THE RELATIONSHIP BETWEEN HUMAN FACTORS AND TECHNOLOGY ADOPTION AT SISHEN MINE

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DEDICATION

This report is dedicated to my family, especially Bomma, Mathapelo, Mabohlale Tumishang and MmaKotelo, friends and colleagues for their encouragement, support and inspiration.

ABSTRACT

Mining of raw materials and minerals started centuries ago in South Africa. Mining methods, then, were very primitive and labour-intensive with the use of slaves in some instances. With industrial revolution came the development of other industries and supply chain process between industries which gave rise to human civilization and improvement of people's livelihoods. The mining industry progressed as an adopter of technology with operations moving from mechanisation to digitisation. People however remained an integral part of the industry and in the case of South Africa, that is going to be the case for the foreseeable future.

South Africa has a high unemployment rate and the mining industry employs approximately half a million people and Sishen Mine employs about 10 000 people. Given the role of mining in the country, it is important that adoption of technology and digital revolution take into consideration human factors in order to be successful. Some of the challenges the mining industry is faced with that requires the adoption of technology, include safety of employees, depleting orebodies and declining commodity qualities, rising input costs, supply chain constraints and macro-economic factors such as competitive commodity markets. To address some of these challenges, the mining industry is adopting technology and there has been significant benefits realised in the safety of mines.

Sishen Mine strives towards zero harm and achievement of hundred percent overall equipment efficiency in order to remain sustainable. With technology, there has been some progress in reducing fatalities but there are still significant safety incidents taking place even in areas where technology was implemented to prevent such incidents. The aim of this research was to investigate the impact of human factors on the adoption of technology at Sishen Mine. The objectives of the research were to identify benefits and challenges to adoption of technology and investigate factors that support and/or hinder technology adoption. Another objective was to establish the gaps in the implementation of technology in consideration of the impact human factors have on adoption of technology.

Literature studies on mining technology, human factors and how they affect adoption of technology was conducted and found that human factors play a crucial role in the success of technology adoption. Several technologies employed at Sishen Mine were studied and their OEMs interviewed to share the benefits of these technologies and how they performed at Sishen Mine. Mine employees were also interviewed to share their personal experiences of technology in their work. It was found that human factors do have an impact on technology adoption. Key findings were that the benefits of technology were fairly understood and some of the challenges to adoption of technology at Sishen Mine related to human factors. The results showed that there were gaps in the capability of the technologies under study and the benefits realised in Sishen Mine. Some of the gaps included lack of understanding of how the technology worked and inadequate buy-in from end-users due to fear of job losses and inadequate engagement of all stakeholders.

It is recommended that human factors are considered during technology implementation for successful technology adoption. This must be supported by adopting the design thinking approach to problem-solving wherein all stakeholders will be engaged on the technology solution before it is implemented. This will drive buy-in and address the human factors that may hinder the adoption of technology. Another recommendation is that a thorough management of change process be employed to cover technology implementation and adoption from the start of the process to the support provided by OEMs post installation, in order to ensure full adoption and integration into the operating model.

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Change management is a systematic approach to dealing with the transition or transformation of an organization's goals, processes or technologies.

Operating Equipment Effectiveness is the calculated product of equipment utilisation, effective rate and quality achieved

Technology is defined as the products, processes, tools, methods and systems that are employed in the manufacturing of goods and services

LIST OF ABBREVIATIONS

ADS	: Autonomous Drilling Systems
AI	: Artificial Intelligence
CAS	: Collision Avoidance System
ER	: Employee Relations
FMS	: Fleet Management System
GDP	: Gross Domestic Product
HME	: Heavy Mobile Equipment
IM	: Information Management
IoT	: Internet of Things
IT	: Information Technology
KPI	: Key Performance Indicators
LOM	: Life of Mine
MCSA	: Minerals Council South Africa
MHSA	: Mine Health and Safety Act
MHSC	: Mine Health and Safety Council
MW	: Megawatt
OEE	: Operating Equipment Effectiveness
OEM	: Original Equipment Manufacturers
PEAT	: Personalised Emergency Alerting Tag
PGMs	: Platinum Group Metals
R&D	: Research and Development

