influences adoption decisions. Technological, organizational, and environmental are three elements. Each of the three elements have an impact on technology selection and innovation (Baker, 2012a). The company's technological context encompasses all important technologies, including those that are now in use and those that are on the market. Existing technologies of the company are significant in the adoption process because they create a general limit on the scope and speed of technological advancement that the company can make (Baker, 2012a). The organizational context describes the features and assets of the business, such as the relationships between organizational structures and employee relationships, internal communication channels, scale, and slack resources. The regulatory environment, the industry's structure, and the existence or lack of technology suppliers are all considered to be part of the environmental context. This study used TOE Framework theory.

One of the three major factors for technology adoption according to TOE framework is technology, it is therefore very important for mining sector to constantly search for latest available digital technologies and solutions to adopt. This section of the study present literature review outcome on potential digital technologies and solutions that can be adopted by mining sector in their management and operational processes. Digital technology and solutions adoption is not a simple process of selecting and installing successful digital technologies and solutions from other industries, this applies to mining sector due to the unique mining and operations conditions (Barnewold et al., 2020). Technology selection can be achieved in the mining sector by using multi-criteria methods when selecting digital technologies and solutions. This

criterion will assist with digital transformation process roadmap for mining sector to facilitate their digital transformation in their sector (Dayo-Olupona et al., 2020).

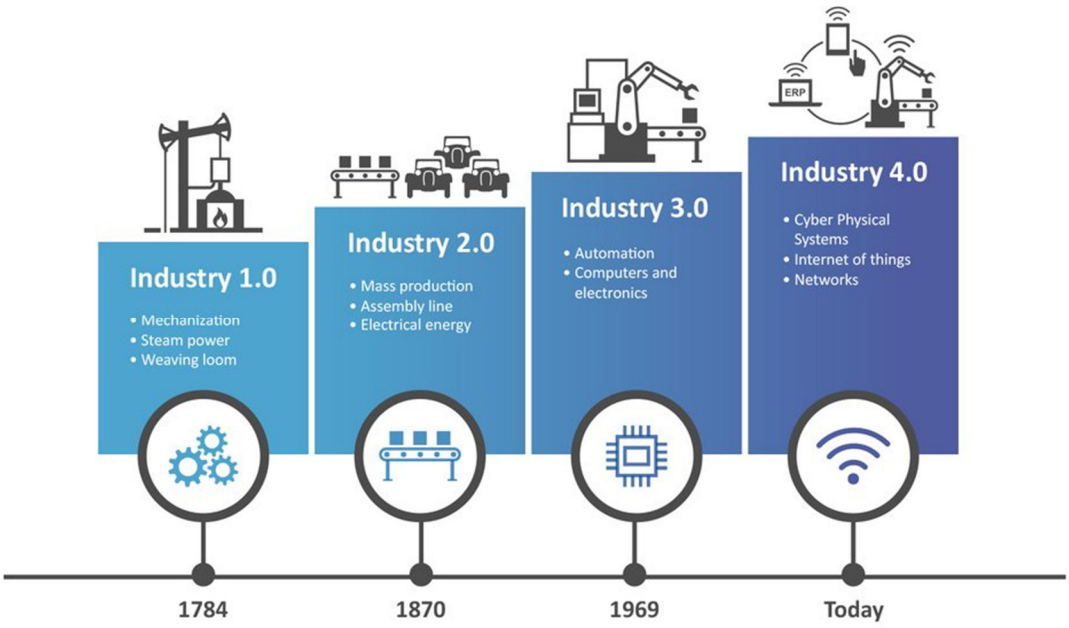


Figure 2-2 - Fourth Industrial Revolution (*Industry 4.0 with the Professionals - b.Telligent*, n.d.)

Industrial Revolution Figure 2.2, is the process of technological change by the industry and machine manufacturing. These changes introduce different ways of working and living and transformed society (*Industrial Revolution | Definition, History, Dates, Summary, & Facts | Britannica*, n.d.). The concept is based on digital technologies implementation to production processes, it is the combination of internet-oriented digital technologies, smart connected sensors, smart machines, and Information Technology (IT) and Operations Technology (OT) systems across company's value chain (Jacobs & Webber-Youngman, 2017). Mining sector needs to create their own industrial revolution Mining 4.0 (Hamzeh et al., 2018; Kagan et al., 2021; Santos et al., n.d.) and adopt digital technologies and solutions in the mining and operations.

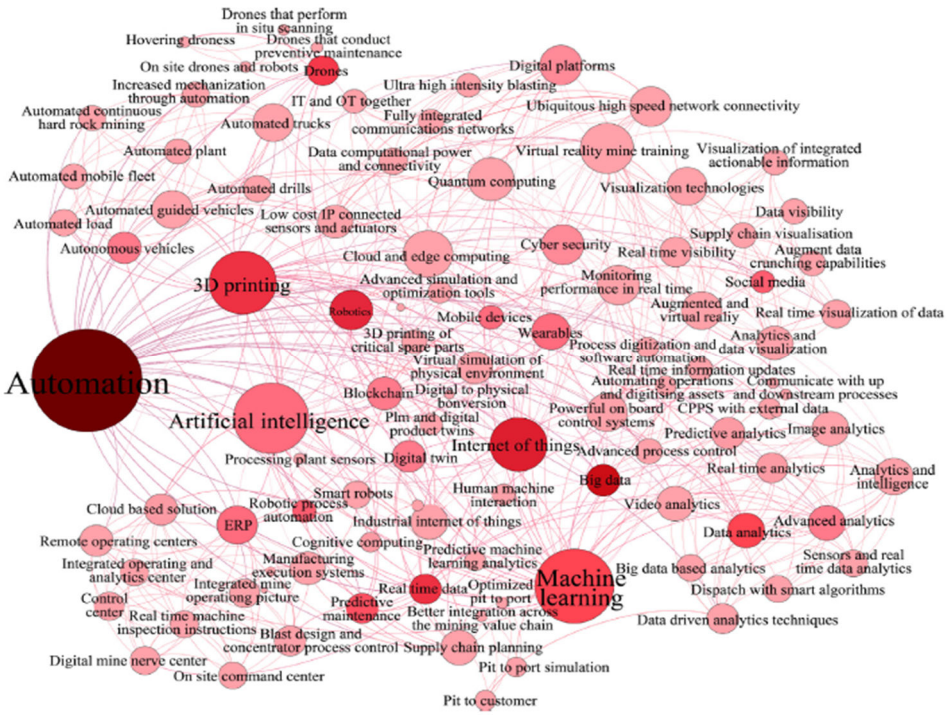


Figure 2-3 - Digital Technologies and Solutions that can be adopted by Mining Sector (Barnewold & Lottermoser, 2020)

(Barnewold & Lottermoser, 2020) identified one hundred and seven digital technologies and solutions that are being pursued by mining sector. Figure 2.3 shows some of these technologies were actively implemented in one hundred and fifty-eight underground and surface mines. (Barnewold et al., 2020) also identified ten digital technologies and solutions for the mining sector.

As indicated in chapter 1, the study will be limited to digital technologies and solutions that can be adopted mining sector and have impact in management and operational processes.

Table 2-1 - Digital Technologies and Solutions for Management and Operational Processes

Digital Technologies and Solutions applicable to Management Processes	Digital Technologies and Solutions applicable to Operational Processes
Advanced Analytics	Internet of Things (IoT)
Cloud Computing	Automation
Big Data Management	Remote Control Centre
Integrated Platforms	Connected Worker
Artificial Intelligence	Robotics

Table 2.1 presents digital technologies and solutions that were identified by different authors during literature review, these technologies and solutions can assist mining sector in achieving their digital transformation strategy by adopting them in their processes value chain.

Internet of Things (IoT) is considered as the overarching digital technology and solution that mining sector must adopt. It is the digital technology platform that interconnect digital technologies and solutions in different process levels. It has brought a lot of benefits for other industries sectors and can do the same for mining sector. Increasing digital technology and solution adoption result in increased digital transformation. IoT has the potential to improve both management and production processes by enabling the extraction of valuable data and information from these processes.

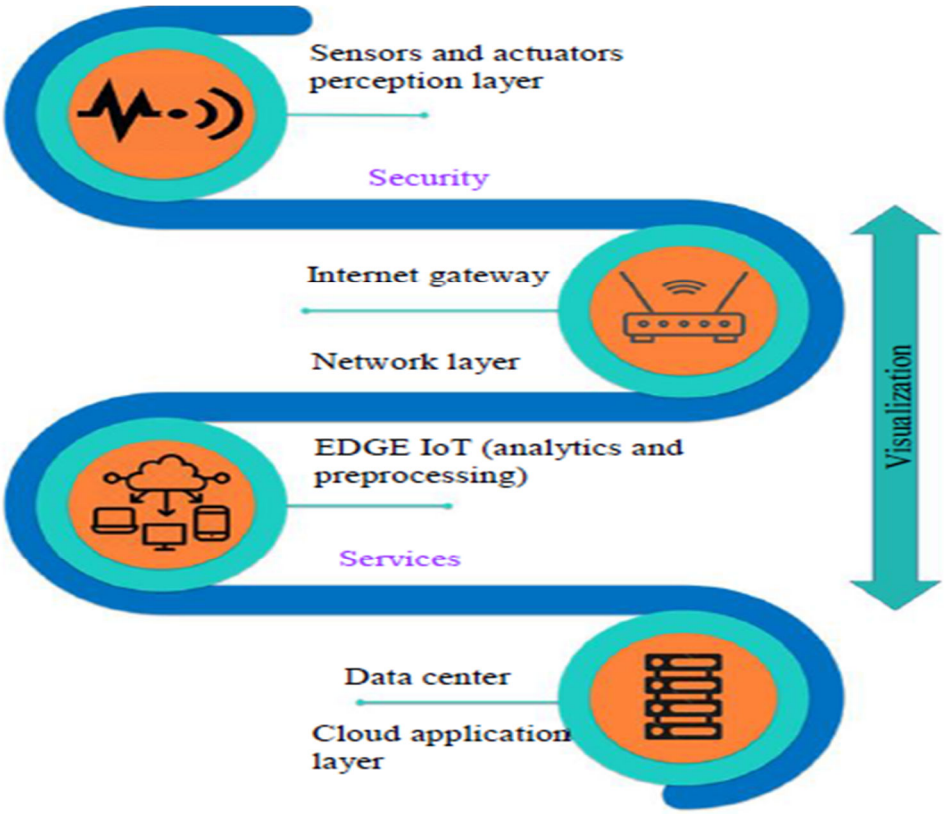


Figure 2-4 - Schematic Architecture of IoT (Molaei et al., 2020)

Figure 2.4 is the schematic architecture of IoT showing the link between all the IoT digital technologies that mining sector can adopt to realize their digital transformation.

2.4 What are the Drivers for adopting Digital Technologies and Solutions in South African mining sector?

Organization and environment are two of the TOE Framework three elements. During the literature review, different researchers identified different drivers for digital technologies and solutions adoption by mining sector in their management and operational processes. These drivers emanate from both organisation and environment elements as outlined in the TOE Framework.

The mining sector is adopting digital technologies and solutions to increase its competitiveness through business production improvement (Lazarenko et al., 2021); (Barnewold & Lottermoser, 2020). Reducing operational risk and increased competition for scarce resources and their remote location was identified by (Lazarenko et al., 2021) as the driver for digital transformation in the mining sector. Plant performance increase and reduction in breakdowns were identified as other reasons for the mining sector to adopt digital technologies and solutions in their operations (Lazarenko et al., 2021); (Molaei et al., 2020). Efficient and secured mining operational process (Lazarenko et al., 2021); (Molaei et al., 2020). Commodities price fluctuations both local and global have pushed the mining sector to look for digital technologies and solutions to assist them to remain competitive (Dayo-Olupona et al., 2020). There is a big need for mining and operational cost reduction in the mining sector (Barnewold & Lottermoser, 2020); (Molaei et al., 2020).

Increase in operations costs due to extraction of low-grade material, using specialized drilling technologies (Dayo-Olupona et al., 2020); (Gruenhagen et al., 2022); l (Aziz et al., 2020; Ralston et al., 2014; Barnewold & Lottermoser, 2020; Fedulova et al., 2020;). Most mining companies operate mines that are reaching their life of mine and they a mining remote and deep terrain which require special technologies (Gruenhagen et al., 2022). Mining deep and dangerous terrain has forced the mining sector to adopt digital technology and solutions to remove workers from dangerous activities, especially underground mines (Fedulova et al., 2020); (Cudjoe & Cawood, 2022).

The mining sector has strict Health, Safety, and Environmental compliance Laws and Regulations. The mining sector is therefore looking for digital technologies and solutions that will assist and improve their compliance, digital technologies and solutions that will help them to detect and prevent any SHE risks (Dayo-Olupona et al., 2020); (Gruenhagen et al., 2022); (Fedulova et al., 2020); (Molaei et al., 2020). Social distancing and remote working due to the Covid 19 Pandemic, was the biggest driver for mining companies to adopt digital technologies and solutions to continue operating during lockdown. Digital ineffectiveness has been identified as a Top 10 business risk (Lazarenko et al., 2021).