RIIS : Research Institute for Innovation and Sustainability

SaaS : Software-as-a-Service

SAIMM : Southern African Institute of Mining and Metallurgy

SAMI : South African Mining Industry

SARS : South African Revenue Services

SLT : Sishen Leadership Team

SM : Section Manager

TAM : Technology Adoption Model

TMM : Trackless Mobile Equipment

TRCFR : Total Recordable Cases Frequency Rate

VIS : Vehicle Intervention System

ZEHS : Zero Emission Haulage Solution

CHAPTER ONE: INTRODUCTION AND STUDY OBJECTIVES

1.1 Background and Context

The mining industry has seen improvements in health and safety, productivity, and profitability of mining operations with the introduction of technology. According to Jurgens (2017), BHP realised about 20% reduction in haulage costs, safety incidents involving mobile equipment and increased truck utilisation in their fleet of self-driven trucks. The benefits that come with technology have led to mining operations making investments towards technology with the objective of automation as an end-goal for most operations.

Amongst the mining companies that are taking the lead in technology integration is Anglo American, which has announced its ambition of becoming the leading global mining company to adopt technology across the mining value chain (Anglo American, 2013). This is seen in one of its companies, Kumba Iron Ore which has implemented several technology initiatives in high-speed exploration, automated drilling, advanced process control and modular dispatch upgrades (Cornish, 2016). According to Mari (2018), Kumba Iron Ore spent more than R749 million on modern technology between 2014 and 2017 to increase production at both their Sishen and Kolomela mines. To this effect, Anglo American through innovation and implementation of surface mining technology has resulted in the extension of the Sishen mine's life of mine (LOM) to 2035.

According to Deloitte (2020), for successful technology adoption, it is important to understand how humans interact with technology and this requires an emphasis on change management to shift their behaviour. Lawton (2022) defines change management as a systematic approach to dealing with the transition or transformation of an organization's goals, processes or technologies. The purpose of change management is to implement strategies for effecting change, controlling change and helping people to adapt to change.

Technology comprises of tangible and intangible elements, and organisations often invest more on tangible factors such as infrastructure and installation of technology hardware and software on the mining equipment. It has been found that inadequate attention is directed to the intangible elements necessary to support technology uptake. To understand the intangible factors, Robert. et al. (2021) investigated the psychological factors that affect technology adoption and identified fifteen factors that have been grouped into six overarching categories. These groups are motivation, cognitive, personality, attitude, social and organisational factors.

This research is aimed at investigating human factors that impact the implementation and adoption of mining technology at Sishen Mine. The mine is over sixty years old and currently exploiting one of the largest iron ore deposits in South Africa. It has an estimated ore reserve of 571.9 million tonnes, with plans to extend the life of mine up to 2035 (Anglo American, 2021). The mine employs different technologies across the mining value chain to optimise safety and productivity for improved cost competitiveness, profitability and sustainability. While the benefits of technology adoption have been recorded, the occurrence of safety incidents and poor production performance reveal the shortcomings of technology solutions that have been employed which have not realised their full benefits.

At a conference hosted by the Southern African Institute of Mining and Metallurgy (SAIMM) in Botswana, Jordaan and Hendricks (2009) presented challenges to technology adoption and utilisation by mining companies. They stated that, while mining companies recognise the benefits of mining technology, they often lack the appetite and/or ability to define and undertake the necessary change management required to integrate new technologies appropriately. Research conducted by Ntsoelengoe (2019) on change management and behavioural factors made the following recommendations based on the gaps in technology implementation:

- Communication for buy-in and support is crucial for the alignment of stakeholders to a strategy and their support in the short-term and future plans. Employees must be taken along the journey from the start as they are the “true” owners of the technology solutions.
- Contextualising the required change is important for all stakeholders to understand the required change, its benefits and how it impacts them.
- Behavioural change is defined as the mindset and individual perceptions of benefits of the change, which supports the change if people see it positively.

- An organisational culture that promotes innovation is a major enabler for technology acceptance in organisations.

For mining companies to be successful at adopting and utilising technology, their business and technology strategies must be aligned (Jordaan and Hendricks, 2009). The alignment of strategies and change management cannot happen without understanding the perceptions of people who work in the mines on the use of technology and how that affects the interaction and integration of technology in the workplace.

The South African mining industry is still relatively labour-intensive, and work needs to be done to integrate the current and future workforce with emerging and developing technologies. According to Khalil (2000), the first step to aligning business and technology strategies is establishing the companies' core competencies. The core competencies of a company are embedded in its intangible or human technology elements, namely, knowledge, "know-why" and "know-how". This is true in mining companies that have been operational for many years in that their success has been partly attributed to human capital. It is therefore important to direct the attention to the people that work in the mines for improved safety and operational performance enabled by technology implementation.

1.2 Problem Statement

Sishen Mine employs several technologies which are aimed at improving safety and productivity performance. For example, the mine has installed a collision avoidance system (CAS) on all its trackless mobile machinery (TMM) to prevent collisions. There is also the Modular Dispatch Fleet Management System (FMS) which is used to improve overall load and haul performance between primary loading equipment and haul trucks for maximum productivity. While the mine has realised improved safety and production performance, it is still experiencing safety incidents that prevents the mine from achieving the goal of zero harm and their ambition of becoming a global benchmark in overall equipment efficiencies (OEE). Figure 1.1 shows Kumba Iron Ore's safety performance in terms of total recordable cases frequency rate (TRCFR) and fatalities from 2013 until 2019.