The mining sector is transforming its mining and operations processes due to the need to measure productional variables to respond on time to avoid production losses (Barnewold & Lottermoser, 2020). The mining sector wants to increase plant efficiency through automation of processes and the use of remote-controlled equipment (Fedulova et al., 2020). To remain competitive and operate plants and equipment, the mining sector is adopting digital technologies and solutions that will enable preventative and predictive maintenance in their operations. (Gruenhagen et al., 2022); (Molaei et al., 2020). Mining ore and product double handling due to poor quality checks has pushed the mining sector to adopt technologies that will enable real-time online quality testing and optimize payload (Gruenhagen et al., 2022); (Cudjoe & Cawood, 2022). Real-time reporting for quality assurance and quality control analysis (QA/QC) to the Remote-Control Centres (Cudjoe & Cawood, 2022).

It is very important for the mining sector to measure, monitor, and track material variables in mining plants for quick identification of problem areas, e.g., tonnages at transfer points. Quick and easy accounting and reconciliation. Monitoring the rate and volumes of mining and processing to improve and fast decision-making can be achieved by adopting digital technologies and solutions in their mining and operations (Cudjoe & Cawood, 2022); (Barnewold & Lottermoser, 2020). There is a need for visibility of mining and operations costs and savings across the whole value chain (Molaei et al., 2020).

The mining sector as part of their sustainability objectives, they are adopting digital technologies and solutions to reduce their energy and water use as well wastage (Fedulova et al., 2020; Aznar-Sánchez et al., 2019). Asset and worker tracking during operation to manage human and machine movement. Connected workers, connecting workers and equipment for efficient utilization of resources (Barnewold & Lottermoser, 2020). Remote monitoring of tailing dams, drilling, and blasting (Molaei et al., 2020). Online condition assessment and monitoring, e.g., Gas monitoring for Ventilation and evacuation for underground mines (Molaei et al., 2020).

2.5 What are the Barriers for adopting Digital Technologies and Solutions in South Africa mining sector?

Organization and environment are two of the TOE Framework three elements. Different researchers identified different barriers for digital technologies and solutions adoption by mining sector in their management and operational process levels. These barriers emanate from both organisation and environment elements as outlined in the TOE Framework.

There is a lack of understanding and experience of potential available digital technologies and solutions. Lack of access to the right digital technologies and knowledge (Lazarenko et al., 2021). There is a huge gap and lack of digital business skills and organizational capacity to select and implement digital transformation by adopting digital technologies and solutions for the mining sector (Lazarenko et al., 2021); (Barnewold & Lottermoser, 2020); (Molaei et al., 2020). Mining operators focus on project output instead of sustainable business outcome which is contrary to digital technologies and solutions which focused on long-term business sustainability (Lazarenko et al., 2021). There is an inability for digital technologies and solutions service providers to facilitate the digital transformation process (Lazarenko et al., 2021). Lack of understanding by the potential users of the link between digital technologies and digital principles (Barnewold & Lottermoser, 2020).

Limitations of adoption of digital technologies and solutions in mining and processes due to existing infrastructure such as network coverage, and limited connectivity due to poor network coverage (Barnewold & Lottermoser, 2020); (Molaei et al., 2020); (Aziz et al., 2020); (Fedulova et al., 2020). There is a difficulty in merging Operational Technology (OI) and Information Technology (IT) to create IoT due to old existing operations infrastructure that does not have digital capabilities (Molaei et al., 2020). Difficult integration of old technology with new technology (Molaei et al., 2020). There is a huge data exchange and storage requirements that mining companies do not have. This data requires sophisticated data science and analytics to get value out of it (Molaei et al., 2020); (Aziz et al., 2020); (Fedulova et al., 2020). There is a lack of Research and Development capacity and willingness for mining companies to lead the

diffusion of new technologies and risk being the Pioneers (Barnewold & Lottermoser, 2020); (Molaei et al., 2020). There is a fear and resistance to altering the mining activity risk profile with new technologies and solutions (Molaei et al., 2020). Digital technology adoption requires huge infrastructure investment which small mining companies do not have. Investment in innovations and digital technologies and solutions is less in smaller mining companies than it is in larger mining companies. (Lazarenko et al., 2021); (Majstorovic et al., 2021).

2.6 Analytical Framework

2.6.1 *Technology Organisational Environmental (TOE) Framework*

After the literature review, different frameworks were identified that are relevant to the subject of digital transformation and digital technologies and solutions adoption in the mining sector. It was discovered that the majority of relevant frameworks that dealt with the subject of digital business transformation directly had their roots in business publications. Even while some attempts had been made to apply technology from an organizational point of view, many in academics were more interested in how people used technology and how they adopted it. Academic frameworks that examine technology adoption from a "person" perspective don't go deep enough to comprehend how various industry segments are being altered and transformed by digitisation and digitalization. This is an important shortcoming since technological adoption and digital transformation are more of an issue of organizational strategy than they are of technology adoption and use behaviour. To make Technology Acceptance Model and Unified theory of acceptance and use of technology more solid analytical frameworks capable of addressing the demands of digital technologies and solutions, their industry effect, and organizational strategy, they may need to undergo substantial modifications. The concepts that are covered by the majority of business-derived frameworks, such as human resource concerns, customer engagement/centricity, and agility, highlight the limitations of academic frameworks in comprehending digital business transformation.

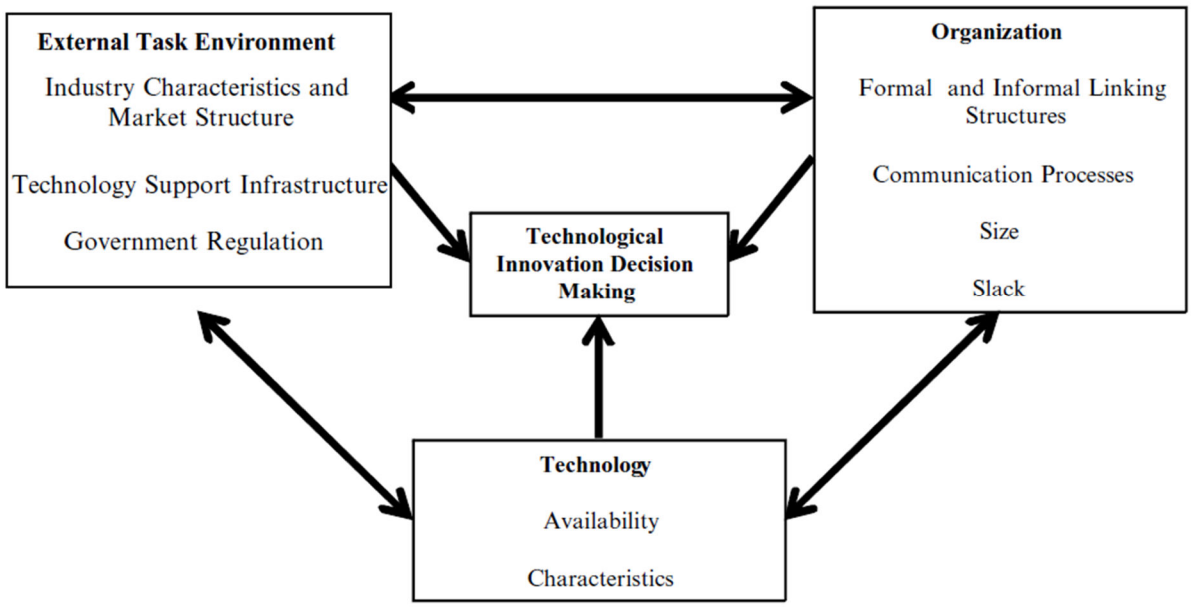


Figure 2-5 - Technological Organisational Environmental Framework (TOE) (Baker, 2012b) pg. 7

The theoretical framework that was used for this study was Technology Organization Environment framework (Baker, 2012a; Tornatzky et al., 1990). Technology Organization Environmental Framework (TOE) as shown in Figure 2-5 is an organizational-level theory which outlines how three different elements of a firm's context affect adoption decisions. These elements are *technological,* organizational, and environmental *context*. They are all said to have an impact on technological innovation (Baker, 2012b). TOE Framework was identified as the perfect theoretical framework for this study due to its relevance to the research topic. It looks at these three organisational elements, these elements were identified during literature review as the key elements for digital technologies and solutions adoption.

TOE framework looks at both existing and new technologies as part of the technology adoption process. Evaluating both compatibility and limitations for adoption of new technologies as well as the interface to existing technologies. TOE framework also looks at the characteristics of the organisation including its human resources, size, and structures. This element is important to identify drivers and barriers for digital

technology and solutions adoption. Organisational skills and existing infrastructure were some of the identified barriers for digital technologies and solutions adoption. Organisation must identify their driver and barriers for their digital technologies and solutions adoption and TOE Framework is the relevant theoretical framework. TOE framework also looks at the environmental factor of digital technology and solutions adoption, which is suppliers of these technology and solutions, regulation that govern the industries. Mining sector is very regulated and digital technologies and solutions that can be adopted by mining have to comply to these regulations. Therefore, TOE framework was the suitable tool for the research problem that this study was trying to answer.

2.7 Conclusion of Literature Review

Digital transformation in the mining sector can be achieved by the adoption and integration of digital technologies and solutions into management and operational processes of a mining companies, optimizing operations and value delivery. The mining sector will tremendously benefit by adopting digital technologies and solutions in their mining and operations, they will optimise operations, increase assets performance and reduce risks. However, to achieve this, they must choose digital technologies and solutions that fit their organisational and environmental requirements. They must evaluate their digital transformation drivers and impact these technologies and solutions will have on their entire management and operational processes. Barriers for the adoption will also have to be clearly identified.

Literature review revealed that mining sector has not yet identified suitable digital technologies and solutions which they can adopt for their environment. There is also a lot of different drivers for mining sector to adopt some of these digital technologies and solutions without a clear understand of their infrastructure limitation and requirements. There is also a lot of barriers that seem to be overlooked when persuading the adoption of these technologies and solutions which might be the reason for slow progress and somehow failure in their adoption. Therefore, the research question to know about the real mining sector drivers and barriers for their

digital transformation by adopting digital technologies and solutions is worth researching to get the real reason for the slow digital transformation progress.

CHAPTER 3. RESEARCH METHODOLOGY

This chapter discusses the research methodology, design, and analysis that was followed during the investigation of the research questions presented in chapter 2. The study wanted to understand the digital technologies and solutions that are being persuaded for adoption by South African mining sectors, what were the drivers and barriers for their adoption. The research used an exploratory study methodology that was centred on the discovery process and involved identifying the influential factors found in research-related literature. Participants' data were collected, and an inferring model was applied to the study's findings (Saunders and Lewis, 2018). This approach supported the selected qualitative research method as it rigorously explores the relevant research factors in-depth (Soiferman, 2010; Creswell, 2018). The reason exploratory approach was used is because it pursues new insights and assess topics from a new perspective. An inductive exploratory approach was used for this study as there was no specific framework that was evident in the literature to test against the adoption of technologies and solutions in the mining industry. Data was collected using interview research questionaries which was conducted online using Microsoft Teams with all participants.

Firstly, the chapter discusses the research methodology and research design used for this study as well as justification why this methodology was used. Detail description of sampling method used, instruments, analysis, and measurements used for data collection was be discussed. Limitations encountered during the study. Validity traceability and transferability of data collected is explained. The chapter conclude by explaining how the research was conducted in an ethical manner.

3.1 Research approach – Qualitative

Qualitative research approach methodology was used for this study, this method was chosen because there's little information about the digital transformation opportunities and challenges in the South African mining sector and this methodology allows for a deeper understanding of research topic. It was also chosen due to its emergent characteristics and flexibility (Barnewold et al., 2020). The intention of this study was to get a deeper knowledge about the opportunities and challenges for digital transformation in the South African mining sector, so it was important to build the understanding as the information emerges. Data was analysed until themes and patterns were established.

The research results and conclusions were linked back to the research questions. Online interviews were conducted using Microsoft Teams and findings were identified that can assist the South African Mining sector in starting and increasing their digital transformation journey by adopting digital technologies and solutions in their mining and operations.

3.2 Research design

According to Saunders and Lewis (2018), for a qualitative research study, there are three main research designs: exploratory, descriptive, and explanatory. The research design for this study facilitated the understanding of potential Digital Technologies and Solutions that the South African mining sector can adopt, including the factors that drives their adoption as well as barriers that prevent their adoption using the collective case study design. According to Baxter and Jack (2008), the collective case study technique aims to provide insight and understanding into the situation or phenomenon under consideration when more than one instance is being studied. The results from a collective case study are robust and reliable (Baxter & Jack, 2008). The purpose of this research was to uncover the main factors influencing and impeding the South African mining industry's adoption of digital technologies and solutions, collective case study methodology was used. The strategy involved detailed description of the multiple cases within South African mining sector. Qualitative case study provided tools to

study the drivers and barriers of digital transformation in the complex South African mining sector (Creswell et al., 2016). This research case study was based on different mining companies operating in different commodities adopting digital technologies and solutions across their business processes value chain. A case was group of mining companies operating in the different commodities field such as coal, platinum, and diamonds, etc.

The study collected information from six different South African mining companies' sizes operating different commodities where data was generated by conducting online interviews. The data gathered provided context on the drivers and barriers for adoption of digital technologies and solutions in the South African mining sector.