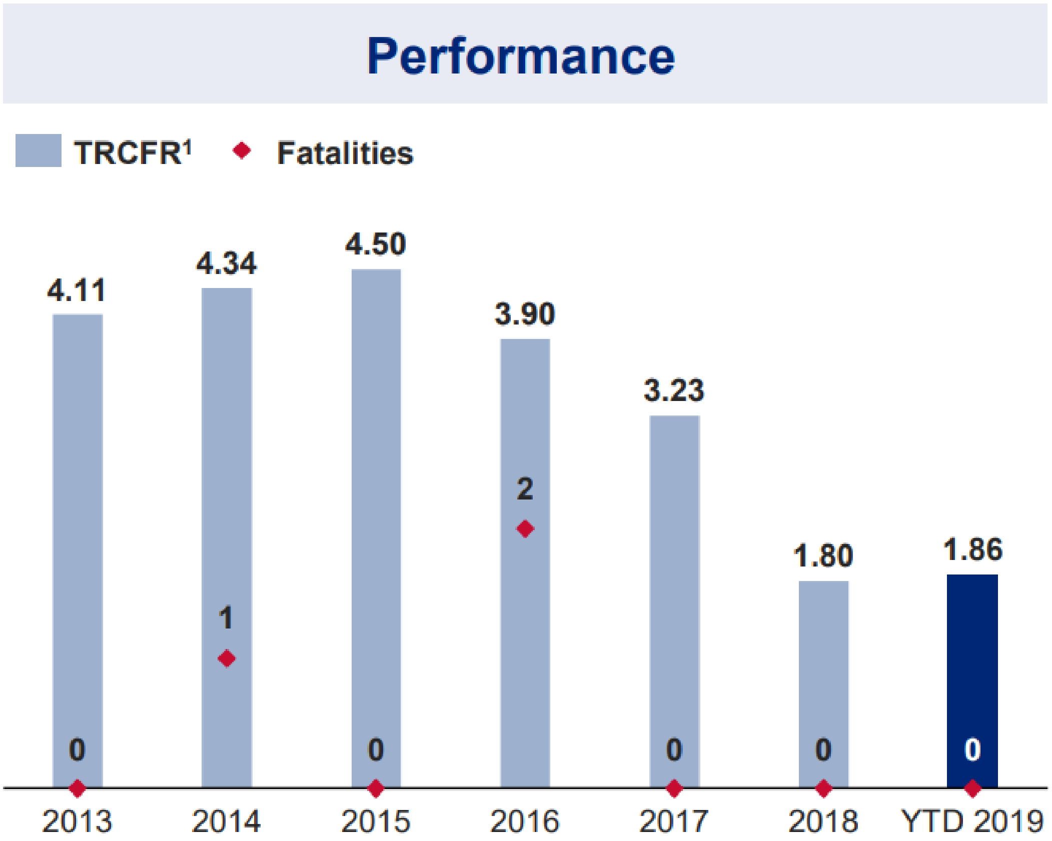

Figure 1.1: Total Recordable Cases Frequency Rate Anglo American (Source: Anglo American Kumba Iron Ore, 2019)

While figure 1.1 shows that there is an overall reduction in safety incidents, the mine has not reached the target of zero incidents. From safety-related incident investigations that have been conducted by the mine, it has been found that amongst the main contributors of the incidents is the interaction of employees with technology that has been put in place to prevent safety incidents from occurring. It has been found that equipment operators do not respond to alarms at times.

The second objective of adopting technology at the mine was to enhance productivity performance. Figure 1.2 shows the mine's operating equipment efficiency which is defined as the calculated product of equipment utilisation, effective rate and quality achieved (Anglo American Kumba Iron Ore, 2019). Sishen Mine has seen significant improvement in its overall equipment efficiencies (OEEs) between 2012 and 2019. The mine's target is working towards a 100% overall equipment efficiency in 2023.

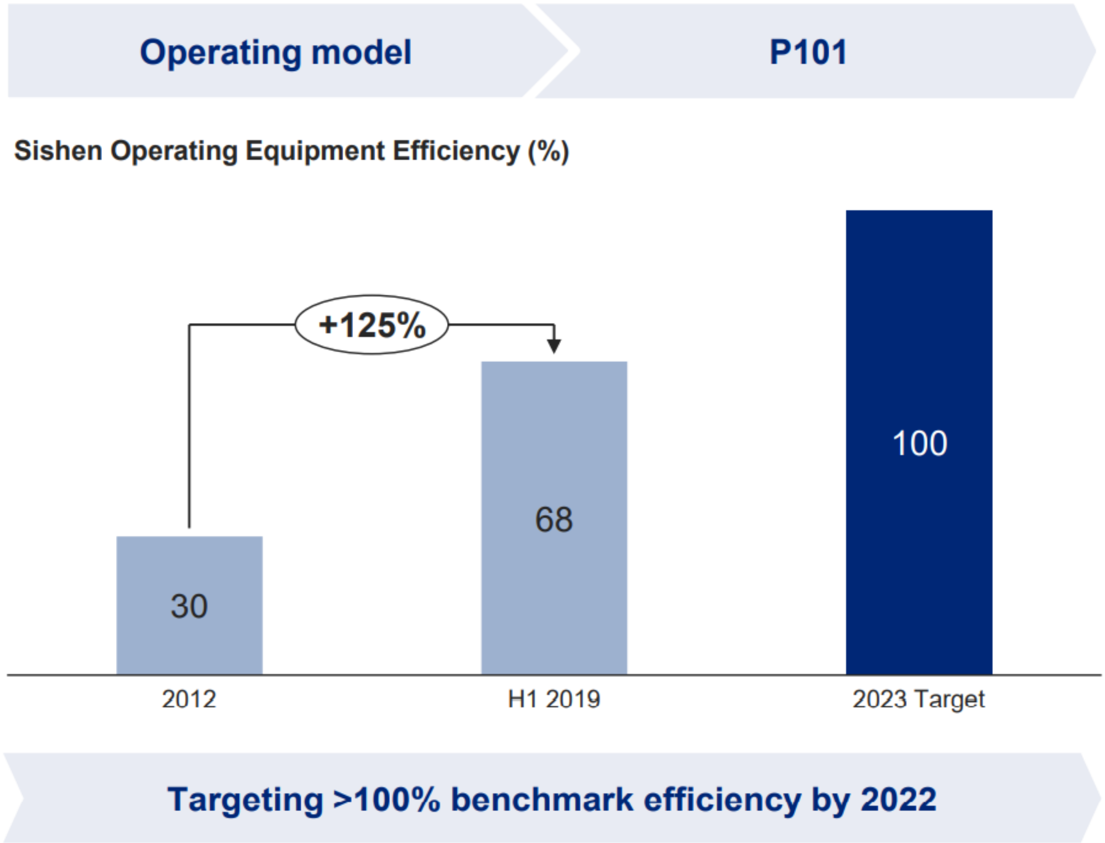

Figure 1.2: Sishen Operating Equipment Efficiency (Source: Anglo American Kumba Iron Ore, 2019)

The importance of realising the full benefits of technology is underpinned by the challenges that the mine faces. The continuing trend of safety incidents threatens the mine's license to operate and compromises the organisation's reputation as well as investor confidence. With fluctuating iron ore prices and market volatility, the mine needs to operate at optimal efficiencies to reduce their costs and continue to be competitive in the market as a premium ore supplier.

1.3 Research Aim and Objectives

The research aims to assess the relationship between human factors and technology adoption at Sishen Mine in the Northern Cape. The objectives of the research are to:

- Identify the benefits and challenges relating to technology adoption and implementation at the mine;
- Establish the links between human factors and technology adoption and implementation at the mine;
- Assess the extent to which the human factors are incorporated in technology adoption;
- Investigate factors that support and/or hinder adoption of technology in the mine; and
- Identify gaps in the implementation of technology and make recommendations towards the integration of human factors in technology adoption for realisation of the benefits thereof.

1.4 Research Questions

The main question that the research aims to address is what is the relationship between human factors and technology adoption at Sishen Mine? This question is supported by the following sub-questions which form the basis of the research:

- What are the benefits of technology in mining?
- What is the performance of the different technologies that have been implemented in the mine?
- What are the challenges with technology adoption and implementation at the mine?
- What are the factors supporting and/or hindering technology adoption?
- Are human factors considered and how have they been incorporated in technology adoption?

1.5 Research Motivation

The findings of the research will enable mining operations to improve technology implementation and adoption by integrating human-related factors and change management processes. The research aims to contribute towards improving the human-technology interface leading to improvements in health and safety performance as well as operational efficiencies and sustainability of mining operations.

Through successful integration of technology, Sishen Mine will realise its goal of zero harm, eliminate fatalities as well achieve as 100% operating equipment efficiency.

The findings of the research are also expected to improve employee-technology interaction and uptake at Sishen mine. This can be achieved by forming the base for thorough employee engagements in order to ensure that they are well-informed and trained on technology and its benefits. Informed engagements will also empower all stakeholders to discuss human factors that may cause motivation or demotivation for technology adoption. Employees will also be more welcoming of new technologies and participate more positively in ensuring that the technologies work well through buy-in and improved sense of ownership. There will also be reduced reliance on technology original equipment manufacturers (OEMs) and cost post-implementation phase in terms of support required and also improvement of technology ownership by end-users. According to the Minerals Council South Africa (2019), the achievement of people-centric technology adoption will result in a mining industry that is safe, healthy, profitable and sustainable.