3.3 Data collection methods – Online Interviews

Data was collected using online Microsoft Teams one-to-one interviews. This method is commonly utilized in qualitative research for collecting information or data. It was very important for the success of this study to establish trust between the participants and the researcher. Direct conversations with the participants were used by the researcher to gather information. This method offered the chance to be inventive and ask follow-up questions to clarify different responses.

The interviews were semi-structured, all participants were asked similar open-ended questions in the same order, this made it easier and credible for data analysis. The structured interview assisted in obtaining information about each participant experiences on the research questions, which was critical for the understanding of the research objectives from the participants experience point of view. The structured prepared interview questions assisted during the data analysis, development, and comparison of emerging themes.

3.4 Population and sample

3.4.1 *Population*

The complete population for this study comprised of South African mining companies that have implemented or are in the process of implementing digital technology and solutions adoption in management and operational processes.

The study was not limited to any commodity or mining company size for the purposes of data collection. There were no selection criteria for South African mining companies to participate on this study, results were also not according to any commodity or size of the mining company. The results looked at digital technologies and solutions that South African mining sector is adopting or looking to adopting, drivers and barriers for their adoption without linking them into any commodity or company size.

3.4.2 *Sample*

The participants comprised of senior, middle, and junior management levels within the South African mining companies. The total number of participants that were interviewed came from different role categories within their company's management and operational structure levels. The reason for sampling these levels was for the study to have a spread data composition from different management and operational process levels as intended by the study. Five senior, two middle and two junior management level participants were interviewed.

3.4.3 *Sampling method purposive sampling*

Purposive sampling, a non-probability sampling methods was used for this study. This method was appropriate due to the researcher experience and knowledge of the South African mining sector. The sample for the research was employees who were in senior, middle and junior management roles in their organisations, Table 3.1. This was done to cover participants who are in management and operational levels. Nine participants were interviewed from different mining companies that operate in different

commodities within the South Africa mining sector. While some experts in qualitative research avoid the topic of ‘‘how many interviews are enough?’’, there is indeed variability in what is suggested as a minimum. The number of participants required to conduct qualitative investigations varies between 5 to 25, according to Creswell (2013). Therefore, nine participants were selected for this study.

Table 3-1 - Participants Profile

Management Level	**Participants**
Level 2	**Senior Management**
	1. Engineering Manager
	2. Principal Process Engineer
	3. Principal Operations Manager (Digital Products – Assets, Strategy and Reliability)
	4. Human Resource Manager
	5. Senior Procurement Manager
Level 3	**Middle Management**
	1. Senior Lead Digital Value Chain
	2. Reliability Engineer
	3. System Engineer
Level 4	**Junior Management**
	1. Digital Lead
	2. Foreman

The interviews were conducted online using Microsoft Teams, single interview was conducted per participants and telephonic follow-ups were made to participants after the interview and during data transcribing to seek in-depth and clarification on information and data collected to assure credibility of the data.

3.5 The research instrument - interview guide

Structured interviews were scheduled as the research instrument for the study, which was used to guide the open-ended, one-on-one interviews with all participants. Interviews were appropriate for this study because they facilitated conversation and a view of how everyone felt and their experience on the research topic (Alshenqeeti, 2014). Interviews were interactive which made participants comfortable to share their knowledge and experiences (Alshenqeeti, 2014). Interview questions incorporated the objectives of the study as stated in Chapter 1, literature review and theoretical framework highlighted in Chapter 2 were used and the resulted questions that was put forward in Chapter 2. The composition of the questions was created to draw out information from the interviewees, allowing them to reflect deeply on their knowledge and share their insights. The interviews were designed to enable flexibility and permit deviations when necessary.

The themes out of the questions did not discover which specific potential technologies and solutions South Africa mining companies are persuading in their journey to adopt or looking at adopting in their mining and operations. It did however discover the drivers and barriers for digital technologies and solutions in their mining and operations.

3.6 Procedure for data collection online interviews

Participants were sourced through networks within the South Africa mining sector. They were identified based on their management levels they occupy in their companies in relation to the research area of interest which was management and operational mining processes. Participants were made comfortable to share their experience, insights, thoughts, and feelings about their digital transformation in their mining and operations. All participants were given detail background and purpose of the topic (Kajornboon, 2005). They were contacted by email requesting their participation in the study and scheduling of the interview.

Participants were also contacted telephonically to clarify any issues they might have related to their participation in the study. Those that agreed to participate were sent formal email three weeks prior to the interview, explaining the purpose of the interview, overview of the research and its objectives as well as the anticipated duration of the interview. Participants were also made aware that interviews were going to be recorded, interviews were recorded in order to assure validity of interview information as required by qualitative research. Participants were asked to confirmed date and time that will be suitable for the interview to be conducted.

Consent forms and interview guide were attached to the meeting invites for the participants to complete before the interview. This provided an assurance to the participants about the confidentiality of the interview and the nature of the data to be collected. Ethical considerations regarding the use of the data collected were also communicated with the participants. Microsoft Teams was used to conduct the interviews as most participants were either working from home or in their mining and operations that are far and remote. The interviews lasted for average of one hour and video functionality was enabled from both ends to create a face-to-face physical interview environment. The interviews were video recorded using a screen recorder, which was then processed, verified, and transcribed. The combination of all data that was collected, including video recording, transcripts were then analysed.

3.7 Data analysis strategies and interpretation - Thematic Analysis

Qualitative research produces huge amounts of data in the form of transcriptions and notes, clear approach on how data will be analysed and reported is crucial (Pope, Ziebland, & Mays, 2000). Identifying the best data analysis approach that will enable the exact data interpretation that should be achieved (Alhojailan, 2012). The data collected through the interviews were transcribed, analysed, and coded to interrogate it in details, using a thematic approach. The use of thematic analysis in qualitative data analysis makes it easier to identify patterns and themes in a particular data set and is theoretically flexible, hence it was chosen as the interpretive method to utilize for this

study (Braun and Clarke 2012). The following six steps according to Braun and Clarke's thematic analysis method were followed during data analysis.

1. Familiarization with the data generated from the interview transcripts.
2. Generating codes from the interviews data
3. Generating themes from the coded data
4. Reviewing themes generated from the coded data.
5. Defining and naming generated themes
6. Locating exemplars from the themes.

The transcribed data was analysed through the lens of the research questions and the interview questions to find themes and patterns from the data obtained by using the six-step iterative method described above. Twenty-five categories arise during transcripts coding processes resulting in six themes that emerged from the thematic analysis.

3.8 Quality Assurance

Qualitative research methodology is still considered with scepticism and accused of being subjective and lacking in facts. An iterative process of studying and analysing the data collected during interviews was undertaken to minimise some of these concerns. It was supplemented by the insights gained during the literature review and reviewing literature from different authors to gain different perspectives of digital transformation in the mining sector. It was checked against the research objectives set in Chapter 2 (Lincoln & Guba, 1986). A method of member checking was l also utilised by continually providing the research to the supervisor at different stages to interrogate and challenge the findings.

3.8.1 *Transferability*

Transferability refers to whether the research finding can be transferred to another of a similar context while still upholding its own meaning. This implies that comprehensive rich data must be collected should another researcher wish to replicate the steps for

another context (Houghton et al., 2013; Lincoln & Guba, 1986). A deliberate effort was applied in providing a comprehensive and detailed description of the case site, and how the data was collected from the senior, middle, and junior management participants from different South Africa mining companies, still ensuring anonymity and confidentiality. The research wanted to understand the potential digital technologies and solutions that South African mining sector can adopt as well as the preserved drivers and barriers for their adoption in their mining and operations.

3.8.2 *Credibility*

Credibility must be carried throughout the study and tested against key principles. To increase credibility and trustworthiness of the study, the transcripts were discussed with the participants to determine whether their views were captured appropriately and are true representative of their views and opinions (Cope, 2014), this was done after the interviews were completed and transcribed, before being analysed. The number of participants that were selected varied in management levels, roles, functions, and experiences which brought depth and different perspective to the study. This brought about a more representative view of the study. Literature review on the different digital technologies and solutions, drivers and barriers for technology adoption in mining sector was done in Chapter 2 in order to get a better understanding of the context within which the study was going to be conducted. Different studies on digital technologies and solutions adoption in mining sector were reviewed and those insights were used to inform and enrich this study (Cope, 2014).

3.8.3 *Dependability*

A deliberate and systematic method of analysis was used to ensure the data collected is interrogated thoroughly and was reviewed by the researcher's supervisor to identify any personal biasness and to make sure that the decision trail is followed through effectively and consistently (Houghton et al., 2013). Raw data and audio were made available for the supervisor to verify the dependability of the data collected. This

reflected that the study was congruent, and conclusions can be reached by another reader when going through the same study (Kemparaj & Chavan, 2013).

3.8.4 *Ethical considerations*

Conducting interviews can raise numerous ethical concerns, specifically for the participants. It was, therefore, crucial to ensure all steps are taken to address any ethical concerns and to make participants comfortable that confidentiality was observed with the data being collected and the insights gained from the interviews (Kajornboon, 2005). As described earlier, prior to the interviews, all potential participants were sent emails requesting their participation and were given details of the study. Participants emails were obtained from my network after reaching out to them and those that were interested replied and share their emails. Those who were interested further shared their network, whom I reached out to and those that were interested shared their emails. They were assured that data collected from the interviews will solely be used for the study purpose and will be treated confidential. After the participants had agreed to participate, they were sent consent form that stipulated their rights to participate and requested permission to record the interviews. The participants were assured and made comfortable that their input will not be used in any devious manner. Prior to the commencement of the interview, participants were again requested to give permission to record and use the video function during the interview.

All participants interviews were voluntary and they were informed that they can cancel or postpone the interview should they feel uncomfortable for whatever reason during the interview. The interviews were conducted in an ethical conduct throughout the entire interview process by the manner how questions were posed and any further probing (Kajornboon, 2005). The participants will remain anonymous as stipulated on the consent form that they were requested to sign prior to participating in the interview (Ryan et al., 2009). Ethical clearance was issued by the university prior to commencing with any interviews with the participants.

CHAPTER 4. RESEARCH FINDINGS

4.1 Introduction

This chapter presents the research findings, which seek to answer the research questions presented in Chapter 1 of the research. The research aimed to identify potential digital technologies and solutions that the South African mining industry can deploys in their management and operational processes. It also sought to determine the drivers and barriers for the adoption of these digital technologies and solutions to achieve their digital transformation strategy. For this investigation, a qualitative research methodology was adopted and nine semi-structured interviews were conducted to collect data recordings from participants.

The research findings are presented using direct and indirect quotations and interpretation of participants' responses to the interview questions. The extracts taken from the transcripts during the data fragmentation process were analysed. Themes that emerged, and viewpoints across the sample of participants are provided, to show how different themes arose for each research question. Findings are summarized for each research question.

4.2 Participants Sample and Data Analysis Process

4.2.1 *Participants Sample*

The planned number participants for the research were ten but only nine interviews were conducted after reaching saturation. Interviews were conducted with participants that were in their senior, middle, and junior management levels within their companies. Participants were from different South Africa mining companies operating in various commodities, ranging from coal, platinum, iron ore, diamond, and manganese. Table 4.1 below presents participants information including their titles and roles categories. All participants were either direct or indirect involved in the creation, approval, execution, and implementation of their company’s Digital Transformation Strategies in

their departments and area of responsibilities Some participants were Digital Leads in their companies, responsible for digital transformation strategy implementation. This indicates evidence of the relevance of selected participants for this research. All participants had more than 10 years' experience in South Africa mining and operations, their companies were undergoing digital transformation. They had vast knowledge and understanding of South African Mining Sector.

Table 4-1 - Participants Information Details

PARTICIPANTS IDENTIFICATION	COMMODITY	JOB TITLE	ROLE
Participant 1	Gold	Engineering Manager	Senior Management
Participant 2	Coal	Senior Lead Digital Value Chain	Middle Management
Participant 3	Coal	Digital Lead	Junior Manager
Participant 4	Gold, Platinum, Coal, Iron Ore	Principal Process Engineer	Senior Management
Participant 5	Gold, Platinum, Coal, Iron Ore	Principal Operations Manager (Digital Products – Assets, Strategy and Reliability)	Senior Management
Participant 6	Coal	Reliability Engineer	Middle Management
Participant 7	Platinum	Human Resource Manager	Senior Management
Participant 8	Coal	Foreman	Junior Manager
Participant 9	Manganese	Senior Procurement Manager	Senior Manager

4.2.2 *Interviews Transcripts Information*

Total of nine participants were interviewed, with an average of thirty-seven minutes per interview, totalling to six hours duration for all nine interviews as shown in Table 4.2. The shortest interview was twenty-eight minutes, with all the questions covered. The longest interview time was from a participant who is a Digital Lead, and his company was on their advance stages of their digital transformation strategy. He gave detailed descriptions and information when answering the interview questions. He is based in their company's business unit responsible for digital transformation projects and initiatives implementation driving their organization's digital transformation strategy.

Table 4-2 - Interviews Duration Analysis

NO	DESCRIPTION	DURATION (Minutes)
1	Total interviews Duration	332,24
2	Average Interview Duration	36,92
3	Longest Interview Duration	57,08
4	Shortest Interview Duration	27,44

4.3 Research Themes

Thematic analysis was applied to generate themes from the transcript according to Saldana (2013) recommendations which was also aligned with Braun and Clarke thematic steps. Total of twenty-five categories arise during transcripts coding processes. These categories were then organized and thematical analysed; six primary themes emerged from the analysis. Further analyses were performed on the twenty-five categories to examine their relationship with their respective themes to create themes network diagram. Figure 4-1 provides thematic analysis network diagram showing relationship between categories and themes. Each of the themes and their associated categories are presented in details in the next sections.

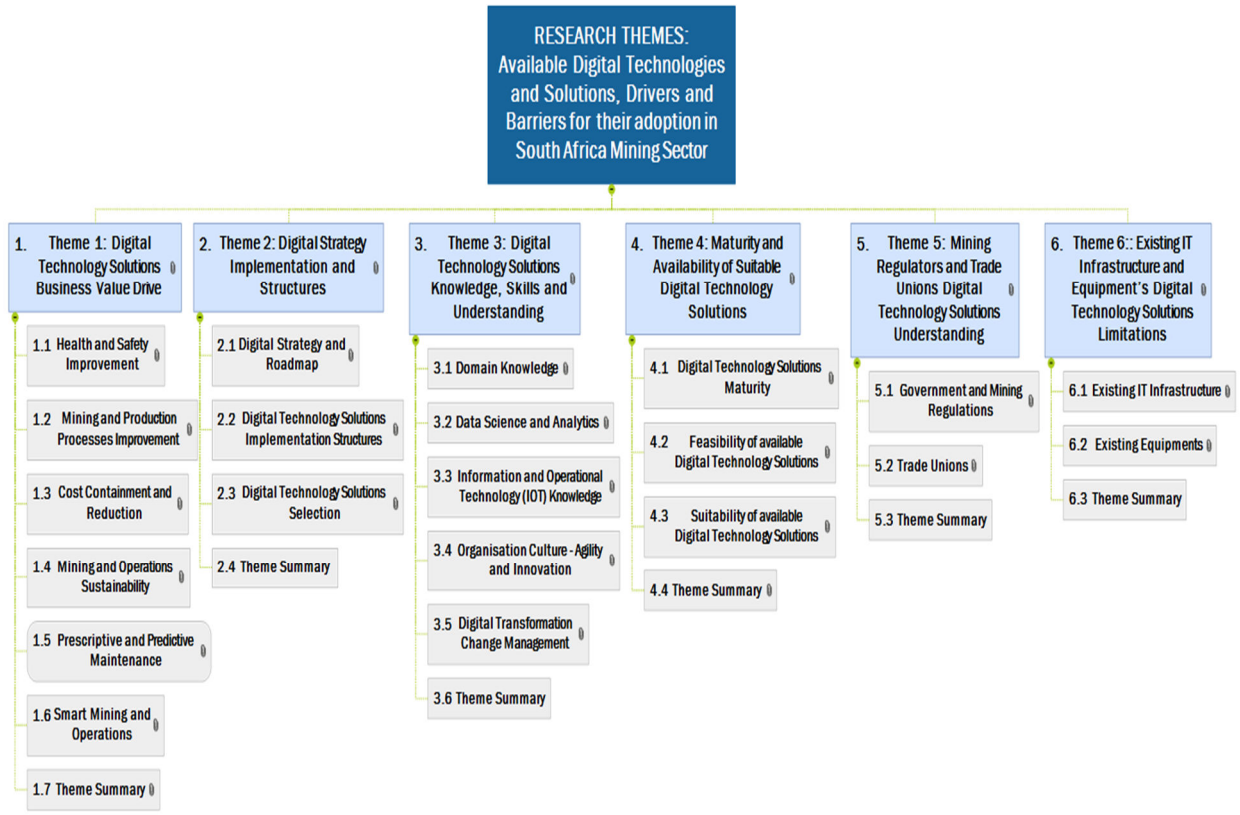


Figure 4-1 - Thematic Analysis Network Diagram – Researcher, 2023

4.3.1 *Theme 1: Digital Technology Solutions Business Value Drive*

Digital Technology Solution Business Value Drive theme outlines the reasons why South Africa mining companies were adopting digital technology and solutions, what business values they expect to get from these solutions. This theme elaborates important elements for South African mining companies to digitally transform their mining and operations process value chains.

Quotation from Participant 2, their company has highly invested in digital transformation and believed that there's value in adopting digital technologies and solutions in their operations. They have digital transformation strategy as a leg of their overall company strategy, to improve their production output. This theme was echoed by other participants, confirming that digital technologies and solutions will add value to their businesses.

> "*Digital Transformation is the biggest lever to add business value in the mining sector." (Participant 5)*

> *"Our company believe that there is value in Digital Transformation and other Operation Technologies. It will assist to improve our production by 5% on year to year for the next 5 years." (Participant 2)*

Participant 4 mentioned that there were a lot of opportunities they can achieve and challenges they can solve by adopting digital technologies and solutions which they could not do in the past which can add value to their business, e.g., mining areas that were difficult and unsafe to mine.

> *"There are a lot of opportunities that can be solved using digital technologies, there are a lot of issues that mining could not sort in the past, maybe because they did not have influence on production. They did not have big financial constraints and were not worried about efficiency in production, savings, and safety" (Participant 5)*

The above quotes reflect the views of most of the participants which explained why South Africa mining companies were adopting digital technologies and solutions in their mining and operations processes. This was driven by the need to support their business objectives. The following business value drivers were identified by many participants: *Health and Safety Improvements, Mining and Production Process Improvement, Cost Containment and Reduction, Mining and Operations Sustainability, Prescriptive and Predictive Maintenance and Smart Mining and Operation.*

a. ***Health and Safety Improvement***

South African mining sector is heavily regulated, health and safety of employees and other persons is highly important. Health and Safety improvement was found to be the common reason mentioned by all participants across all commodities. This was due to the pressure from Department of Minerals and Energy for South Africa mining sector to reduce health and safety incidents as well as fatalities.

> *"Unions do not understand the roles and benefits of digital technologies, digital technology is not coming to take jobs but to improve safety and the way of working)." Participant 3*

Participant 4 mentioned that one of their key drivers for their digital transformation was to improve their safety scorecard by solving and preventing health and safety incident using digital technologies and solutions.

> *"Safety Compliance, solving incidents using Digital Technologies, e.g., using sensors to predict landslides." (Participant 5)*

Participant 3 stated that they have four digital technologies and solutions adoption drivers, User Experience was one the drivers which encompasses Health & Safety and Production, this was their value adds in their mining and operations.

“Digital technologies will help us to ensure continues risk assessment and management.” (Participant 1)

“Our company has taken a stand to be the change, safety, improve people's live, sustainable mining, environmental effect.” (Participant 1)

All participants agreed that mining companies must meet and improve their safety standards as stipulated by the Mine Health and Safety Act, 1996 (Act No. 29 of 1996). Mining companies should protect their employees and other persons health and safety in their mining operations. Most participants indicated the need to improve safety throughout the mining process to provide safer working environments as key value driver.

b. ***Mining and Production Processes Improvement***

All participants agreed that mining companies urgently needed to increase the productivity and efficiency of their operations due to decrease in commodities pricing and increasing production cost (Rate per Ton). This was one of their primary drivers for adopting digital technologies and solutions throughout their mining and operational processes value chain. The Industrial 4.0 that assisted manufacturing in improving their production throughput, has positively impacted mining sector appetite to undergo their Mining 4.0 by adopting digital technology and solutions in their operations to also improve their production throughput.

Participant 1, who is an Engineering Manager for one of the Gold Mines, mentioned that inefficiency in mining and operations was caused by poor labour and assets management. This was agreed by all participants that to improve both mining and production efficiency, proper labour and asset management was critical.

Our company digital strategy is to improve our production output by 20%, from 32 million to 37 million tons of coal.” (Participant 6)

This was one of participant 6 company drivers for adopting digital technology and solutions in their mining and operations.

> *"Areas of mining and operations inefficiency are caused by Labour and Asset Management Issues." (Participant 6)*

Coal 4 who is a Foreman for one of the digital mines mentioned that his company wants to create a digital connected mine by installing more digital technologies and solutions in their mining and operations. They want to connect their assets and people together, in order maximise their mining and plant efficiencies to reach the next level performance in terms of health, safety, production and cultural performance.

> *"Operational drivers for digital transformation for our company are throughput, optimizing for our mining and plant processes. Mining drivers for digital transformation are to be able to do selective mining, selecting sweet spots, areas with good quality." (Participant 5)*

Manganese 1 mentioned that their company was adopting digital technologies and solutions to identify and remove bottleneck in their mining and operations processes.

c. ***Cost Containment and Reduction***

High production costs due to high energy and labour cost as well decline commodity prices, has put South Africa mining sector under pressure to reduce their production cost per ton. Most of participants highlighted cost containment and reduction as an important focus throughout their mining and operations value chain to reduce their production cost.

> *"Our company business unit drivers are productivity and cost containment in all our operations." (Participant 2)*

> *"Our drive is to drive up asset performance and drive cost down" (Participant 7)*

All Participant agreed that cost containment and reduction can be achieved by efficiency and productivity improvements and digital technologies and solutions can help them achieve it.

> *"One of our company digital technologies and solutions adoption drivers is cost per ton reduction due to coal price decline which is due to investors pressure to exit coal and need decarbonize the coal mining sector" (Participant 2)*

> *"Cost containment, KPI's for Top management is set aside to 25% for digital transformation." Participant 5*

d. ***Mining and Operations Sustainability***

Participant 1 who is an Engineering Manager mentioned that one of their drivers for digital technologies and solutions adoption was climate change mitigation to achieve environmentally sustainable mining and operations.

> *"We have pressure from the market and financial institutions to decarbonize our operations to get finance for our expansion projects. Market demand for sustainable mining." (Participant 6)*

Participant 4 who is a Principal Process Engineer for Sustainability Department stated that their driver for digital technologies and solutions adoption was to be able to run a sustainable and profitable mining and operations.

> *"Water is a scarce resource, sustainable mining and operation require reduction of water usage by minimizing the use and loss of water in our operations" (Participant 5)*

All participants from various commodities highlighted environmental sustainability as the driving force for their companies to adopt digital technologies and solutions in their operations to reduce their carbon footprint and water consumption.

e. *Prescriptive and Predictive Maintenance*

Prescriptive and Predictive maintenance was identified by all participants as the key important element to get maximum performance from their assets by understanding their asset health and maintain them when necessary and on time. They believed that digital technologies and solutions will assist them by predict failures before they occur. It will help them to get maximum value from their assets as they will only do maintenance when its necessary and schedule their production efficiently.

Participant 6 mentioned that digital technologies were the enabler for predictive maintenance as they will give their maintenance personal an ability to monitor their equipment's while in operation and predict future failures.

Participant 9 also mentioned that doing maintenance at the right time can be achieved by installing digital technologies and solutions on their plant and equipment's which increases their mining and operations uptime.

> *"Predictive Maintenance data and information can be linked to supply chain in order to secure spares and maintenance personal at the right time." (Participant 4)*

> *"Digital technologies and solutions will help companies to move away from reactive and planned maintenance to predictive maintenance." (Participant 3)*

Manganese 1 mentioned that monitoring equipment's performance was the driver for their digital technologies and solutions adoption, due their aging equipment's. Digital technology sensors will enable online condition assessment of their equipment's and prevent unplanned plant stoppages.

> *"Automated trucks give more uptime than human driven trucks. Help move away from Reactive and Planned maintenance to predictive maintenance." (Participant 7)*

> *"Predictive maintenance, assist in making use of the equipment better and shut the plant when its necessary." Participant 4*

f. *Smart Mining and Operations*

Smart operations and mining were identified by most of the participants as their ultimate final goal for their digital transformation, they agreed that it can be achieved by creating a digital connected mine by installing digital technologies and solutions across their entire mining and operations value chain.

Participant 2 mentioned that digital technologies and solutions can be connected into a single digital platform where the whole value chain can be managed and monitored (Pit to Process Plant). Starting from scanning a product block, calculating expected product yield, preparing the plant while tracking the product until it received at the processing plant.

> *“We have strategy to improve our production output by 20%, from 32 million to 37 million tons of coal product.” (Participant 2)*

> *"Our company believes in Digital Transformation by installing digital technologies and solutions, due to the advantage of reducing delays in information retention or momentum in terms of information as well being able to tap on information from any point without waiting for manual information updates. You have information in your fingertips, it is easy to manage the entire process, especially look at it in value chain perspective, you are able to determine how many tonnages are in a particular block, prepare the plant and track where the block is, until it is received at processing plant. Determine how much is expect which makes it easy to model and decrease leakages." (Participant 6)*

> *"Digital Transformation is the biggest lever for business value in the mining sector." (Participant 3)*

Participant 1 mentioned that they have invested a lot of money in creating infrastructure that will enable digital technologies and solutions adoption, they have installed Wi-Fi in their underground mine to create platform for their digital transformation. Their strategy was to create a smart operations "Smart Mine".

“Management vision as a company wants to be the Smart Mine in the future, that’s the main management driver and vision.” Participant 2

Participant 3 mentioned that automated trucks give more uptime than human, these trucks can be linked to the central control centre for dispatch and monitoring.

4.3.2 *Theme 2: Digital Strategy Implementation and Structures*

This theme outlines the importance of clear digital strategy, its roadmap as well as the structures for digital technologies and solutions selection and implementation that was highlighted by most participants for the successful adoption of digital technologies and solutions in their mining and operations.

a. *Digital Strategy and Roadmap*

Clear Digital Strategy and Roadmap was identified by all participants as an important element of digital transformation. All participants agreed that without a clear strategy and roadmap, digital transformation will not be successful and results in slow digital technologies and solutions adoption.

Participant 1 indicated that his company does not have official digital transformation strategy in as much as the company was already implementing digital transformation.

Participant 2 said his company has Digital Transformation Strategy as a leg of the Company strategy. Their digital strategy was made up of three phases, Data Collection phase (Installation of sensors – digital technologies and solutions), Value Creation Phase (Creating value from collected data by Data Scientist and Analytics) and Intelligent Operation Creation Phase from collected data (AI and Machine Learning on the analysed historic data).

> *"Our Company does have Digital Transformation Strategy and have a Roadmap for the Strategy." (Participant 3)*

> *"Digital transformation is a core to our strategy. It is critical that we do." Participant 6*

It was clear that companies that have clear digital transformation strategy and roadmap were seeing gains in their digital technologies and solutions adoption. Clear strategy and roadmap that was understood by all levels of the organisation was important for the success of its implementation.

"There's a clearly defined Digital Transformation Strategy and Clear Roadmap" (Participant 2)

"We don't have an official Digital Strategy and still developing the strategy." (Participant 1)

"Our company does have digital strategy on Asset Management, by installing digital sensors in the field and plant equipment in order to understand asset condition (asset health), vibration, pressure, oil analysis, thermal analysis. This analysis assists in order to understand whether the asset is healthy or not healthy." (Participant 5)

b. ***Digital Technology Solutions Implementation Structures***

It was quite clear from all participants that proper structures for digital transformation implementation was very important, mining companies have different structures due to their digital technology business needs and requirements. Most participants mentioned that their Digital transformation was owned by their Head Office but implemented through their mining and operations structures.

“We have a centralized approach, Digital Innovation Division owns the Strategy, they own the strategy in collaboration with BU Management/Operation.” (Participant 3)

Participant 3 who is a Senior Digital Lead mentioned that their company has Digital Leads that are based in their Business Units who are the custodian of digital transformation initiates and projects. They report to Digital Transformation committee in their Head Office.

“I believe that digital transformation is not about showing one’s financial strength but to improve their bottom line, we are driving our digital transformation from central structure, focusing on digital transformation initiatives that support our business case.” (Participant 1)

c. *Digital Technology Solutions Selection*

Most participants indicated that their digital technologies and solutions selection was done by a centralized digital transformation committee. Mining and operations present their digital transformation initiatives to the central committee for evaluations and approval to ensure that digital initiatives address business needs. Centralized technology selection assist in making sure that technologies were standardized and there were no duplicates.

> *"Centralized digital technologies and solutions selection help with cost control and standardisation of the solutions." (Participant 4)*

Other participants mentioned that they use decentralized digital technologies selection cited the reason that mining and operations have better understand of their environment and were best suited to choose technologies and solutions that will work on their environment.

Participant 1 mentioned that currently they rely on their engineers for the selection of their digital technologies and solutions, this was because of their technical knowledge and operations understanding.

> *“Allowing Engineers to select their digital technologies and solutions comes with its own challenges, implementation of different digital solution for similar problem which results in wasteful expenditure.” (Participant 1)*

Participant 2 indicated that their IM was also involved in their digital technologies and solutions selection as they must support them with their IM infrastructure.

> *"IM is involved in our Digital Technology selection, there's a committee that does vetting of technology and technology suppliers." (Participant 6)*

> *“Engineering Consultant using old non digitalized designs for new plant designs, not incorporating digital transformation in their designs.” (Participant 4)*

4.3.3 *Theme 3: Digital Technology Solutions Knowledge, Skills and Understanding*

Most participants agreed that Digital Transformation require a digital literacy organisation, organisation that understand the impact and benefits of digital technologies and solutions.

a. ***Domain Knowledge***

Domain knowledge was identified by all participants as one of the major important skills for successful identification of digital transformation opportunities. Domain experts in Mining, Geology, Metallurgy, Engineering etc which have the information, knowledge and understanding of where the digital technologies and solutions can effectively be deployed and opted to get maximum value and meet business needs.

> *"Domain and Digital knowledge, combination of domain knowledge (Mining, Geology, Metallurgy, Chemical, Mechanical, Electrical) and Data Analytics and Scientist unable us to achieve full digital transformation adoption." (Participant 7)*

> *“Experts on the field where the digital tool is being deployed are required skill set.” (Participant 2)*

> *“Knowledge about operations, conditions.” Participant 1*

b. ***Data Science and Analytics***

Without ability to make sense and extract value from data collected by the digital technologies and solutions, digital transformation adds no value to our businesses, this was the common belief by all participants. They believed that Data Science and Analytics were the major essential skills for digital transformation. Digital transformation success can be achieved by combining Domain knowledge and Data Science & Analytics to identify digital transformation opportunities and implement their solutions.

"Need both the native technology (functional skills) and modern mining technology 4.0 skills (modelling, data science and data analytics) ability to match problems or challenges in operations with available digital solutions or that can be developed." (Participant 9)

Data Analytics and Science skills were essential skills for analysing data collected by the digital technologies and solutions, making sense of the collected data. Making data a commodity and add value to this commodity, to understand management and operations internal and outside environment to make informed business decisions.

“Data Science, Development Skills (Do locally produces solutions and application, to take advantage of Data).” (Participant 7)

“Technology understanding behind the solution, IT Skills, Data Management, Data Analytics, Cloud Computing Skills are the required skills” Participant 2

“Digital Skills are Data Analyst.” (Participant 4)

c. ***Information and Operational Technology (IOT) Knowledge***

Digital transformation is the merger of Information and Operational Technologies this combination of is now known as Internet of Things (IOT's) which is the enabler of digital transformation. Information and Operation Technologies was identified as one of the important knowledge areas mentioned by all participants. They believed that to have maximum benefit and successful implementation of digital transformation, connection between IT and OT was very important, therefore installation of digital technologies in their operations will unable their digital transformation and link their operation into their IT systems for data analysis.

“Digital Skills in South Africa doesn't exist; digital skills are still being developed and even the OEM don't have skills themselves.” (Participant 5)

“Front line worker needs to be trained on digital technologies. Their importance, they need skills to select the digital sensors.” (Participant 1)

Information and Operation Technology skills combined with Data Management, Data Analytics, Cloud Computing, Modelling and Development, Network Infrastructure, Information Management were essential for transforming and interpretation of data from assets into business insight.

> *“Need artisans that understand digital technologies and solutions in order to maintain them properly.” (Participant 2)*

d. *Organisation Culture - Agility and Innovation*

Without an innovative and agile organisation or workforce, opportunities where digital technologies can be a solution will not be realized. Innovation and agility were identified as key elements for digital transformation. It was important to create an innovation culture where employees are encouraged to seek for solution for their mining and operational challenges. Digital transformation requires an agile management which understand the concept of fail fast by making decision very fast as digital technologies and solutions changes quick and frequently. This was agreed by all participants.

> *"Agility, be able to move very fast, make decisions very fast. Not making decision very fast will lead to not be able to see benefits of Digital Transformation through Technologies and Solutions" (Participant 3)*

> *“Creation of culture of innovation through digital transformation initiatives.” (Participant 5)*

> *“Agile and Innovation is very important skill for digital transformation, ability to lead digital programmes and be up to date with the latest digital technologies and solutions trends.” (Participant 3)*

All participants agreed that an innovative culture in an organization helps employees adopt new technology. Participant 2 stated that their company promotes an innovative culture and that employees were encouraged to create innovative concepts to improve their work environment.

Our culture "supports the ability for people to be the innovators, to come up with ideas to our business challenges." (Participant 2)

Participant 5 confirmed innovative culture as creating a foundation for encouraging innovative thinking and the adoption of technology throughout the mining value chain.

e. ***Digital Transformation Change Management***

It was common knowledge and understanding among all participants that Digital Transformation was coming to take traditional job which results in job losses and retrenchments. They all agreed that Change Management was very key success factor in introducing and implementation of Digital Transformation. It was important for the entire workforce to understand the reasons, impacts, and benefits of digital transformation in their work.

“Resistance to change. Change management is critical and is a biggest barrier.” (Participant 1)

Digital Transformation heavily relay on building the skills and capabilities of the work force because they are the ones who will ensure sustainability and continuity of these digital technologies and solutions.

"Leadership that understand that there's the need for change, be able to lead that change and be able articulate the change very clearly to the entire work force about the benefit that will come with the digital transformation." (Participant 5)

Digital transformation requires a good change management process to guarantee its success. Employees understanding of the reason for digital transformation is critical, knowing how it will affect their jobs and personal circumstances. Successful implementation of Digital transformation strategy relies on leadership that take along its people in the strategy development up execution, involving them in all strategy phases.

“There is lack of Change Management skills that are aligned to digital transformation complex scope.” (Participant 2)

Participant 1 highlighted that insufficient investment in change management processes, result in people reverting or sticking to their old ways of doing things and not get full benefit of digital technologies and solutions.

> *“Insufficient Investment in Change Management, organisation inertia, people sticking to their old ways of doing things.” Participant 7*

4.3.4 *Theme 4: Maturity and Availability of Suitable Digital Technology Solutions*

This theme discusses the availability of developed digital technologies and solutions that are suitable for adoption in the mining sector, risk associated with their selection. It also looks at processes used by mining companies to choose their appropriate digital technologies and solutions. This theme also covers how mining companies demonstrate feasibility of the technologies and solutions they were adopting. The intention is to understand how digital technologies and solutions can be effectively deployed to achieve the intended objectives of the South African mining companies. This theme is made up of three categories, The maturity, feasibility, and suitability of available digital technologies and solutions for the mining industry in South Africa can adopt in their mining and operations.

a. *Digital Technology Solutions Maturity*

Most participants described digital technology readiness as the maturity level of digital technologies and solutions, including testing and implementation in a mining and operations environment, if the technology has already achieved commercial viability. When there is a low level of technological maturity, there is a significant risk when implementing an unproven technology into mining and operations processes.

> *"Technology maturity, there's very few digital technologies for mining environment, and not well matured and proven" (Participant 3)*

Most participants stated that they were hesitant of adopting new untested digital technologies and solutions into their operations. Most South African mining companies delay until it was necessary to adopting new digital technologies and solutions. The risk depends on how dependent the company was on the business value that the new digital technologies and solutions will bring to their mining and operations against the traditional alternatives.

> *"Difficult to prove value for money and digital products haven't been widely tested and implemented in order to ensure that they are robust." (Participant 2)*

Participant 6, mentioned contrarily to most participants that his company was willing to taking risks associated with digital technologies and solutions adoption in their mining and operations. Their company partner with digital technologies and solution providers to develop proof of concept in their mining and operations. Only a few of the participants agreed with Participant 6 and were mostly from companies that were part of large mining companies.

> *"Our company partner and allow digital technologies and solution service provider to prove their digital solutions in our operations, Proof of Concept" (Participant 6)*

b. ***Feasibility of available Digital Technology Solutions***

Most of the participants agreed with Participant 3 and Participant 5 that it was essential for mining companies to discover, evaluate the viability of the available digital technologies and solutions into the existing mining and operations value chain process. The participants highlighted digital technologies and solutions assessment as an essential phase in confirming the practicality and feasibility of the digital technology solution, thereby increasing its adoption success.

> *"There's no single digital platform tool that can manage everything" (Participant 1)*

To minimize the risk that come with the new technologies and solutions that lack of maturity, it was essential to first test and evaluate it. According to the participants, larger mining companies usually have specialized resources within the organization's structures that were responsible for assessing the viability of digital technologies and solutions before adopting them into their mining and operations.

Some participants, including Participant 2, who agreed on installation of digital technologies and solutions that were not proven in the mining environment, highlighted the importance of having Digital Leads at their operations. Digital leads are responsible for technical support of the technologies and solutions, to ensure sure that all

requirements are met to provide the new technology and solution sufficient time to demonstrate its feasibility.

> *"Collaborate with other partners (Original Equipment Manufacturers) for new technology evaluation and test the technology." (Participant 5)*

c. ***Suitability of available Digital Technology Solutions***

According to Participant 2, a suitable digital technology and solution was one that was both technically and financially viable, solution that advances and drives business objectives.

> *"Allowing suppliers to come and prove their technologies assist proving suitable digital technologies in our operation before purchasing them" (Participant 3)*

Most participants recommended establishing partnerships with original equipment manufacturers, equipment, and digital technology suppliers to identify the most appropriate digital technologies and solutions for their mining and operations process value chain.

> *"Partnership between existing equipment suppliers and digital technologies suppliers can assist in retrofitting and installation of digital technologies and solutions onto existing plant and equipment's. This will provide digital transformation of the existing equipment's." (Participant 5)*

> *"Equipment suppliers not willing to assist with technology that will assist in Digital Transformation." (Participant 5)*

4.3.5 *Theme 5: Mining Regulations and Trade Unions Digital Technology Solutions Understanding*

South Africa mining sector is the biggest contributor to the South Africa economy, it employs millions of people and highly unionized and regulated by Department of Minerals and Energy. This was mentioned by most participants, they agreed that government and unions mandate is to protect jobs losses. This theme looks at the impact of government and trade unions in their digital strategy adoption and implementation.

a. *Government and Mining Regulators*

It was quite clear from all participants that government and the current regulations were their biggest barriers for their digital transformation strategy, they believed that Department of Minerals and Energy still have requirements that does not support digitisation which is the requirement for digital transformation. Certain processes still require manual and physical evidence by the regulator. Regulation rules not aligned with digital transformation.

> *"Department Minerals and Resources doesn't allow digitisation of certain processes." (Participant 5)*

All participants shared the same view with Participant 5 that Government and regulators was one of their barriers in their digital transformation, they require physical proof for certain documents and processes. There's still misalignment between digital transformation benefits and mining regulations requirements.

> *"Regulator still have rules that are not aligned with digital transformation" (Participant 3)*

> *"The sector needs to be Agile, in their rules and regulations. mining governance need to be aligned with Digital Transformation." (Participant 5)*

b. ***Trade Unions***

South Africa mining sector is the biggest employment contributor in the country's economy, it is also highly unionised. Participants all agreed that union were another barrier in their digital transformation strategy, unions as part of their companies' stakeholders demand proof that digital transformation will not lead to job cuts and retrenchments. This has led to many digital transformation initiatives being sabotaged or not successfully implemented due to lack of support.

> *"Trade unions do not understand the roles and benefits of digital technologies and solutions, they see digital transformation as job reduction initiatives." (Participant 5)*

4.3.6 *Theme 6: Existing IT Infrastructure and Equipment's Digital Technology Solutions Limitations*

A lot of South African mining companies operates old mines with old IT infrastructure. This theme details the limitations in adopting digital technologies and solutions due the existing IT infrastructure and equipment's. All participants agreed that existing equipment's and IT Infrastructure was one of their digital transformation barriers for South Africa mining sector.

a. *Existing IT Infrastructure and Networks*

South Africa mining operations are situated in the remote areas with limited IT infrastructure and connectivity. Participant 6 mentioned that IT infrastructure (IT network and Storage Servers) was the biggest challenge for their digital transformation to get full benefit of their digital technologies and solutions. Connectivity was also mentioned by most participants as another challenge for data transmission between digital technologies and storage servers (Onsite and offsite storage) as well as Control Rooms. Most participants agreed that IT infrastructure was their biggest barrier for their digital transformation.

> *"In order to get maximum value from digital technology solutions reliable IT infrastructure is required but it cost a huge amount of money." (Participant 9)*

> *"Digital technology and solutions require reliable IT Infrastructure" (Participant 3)*

> *Capital outlay for Digital Transformation is high, to create connectivity and IT Infrastructure" (Participant 4)*

> *"IT Infrastructure and Data Storage is very key for digital technologies and solutions adoption." (Participants 3)*

b. ***Existing Plant and Equipment's***

A lot of South African mining companies have old mines which have aged and old assets, all participants cited existing assets and equipment's as one of their digital transformation barriers and limitations. They mentioned that original equipment suppliers were not willing to invest in digital technologies and solutions that will enable digital transformation in the exist assets and equipment's. They also mentioned that existing plant and equipment's does not have digital capabilities and too expensive to replace or retrofit.

> *"Lack of willingness to retrofit and install digital technologies onto the existing equipment's by suppliers." (Participant 1)*
>
> *"Existing assets and equipment's are the biggest barrier to South African mining sector as they do not have IOT capabilities" (Participant 2)*
>
> *"Equipment suppliers not willing to assist with technology that will assist in Digital Transformation" (Participant 3)*
>
> *"Proprietary and warrantee issues when installing digital technologies to mining equipment's, e.g., Mining Trucks" (Participant 5)*

4.4 Themes Summary

4.4.1 *Business Value Drive Theme*

It was quite clear and agreed by all participants that digital technologies and solutions can or will add value to their business processes and has a positive ripple effect to other mining and operations processes. The were six drivers (*Health & Safety Improvement, Mining & Production Process Improvement, Cost Containment & Reduction, Mining & Operations Sustainability, Prescriptive & Predictive Maintenance and Smart Mining & Operations*) that were identified by different participants as their business value adds initiative to adopt digital technologies and solutions in their mining and operations. South Africa mining sector is facing a lot of challenges which require innovative ways to improve their businesses value. Digital transformation by adopting digital technologies and solutions have been identified by South Africa mining sector as the biggest lever to mitigate these challenges and improve their mining and operations.

4.4.2 *Digital Strategy Implementation and Structure's Theme*

It was evident from all participant's responses that digital strategy understood by all levels of organisation was very important and mission critical, it requires dedicated structures for its implementation for it to be successfully. Clear digital strategy is the foundation for the formation of structures for its implementation. These structures are critical for the selection of the right digital technologies and solutions that will support the business goals and fulfil the strategy. Without a clear digital strategy and structured technologies and solutions selection and implementation structures, digital transformation will not succeed. This was agreed by all participants that indicated that some of their digital transformation projects failed due to selection of digital technologies and solutions that does not meet their environment requirements. They also mentioned lack of resources to manage and implement these digital technologies and solutions.

4.4.3 *Digital technology solutions knowledge, skills and understanding Theme.*

All participants agreed and highlighted that digital transformation require both tradition functional skills as well 4th industrialisation skills to successfully identify opportunities and select correct digital technologies and solutions for their mining and operations. All participants shared the same view that South Africa does not have digital skills that understand mining sector, and this was one the barrier in their digital transformation, Data Scientist and Analytics were identified as the major skills shortage. There was also mentioning of lack of digital transformation change management skills by the participants, citing that traditional change management does not address uncertainty amongst employees regarding digital technologies and solutions replacing their jobs. Most participants agreed that South Africa mining sector needs to invest in digital skills development including transformed change management processes that is aligned with the changes that comes with digital transformation to advance their digital transformation strategy.

4.4.4 *Maturity And Availability of Suitable Digital Technology Solutions Theme*

It was evident from all participants response that for South Africa mining sector to succeed in their digital transformation journey, they need matured, suitable, and feasible digital technologies and solutions. Digital technologies and solutions that can work on their robust and dirty environment conditions. All participants mentioned that existing digital technologies and solutions have not been tested for their environment and were mostly designed for manufacturing environment. They also indicated that some digital technologies and solutions suppliers do not want to test their solutions which pose a risk to their mining and operations. For South Africa mining sector to progress in their digital transformation, they need to spend money on testing the available digital technologies and solutions. On the other hand, digital technologies and solutions suppliers need to design technologies and solutions that are suitable for mining sector. Maturity and availability of suitable digital technology was identified as

the biggest barrier for South Africa mining sector as they were sceptical on adopting digital technologies and solutions that have not been proven for their environment.

4.4.5 *Mining Regulations and Trade Unions Digital Technology Solutions Understanding Theme*

Government and trade unions mandate is to create and save jobs, this was what all participants highlighted. Therefore, they both have an interest in the digital transformation strategy and they are an important stakeholder to be involved in the creation and implementation of the digital strategy. It was agreed by most participants that trade unions always question the motive behind digital transformation. They accuse mining companies of wanting to replace employees with robots by installing digital technologies and solutions in their mining and operations. On the other hand, government is lacking behind in making rules and regulations that supports digital transformation. Government processes and applications are still manual and paper based. Government still requires physical evidence in the event of incidents and fatalities. Some of the processes cannot be digital transformed fearing breaking or noncompliance to the Mining and Safety regulations. Government and trade unions were identified as digital transformation barriers for South Africa mining sector. Therefore, there is a need for alignment between all the three important stakeholders, mining sector, government (DMR) and trade unions about the need and benefits of digital transformation in the sector.

4.4.6 *Existing IT Infrastructure and Equipment's Digital Technology Solutions Limitations*

All participants agreed without hesitance that their existing infrastructure is their biggest barrier for their digital transformation. A lot of their mines and operations have been operating for more than 25 years and they do not have any digitalization capabilities. To retrofit and install digital technologies and solutions will cost a lot of money that will not be recovered due to their mines nearing their end of life.

Participants indicated that instead of doing full value chain digital transformation, they look for quick wins, areas where digital technologies and solutions can be implemented without huge change on the existing assets and equipment's. Reluctance from the assets and equipment's suppliers to assist mining companies with retrofit of their old equipment's and only offer new equipment's was mentioned by most of the participants. Digital technologies and solutions require huge capital investment on sophisticated IT infrastructure to transmit, store and analyse huge data collected by the digital technologies. The exist IT infrastructure does not have these capabilities and capacities. This was another challenge that most participants mentioned, especially those who have started with their digital transformation and have installed digital technologies sensors in their mining and operations. Connectivity was another challenge as most mines are in remote areas and with no network coverage from telecommunication service providers.

4.5 Conclusion

South African mining companies and the sector are motivated by the need to improve their mining and operations in order to meet their business needs and add values to their business. This is what drives them to embark on their digital transformation by implementing digital technologies and solutions in their mining and operations. Participants agreed that both internal and external barriers which are preventing the sector from progressing with its digital transformation should be addressed with equal importance. There is a need for partnership between digital technologies and solutions suppliers and mining companies to evaluate available digital technologies and solutions because the existing available digital technologies and solutions are not matured and have not been tested for the mining environment. The study's findings are discussed in the chapter that follows, with a view towards confirming or debunking the findings drawn from the academic and business literature reviewed in Chapter 2.

CHAPTER 5. RESEARCH DISCUSSION

5.1 Introduction

This research study aimed to understand the potential digital technologies and solutions that South Africa mining sector can adopt, explore drivers and perceived barriers for their adoption. This will assist the sector with selection and adoption of digital technologies and solutions that are suitable for their environment to increase their digital transformation. This chapter reviews and compares the findings in Chapter 4 with the literature review findings from Chapter 2. The research findings for each research question coming from the qualitative interviews are discussed in the following sections, in addition to a contrast the results from the relevant literature.

5.2 What are the potential Digital Technologies and Solutions that South African mining sector can adopt in their processes?

This research question sought to find out and understand what digital technologies and solutions the South Africa mining sector is adopting in their mining and operations in persuasion of their digital transformation strategy. It was not clear during the research about which specific digital technologies and solutions were South Africa mining companies adopting. South Africa mining sector is looking at multiple digital technologies and solutions that are available in the market that can be implemented in their mining and operations. It was noticeably clear that available digital technologies and solutions were not designed for mining environment. They cannot be adopted without testing their suitability to the mining environment. Most available digital technologies and solutions were not matured and were developed for other industries.

For the South Africa mining sector to adopt the available digital technologies and solutions, partnership between South African mining companies and digital technologies and solutions suppliers is required to prove these technologies before adopting them in their operations. This will minimize the risk of adopting untested and immature digital technologies and solutions in the mining and operations. This finding

was agreed during literature review by (Barnewold & Lottermoser, 2020); (Molaei et al., 2020) that there is a lack of Research and Development capacity and willingness for mining companies to lead the diffusion of new technologies and risk to be the Pioneers.

5.3 What are the Drivers for adoption of Digital Technologies and Solutions in South Africa Mining Sector?

This question sought to find out and understand the drivers for South Africa mining sector adoption of digital technologies and solutions in their mining and operations. South Africa mining sector has been slow in their digital transformation by adopting digital technologies and solutions compared to global mining companies (Wadula, n.d). Business Value Drivers was identified by all participants as the main reason for digital technologies and solutions adoption in South Africa sector in mining and operations. Six business value drivers namely*, Health and Safety Improvement, Mining and Operations Process Improvement, Cost Reduction and Containment, Mining and Operations Sustainability, Prescriptive and Predictive Maintenance and Smart Mining and Operations* were identified during the study. All six business value drivers were interrelated, each business driver has positive impact on another. This means improvement on one diver influence the other drivers positively.

The following sections looks at each business value driver finding outlining the expected business value South African mining companies are expecting from it when adopting digital technologies and solutions. These findings are compared to the literature review findings to either confirm or refute the research findings.

a. ***Health and Safety Improvement***

Health and Safety improvement was identified by most participants as one of the business value drivers, South Africa mining companies are searching for suitable digital technologies and solutions that will increase their Health and Safety performance. They are adopting digital technologies and solutions that can solve their safety incidents and assist compliance. This finding agrees with literature finding that

mining has strict Health, Safety and Environmental compliance laws and regulation (Dayo-Olupona et al., 2020); (Gruenhagen et al., 2022); (Fedulova et al., 2020); (Molaei et al., 2020). South Africa mining companies are also adopting digital technologies and solutions for continuous Risk Assessment and Management to alert employees and other persons of any risk and hazards they might be exposed to and before it happens. This finding was identified during literature review that there is a pressing need for mining companies to adopt digital technologies to remove workers from dangerous activities, especially in underground mines (Fedulova et al., 2020); (Cudjoe & Cawood, 2022). There is a need for condition monitoring in the underground mines, e.g., gas monitoring (Molaei et al., 2020), for quick ventilation and evacuation in the event of gas leaks. Reduction in operational risk by mining companies (Lazarenko et al., 2021). Remote monitoring of ore and mining terrain will reduce safety of falling ground incidents (Gruenhagen et al., 2022).

b. *Mining and Production Processes Improvement*

The need to improve mining and production processes was identified by all participants. Mining and production process improvement was identified by most participants as the business value driver. South Africa mining companies are adopting digital technologies and solutions to improve their mining and operations processes to remain competitive in the market due to the decrease in the commodities prices. Fluctuation in the local, regional, and global commodity prices has driven South Africa mining companies to improve their mining and operations processes to respond according (Dayo-Olupona et al., 2020). South Africa mining companies have urgent need to improve their mining and operations productivity and efficiency. Poor management of labour and assets was also identified as another process improvement that will assist mining and production improvement by adopting digital technologies and solutions. This driver was also identified during the literature review, (Lazarenko et al., 2021); (Barnewold & Lottermoser, 2020) that mining companies are improving their business production to increase their competitiveness. Increase plant efficiency through plant automation and controlling plant remotely (Fedulova et al., 2020). Digital

technologies and solutions assist in mining operation process efficiency (Lazarenko et al., 2021); (Molaei et al., 2020).

c. *Cost Containment and Reduction*

Cost containment and reduction was another business value driver identified by most participants; this driver is driven by the need to reduce production cost. In the recent years, South Africa mining companies says that production cost has increased significantly, this was due to the high energy and labour cost. Therefore, South Africa mining companies are looking at digital technologies and solutions as the means to reduce and contain their production cost, by adopting digital technologies and solutions in their mining and operations. Mining scarce remote resources by using digital technology solution will increase production and reduce production cost (Lazarenko et al., 2021). The other contributing factor to the increase in production cost mentioned by the participants was increase in operation cost due to the difficulty in mining deep reserves. There is a need for mining and operational cost reduction (Barnewold & Lottermoser, 2020); (Molaei et al., 2020). There is an increase in operations cost due to extraction of low-grade material and the use of specialized drilling and mining technologies (Dayo-Olupona et al., 2020); (Gruenhagen et al., 2022); l (Aziz et al., 2020; Ralston et al., 2014; Barnewold & Lottermoser, 2020; Fedulova et al., 2020;).

d. *Mining and Operations Sustainability*

Sustainable mining and operation were another business driver mentioned by most participants. South Africa mining companies are adopting digital technologies and solutions to reduce their carbon footprint. Participants indicated that there’s pressure from financial institutions for decarbonization of the South Africa mining sector to get funding for new and expansions projects. There's also pressure from the market for sustainable mining for commodities they are buying, reduction of Environmental and Social Impact by mining operations. Environmental sustainability was highlighted by most of the participants as their sustainability business driver to achieve their mining and operations sustainability. It was clearly from the findings that water is becoming a

scarce resource, mining companies need to reduce both water consumption and wastage. There is a need for mining companies to reduce water usage and waste (Fedulova et al., 2020). South Africa mining companies are therefore searching, testing, and adopting digital technologies and solutions that will assist them to have sustainable mining and operations.

e. *Prescriptive and Predictive Maintenance*

Prescriptive and predictive maintenance was another business driver that all participants identified, they all agree that with correct timing for maintenance, they can operate their plant and equipment's and get maximum value and performance out of them. Digital technologies and solutions can increase their operations performance and reduce breakdowns (Lazarenko et al., 2021); (Molaei et al., 2020). They want to install digital technologies and solutions in their existing equipment's to monitor their equipment's in operation and predict failure. They believe that installing digital technologies and solutions will help them to move away from reactive and planned maintenance which is costly to predictive and prescriptive maintenance. There is a need for machine and equipment preventative and predictive maintenance in order to increase production and plant efficiency (Gruenhagen et al., 2022); (Molaei et al., 2020). Digital technologies and solutions will unable online monitoring of the assets and equipment and collect valuable information about their health, to be able to predict failure and prescribe maintenance at the right time which will increase the mining and operations uptime. Plant and equipment remote condition assessment is critical to avoid unplanned stoppages and breakdowns, digital technologies and solutions can help achieve this (Gruenhagen et al., 2022). Digital technologies and solutions can also link to supply chain to secure both spares and maintenance personnel at the right time (Zhang et al., 2022).

f. *Smart Mining and Operations*

South Africa mining companies end goal is to create Smart Mining and Operations, all participant mentioned that their ultimate goal for adopting digital technologies and solutions is to create digital mines and operations. They want to be able to track and

monitor their whole value chain from Pit to Port. Smart mining and operations were identified by all participants as their final business value driver, to create a digital connected mining and operations. They believe that digital transformed mine is the biggest business value add. There is a need for mining companies to be able to measure their production variable to respond on time in order to avoid unnecessary production losses (Barnewold & Lottermoser, 2020). Digital technologies and solutions can be connected to a single platform where the whole mining and operations value chain can be managed, monitored, and controlled from as single control room in real time. Real time minerals analysis is one of the smart mining and productions benefits, optimizing the payload by loading quality products (Gruenhagen et al., 2022; Cudjoe & Cawood, 2022; Ge et al., 2018; Martin & Leurent, 2017). Digital technologies and solutions will connect plant, people and equipment's which will increase production, health, and safety performance, decrease production cost. Quick and easy accounting, mining rates and volumes and fast decision making can be achieved by smart mining and operations (Cudjoe & Cawood, 2022; Barnewold & Lottermoser, 2020; Oshokoya & Tetteh, 2018). Real time reporting of quality assurance and control analysis to the remote-control room (Molaei et al., 2020). Tracking of workers and equipment's movement during operations is one of the smart mining and operations advantages (Barnewold & Lottermoser, 2020). Smart mining and operation can be enabled by implementing digital technologies and solutions in the whole mining and operations value chain and mapping them together onto a single digital platform to create a digital connected mining and operation (Karatzoglou Ioanna, 2020).

5.4 What are the Barriers for adopting Digital Technologies and Solutions in South Africa mining sector?

This question seeks to find out and understand the barriers for South Africa mining sector adoption of digital technologies and solutions in their mining and operations. South Africa mining sector has been slow in their digital transformation by adopting digital technologies and solutions compared to global mining companies (Wadula, n.d). Eight barriers were identified by all participants as the reason for the slow digital transformation in their mining and operations. The biggest barriers were availability of digital technologies and solutions that suitable for mining environment, and infrastructure to support these digital technologies and solutions. Most South Africa mining companies are operating old mines that have old infrastructure, plants and equipment's, this is the biggest barrier mentioned by all participants. Below is the list of the six identified barriers.

i. Government regulations.

ii. Resistance to accept digital transformation by the trade unions.

iii. Old existing IT infrastructure and equipment's.

iv. Unavailability of Digital technology solutions that is suitable for mining environment.

v. Shortage and unavailability of digital technology skills, knowledge and understanding.

vi. Unclear digital strategy and roadmap

vii. Inadequate digital technologies selection structures

viii. Inadequate digital technology solution implementation structures

The following sections explains each digital transformation barrier that prevents the adoption of digital technologies and solutions for the South Africa mining sector. These barriers findings are then compared to the literature review findings to either confirm or refute the research findings.

a. ***Government regulations.***

Government and strict regulations were identified as a barrier by most of the participants, they highlighted that there is still a big misalignment between government regulations and digital transformation. Government rules does not allow digitization of certain processes and they must remain manual to be complaint to the regulation. During literature there was no findings that supported this finding, further research is required on this finding.

b. ***Resistance to accept digital transformation by the trade unions.***

Trade unions were identified as a barrier by some of the participants, they stated that unions believe that digital transformation is strategy to reduce jobs. Trade unions do not understand the benefits of digital transformation and sees it as a job cut initiative. Trade unions mandate is to protect jobs and any initiative that threaten their members jobs faces resistance from the unions. During literature there was no findings that supported this finding, further research is required on this finding.

c. ***Old existing IT infrastructure and equipment's.***

Digital technologies and solutions require good and reliable IT infrastructure, old existing IT infrastructure was identified as the barrier by most participants (Kim & Crowston, 2011). There is a huge difficulty in integrating old technology with the new digital technologies and solutions, merging operational technology and information technology (Molaei et al., 2020). Huge volume and variety of data is collected by digital technologies and solutions that require IT infrastructure that can transmit this huge data at high speed and has enough storage. Huge data exchange and storage is required to get full benefit of digital technologies (Molaei et al., 2020); (Aziz et al.,

2020); (Fedulova et al., 2020) There's also a challenge with connectivity as most mines are situated in the remote areas with limited network coverage. The limitation in digital technologies and solution benefits due to existing infrastructure such as network coverage resulting in poor connectivity (Barnewold & Lottermoser, 2020); (Molaei et al., 2020); (Aziz et al., 2020); (Fedulova et al., 2020). Digital transformation requires a huge investment for the IT infrastructure, this was identified by some of the participants. Digital technologies and solutions adoption requires huge infrastructure investment which small mining companies does not have. There is less degree of digital transformation in small mining companies then large mining companies (Lazarenko et al., 2021); (Majstorovic et al., 2021).

d. ***Unavailability of Digital technology solutions that is suitable for mining environment.***

Feasibility and maturity of available digital technologies and solutions were identified by most of the participants, existing digital technologies and solutions have not been tested for the mining environment. South Africa mining companies are reluctant to risk their mining and operations by adopting untested digital technologies and solutions. Digital technologies and solutions suppliers are not willing to test their solutions for the mining environment which makes it impossible for the mining companies to adopt their technologies. There is a big inability for digital technology service providers to facilitate the digital transformation process (Lazarenko et al., 2021). A lot of participants are not willing to spend money in testing available digital technologies and solutions because they are under pressure to produce, they will not risk operations. There is a lack of research and development from digital technology suppliers and wiliness for mining companies to lead the diffusion of new digital technologies and be pioneers (Barnewold & Lottermoser, 2020); (Molaei et al., 2020).

Therefore, unavailability of matured suitable digital technologies and solutions was identified by most of the participants as their biggest barrier for their digital transformation.

e. ***Shortage and unavailability of digital technology skills, knowledge, and understanding.***

Shortage and availability of digital technology skills, knowledge and understanding was identified as the barrier to adoption of digital technologies and solutions by most of the participants. Most participants agreed that Digital Transformation require a digital literacy organization, organization that understand the impact and benefits of digital technologies and solutions. Digital transformation requires both traditional mining and operations skills and digital skills to identify digital transformation opportunities and march them with the correct digital technologies and solutions. South Africa does not have these skills with one person, and this was highlighted by most participants, they have to invest in developing these skills in order to succeed in their digital transformation strategy.

It was also clear from the participants response that there is a lack of domain knowledge (mining and operations) from the Data Scientist and Analytics, as most data analyst do not have a mining and operations background. There is a need to also close this gab and merge these skills. There is a lack of digital business skills and organizational capacity in the mining sector (Lazarenko et al., 2021); (Barnewold & Lottermoser, 2020); (Molaei et al., 2020).

f. ***Unclear digital strategy and roadmap***

Unclear digital transformation strategy and roadmap was identified as a barrier by some participants. They highlighted that for better support from mining and operations, the strategy and roadmap must be understood by employees from all levels. Clear strategy and roadmap are key to its implementation, it is therefore important that the strategy is understood by the whole organization. All participants agreed that without a clear digital strategy and roadmap, digital transformation will either be slow and unsuccessful. Lack of strategy understanding, and needs will affect its priorities (Lazarenko et al., 2021).

g. *Inadequate digital technologies selection structures*

Inadequate digital technologies and solutions selection structures were identified as a barrier by most of the participants, they sited selection of digital technologies and solutions that are not suitable for their mining and operations as their biggest challenge. They believe that proper structures that understand digital technologies and solutions are important and critical. Most of the participants believe that centralized technology structure is more efficient then decentralized structures as they eliminate duplications of digital technologies and solutions. They all agreed that formal technologies and solutions structure is important for successful digital transformation. Lack of access to right knowledge and technologies result is adopting technologies that are not suitable for the applications (Lazarenko et al., 2021).

h. *Inadequate digital technology solution implementation structures*

Inadequate digital technologies implementation structures were identified as barrier by most of the participants, they believe that digital technologies and solutions implementations must be separated from projects and operations. This will avoid any conflict between projects deliverables that have short term deliverables and milestones and digital technologies and solutions initiatives which yields long term benefits. Operations lack understanding of the link between digital technologies and digital principles which will create confusion on their implementation and success factors (Lazarenko et al., 2021). This was agreed by most participants, they also mentioned that operations are more interested in production. Therefore, formal implementation structures are key to the successful adoption of digital technologies and solutions, with dedicated resources to manage the implementation. Mining operators focuses on projects output instead of sustainable business outcome (Lazarenko et al., 2021). Therefore, a dedicated implementation structures are critical for successful digital technologies and solutions adoption.

CHAPTER 6. RESEARCH CONCLUSION AND RECOMMENDATION

6.1 Introduction

The primary research purpose of this study was to understand the potential digital technologies and solutions that the South African mining sector can adopt, in addition to exploring some of the drivers and perceived barriers to their adoption in their mining and operations processes. Understanding available digital technologies and solutions that the South African mining sector can adopt, identifying the drivers for their adoption and barriers to adopting them will assist the South Africa Mining sector in increasing their digital transformation. It will also assist the sector in identifying digital technologies and solutions that are unique to their environment and conditions. Matching the drivers with the potential barriers will assist the South African mining sector in selecting the right digital technology and solutions that will not only fulfil the need but mitigate the barriers to its success.

The research questions findings and results were discussed in the previous chapters. This chapter presents the conclusions, recommendations and suggestions for further research based emerged findings from the study in answering the three research questions. Prepositions are also evaluated against the study findings to confirm or refute them.

6.2 What are the potential Digital Technologies and Solutions that South African mining sector can adopt in their processes?

Based on the research findings, it was evident that there are limited available digital technologies and solutions for the South African mining sector to adopt in their mining and operations. Most of the available digital technologies and solutions are either borrowed from other industries, are still being developed, have not matured, and have not been tested in the mining sector. South African mining companies except a few are sceptical to be pioneers and install technologies and solutions that have not been tested for their environment. Big South African mining companies are testing available digital technologies and solutions on their mining and operations in order to unable their digital transformation. Small South African companies are not able do the same as they don't have enough financial capacity as digital technologies and solution suppliers are not willing to trial run their digital technologies and solutions. Some technologies and solutions suppliers are willing to do proof of concepts on their digital technologies and solutions, this has enabled testing their technologies and proving them in the mining and operation environment which is minimizing the risk of South Africa mining companies from purchasing and installing unproven technologies.

Research findings did not find specific digital technologies and solutions that the South African mining sector is adopting, different companies are all looking at any available technologies and solutions that can address their business needs and can operate on their mining and operations environment.

The research findings agreed with the preposition that was drawn from the literature review that the available digital technologies and solutions are not suitable for the South African mining sector’s complexity and environment and that the reason for slow digital transformation in the sector.

6.3 What are the Drivers for adopting Digital Technologies and Solutions in South African mining sector?

Based on the research findings, the South African mining sector has many drivers for the adoption of digital technologies and solutions in their mining and operations. There were five key drivers which were identified during the study which are driven by South African mining companies' strategies to add value to their businesses, by adopting digital technologies and solutions in their mining and operations. Digital technologies and solutions in the mining and operations have been identified as the biggest lever by South Africa mining companies to add value to their businesses. The following business value adds drivers were identified and common to most South African mining companies.

- *Health and Safety Improvement*
- *Mining and Production Processes Improvement*
- *Cost Containment and Reduction*
- *Mining and Operations Sustainability*
- *Prescriptive and Predictive Maintenance*
- *Smart Mining and Operations Value Chain*

The research findings agreed with the preposition that was drawn from the literature review that the due to the complexity of the South African mining sector, the sector has multiple drivers that are driving their digital technologies and solutions adoption. Due to the complexity of the South African mining sector, addressing all the drivers with a single digital technology or solution is impossible, mining companies are trying to source and integrate different digital technologies and solutions, and this results in the slow digital transformation in the sector. The slow digital transformation is also due to the need for South African mining companies to adopt digital technologies and solutions that will integrate their whole value chain and those digital technologies and solutions are not available as concluded in research question one findings.

6.4 What are the Barriers for adopting Digital Technologies and Solutions in South Africa mining sector?

Based on the research findings, the South African mining sector has many barriers that prevent them from adopting digital technologies and solutions in their mining and operations. These barriers emanate from the complexity of the mining and operations environment. South African mining companies are looking at digital technologies and solutions, and human resources with digital skills and knowledge to mitigate these barriers.

Based on the findings of the study, the following barriers were identified and are the ones preventing the South African mining sector from progressing in its digital transformation

i. *Government regulations.*
ii. *Resistance to accepting digital transformation by the trade unions.*
iii. *Old existing IT infrastructure and equipment.*
iv. *Unavailability of digital technology and solutions that is suitable for the mining environment.*
v. *Shortage and unavailability of digital technology skills, knowledge, and understanding.*
vi. *Unclear digital strategy and roadmap*
vii. *Inadequate digital technologies and solutions selection structures*
viii. *Inadequate digital technologies and solutions implementation structures*

All the barriers were identified during the literature review except government and trade unions. The research findings identified both government and trade unions as some of the barriers, with the government still having rules and regulations that are not aligned with digital transformation initiatives and benefits. Trade unions also sees digital transformation as the strategy to replace humans with robots which will result in job losses. Not all South African companies agreed with trade unions as a barrier and indicated that they have a working relationship with the unions and understand the

need and benefits of digital transformation. But it is worth mentioning that some mining houses do have trade unions as a barrier to accepting digital transformation.

All participants agreed that without overcoming the above barriers, the South African mining sector will not progress in their digital transformation and achieve the full benefit of digital technologies and solutions

6.5 Recommendations

For South African mining sector to increase their digital transformation uptake they have to apply the following recommendations which is informed by both study and literature review findings.

6.5.1 *Digital Strategy and Roadmap*

Mining companies must also develop a clear digital strategy and roadmap that is understood by all stakeholders, both internal and external stakeholders in order to eliminate barriers from stakeholders as identified during the study.

6.5.2 *Suitability and maturity of available Digital Technology and Solutions*

Partnership South African mining sector, companies and digital technologies and solutions suppliers is required to create, trail, and test available digital technologies and solutions in the mining and operations environment to prove them without risking mining their mining and operations.

6.5.3 *Digital Technology and Solutions selection and implementation*

Mining companies must create formal structures for selection and implementation of the digital technologies and solutions. This will assist in matching digital technologies and solutions with the business need. This will also eliminate multiple digital solutions for similar business needs within the same company in different operations.

Mining companies must adopt digital technologies and solutions for new project, Engineering Consultants must incorporate digital technologies and solutions their design for the new projects and upgrades. This will reduce the outlay and cost of the digital transformation when done alone as a project which was seen as one of the barriers as mining companies do imminently see digital transformation benefits in the short to medium term.

6.5.4 *Multiple Digital Transformation Drivers*

Mining companies must identify their digital transformation drivers and prioritize them according to their business value add, this will assist in avoiding searching for multiple digital technologies and solutions resulting in poor evaluation of available digital technologies and solutions. This will also avoid searching for single digital technology and solution that can be adopted for multiple drivers which is currently not available.

6.5.5 *Multiple Digital Transformation Barriers*

Mining companies must evaluate their mining and operations barriers before adopting any digital technologies and solutions. They must understand and match their environment and existing infrastructure with the potential digital technology and solution requirements. Mining companies must match their drivers against possible barriers and limitations that can prevent the potential digital technologies and solutions from being adopted, operated and maintained successfully

6.5.6 *Digital and Domain Skills*

Mining companies must recruit and train their resources digital skilled in order to be able to select, operate and maintain these digital technologies and solutions.

It is there recommended that digital technologies and solutions suppliers, engineering consultants, and South Africa mining companies work together to create digital technology and solutions that are specifically for the mining sector with the support from government and the trade unions in order to increase their digital transformation.

6.6 Suggestions for further Research

This study was not focused understand the potential digital technologies and solutions that the South African mining sector can adopt to increase their digital transformation in their mining and operations, and also to explore the drivers and barriers to adoption these digital technologies and solutions. Literature review highlighted several digital technologies and solutions that mining companies across the globe are adopting on their mining and operations.

Since the study was limited to identifying potential digital technologies and solutions that South African mining sector can adopt and exploration of some of the Drivers and perceived Barriers for the sector to adopt these potential digital technologies and solutions. It is recommended that further studies are done to investigate what digital technologies and solutions that the South African mining sector is exploring, testing, and adopting in their mining and operations. The study findings were that some South African mining companies are already adopting digital technologies and solutions and others conduction proof of concepts with digital technologies and solutions suppliers, but it was not clear which digital technologies and solutions are they adopting and trailing in their mining and operations. Further study is necessary to explore this.

6.7 Limitations and challenges of the study

- Not all management levels were available as outlined on Table 3.1
- Inexperience in interviewing people
- There was poor connectivity during interviews since most participants were at their operations with poor network.
- Rescheduling of interviews due to loadshedding

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APPENDIX A – University Ethics Clearance Certificate

Graduate School of Business Administration
University of the Witwatersrand, Johannesburg

Wits Business School Ethics Committee
Constituted under the University Human Research Ethics Committee (Non-Medical)

Ethics Clearance Certificate

Ethics protocol number: WBS/DB2401902/164
This certificate is only valid with a legitimate ethics protocol number and signed by the Researcher (below).

Project title	Digital transformation opportunities and challenges in the South African mining sector
Investigator / Researcher	Mr Ntokozo Mthimkhulu
Nature of Project	MM (Digital Business)
Decision of the Committee	Approved, provided stakeholders and participants are guaranteed confidentialty.
Issue Date of Certificate	2022-12-02
Expiry date	Date of submission of the project / research report
Chairperson	Prof Anthony Stacey +27 11 717 3587 +27 82 880 4531 anthony.stacey@wits.ac.za

Declaration by Researcher

One copy must be signed by the Researcher and returned to the Chairperson of the Wits Business School Ethics Committee.

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

Signature

15 December 2022
Date:

APPENDIX B – Participant Information Sheet

Dear Sir / Madam

My name is Ntokozo Mthimkhulu. I am a Master's student in Master of Management in the field of Digital Business at the University of the Witwatersrand, Johannesburg. My supervisor is Ayanda Magida. I am conducting a research study about Digital Transformation. The study title is Digital Transformation Opportunities and Challenges in the South African Mining Sector

I am inviting you to take part in an interview. If you decide to take part, your participation in this research study will last about an hour. The interview activity will take place on Microsoft Teams at your available convenient time.

With your permission, I would like to audio/video record the interview/focus group. This data will be stored in a secured password-locked hard drive for five years and/or deleted after five years. Only the researcher will have access to the data.

During the research activity, I will need to ask for some personal information about you, including company's digital transformation strategy.

The interview will be confidential and anonymous. When I share the results of the research study, I will not include your name or anything else that could identify you. With your permission, other researchers may use the data collected from this research study, but your name and any personal information will not be used or passed on.

If you decide to take part in the research study, it should be because you want to volunteer. You do not have to take part. You can stop being in the study at any time. You do not have to answer any questions if you do not want to. You will not get any direct benefits if you choose to join the research study. You will not lose any services, benefits or rights you would normally have if you decide not to join. Taking part in the research study will not cost you anything. You will not be paid for being in this research study.

The risks for this research study are no more than what happens in everyday life. OR Some of the questions asked may make you feel sad or upset. If this happens, I will stop the interview and continue another time.

This research study will be written up as a research report. The report will be available on the university library website. If you would like to receive a summary of this report, I will be happy to send it to you.

If you have any questions during or afterwards about this research study, feel free to contact me or my supervisor on the details listed below. If you have any concerns or complaints about the ethical procedures of this research study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email hrecnon-medical@wits.ac.za.

Yours sincerely,

Researcher:

Ntokozo Mthimkhulu – 2401902@students.wits.ac.za; 0827157429

Supervisor:

Ayanda Magida – Ayanda.Magida@wits.ac.za, +27 11 717 3953

APPENDIX C – Participant Agreement Form

Title of project: Digital Transformation Opportunities and Challenges in the South African Mining Sector

Name of researcher: Ntokozo Mthimkhulu

I, ……., agree to participate in this research project.
I agree to the following:
(Please circle the relevant options below)

The research study was explained to me. I understand what this study is about.	YES	NO
I understand that I can volunteer to take part in the study	YES	NO
I agree that the interview/focus group/other activity may be audio recorded	YES	NO
I agree that direct quotations from my interview may be used by the researcher in their research report.	YES	NO
I agree that my participation will remain anonymous (my name will not be used by the researcher in their research report.	YES	NO
I agree that other researchers may use the information I provide in my interview (depending on their own ethics clearance being obtained) but my name and any personal information will not be used or passed on	YES	NO

…… (signature)
…… (name of participant)
…… (date)
…… (signature)
…… (name of researcher/person seeking consent)
…… (date)

APPENDIX D – Research Questions

Table 0-1 - Research questions

QUESTIONS
Question 1: What are your Company thoughts on Digital Transformation, adoption of Digital Technologies in their Mining and Operations?
Question 2: What do you think are essential skills to Implement Digital Transformation, Managing, Operating and Maintaining Digital Technologies?
Question 3: What is your Company Digital Transformation Strategy and Roadmap?
Question 4: What structures does your Company use or intent using to select Digital Technologies for their Digital Transformation?
Question 5: How does your Company drive or intend to drive Digital Transformation i.e., Department, Division, Committee?
Question 6: What is your Company External Drivers for Digital Transformation? (Suppliers, Government, Competitors, etc)
Question 7: What is your Company Management Process Drivers for Digital Transformation?
Question 8: What is your Company Operational Process Drivers for Digital Transformation? (Mining and Operations)
Question 9: What is your Company External Barriers for Digital Transformation? (Suppliers, Government, Competitors, etc)
Question 10: What is your Company Management Process Drivers for Digital Transformation?
Question 11: What is your Company Operational Process Drivers for Digital Transformation? (Mining and Operations)
Question 12: What are the Infrastructure Barriers for your Company Digital Transformation?