1.6 Report Structure

The report is structured into seven chapters as described below:

- Chapter one provides the introduction and background of the research and outlines its objectives and motivation. It gives context of the research and also defines the problem statement with key research questions.
- Chapter two covers the history of the global mining industry in relation to the industrial revolution and the impact of technology on its development. The definition of technology and its benefits and challenges in mining are also discussed.
- Chapter three discusses the South African mining industry and its challenges and the status of adoption of technology in consideration of human factors.
- Chapter four introduces human factor theories and the link between the theories and how they influence adoption of technology.
- Chapter five focuses on the research methodology which includes approach and design, a brief description of the case study, data collection and analysis

methods. It also outlines the framework, ethical considerations and limitations of the research.

- Chapter six presents findings from the research and discusses the data collected through interviews and analyses the results. In this chapter, the results are interpreted in order to draw up correlation between human factors and technology adoption, factors hindering and supporting technology adoption and how these factors are incorporated in management of change processes.
- Chapter seven provides insights on the outcomes of the research and conclusion on the findings and gives recommendations on next steps for a successful technology adoption at Sishen Mine.

CHAPTER TWO: GLOBAL MINING INDUSTRY AND TECHNOLOGY ADOPTION

2.1 Introduction

The purpose of this chapter is to define technology and key factors for adoption and discuss the history of the global mining industry and how it has evolved through different industrial revolutions. The chapter also covers the benefits and challenges of technology adoption in mining.

2.2 Definitions of Technology and Key Concepts

Technology is defined by Maskus (2004) as the information that is necessary for achievement of certain production outcomes, from particular means of combining or processing selected inputs. Included in these selected inputs are production processes, intra-firm organisational structures, management techniques and means of finance and marketing methods. Production processes in mining may be defined by means of a mining value chain, starting from prospecting and exploration and extraction of mineral resources to delivering products to consumers.

According to Gorner et al (2020) there are interdependencies throughout the mining value chain which can be enhanced through a mine-to-market performance that relies on two underlying factors, namely: organisational enablement and data and technology architecture. Khalil (2000) defines technology as products, processes, tools, methods and systems that are employed in the manufacturing of goods and services which comprise four components, namely:

- Equipment – defined as the physical structure and logical layout of equipment used in performing tasks;
- Knowledge – basic knowledge of how equipment is used to perform task;
- Know-how – knowledge of cause and effect relationships and the resultant reasons for a particular manner of technology application; and
- Know-why – acquired knowledge and technical skills of how things are done well.

Examples of technology in the mining industry include the usage of drones for surveying in surface mines, Autonomous Drilling Systems (ADS), Personalised

Emergency Alerting Tag (PEAT) system to track underground employees and Fleet Management System (FMS) that gives real-time information on machine status and performance. These technology examples brought about change in the way mine surveying, production drilling, surface loading and hauling operations and safety of underground employees were done. The change required a systematic approach in order to ensure success and according to Yeates (2021), the following factors are important for successful technology adoption:

- People – ensuring that all employees across the business understand the change required and why it is important for it to happen. How the change is going to impact them, their role and future expectations for a successful technology change management;
- Organisational alignment – alignment between corporate and operational strategy measures as well as having measures, key performance indicators (KPIs) and incentive schemes that support technology adoption and the required change;
- The structure and operating model – organisations' strategies should focus on a long-term view of future technologies which will be employed and be made integral to the operating model, KPIs and incentive structures. This is supported by having clearly defined roles and support for innovators, both within organisations and OEMs/service providers, who can explore technologies and introduce them to operational teams for training and testing;
- Creatives and inventors – these are creative people who will work within the organisation as innovators with the freedom to explore and try new things. They need support and structure for their work to succeed in driving innovation through the organisation without being involved in the day-to-day operations. These people are critical in driving adoption through engagement with different people across the organisation;
- Leadership – leadership across different levels should focus on removing barriers to technology adoption and making intentional decisions to implement and scale technologies across an organisation. Leadership determines the culture of the organisation and influences all the other factors required for technology adoption; and
- The process – for technology innovation to be successful, organisations need to have a well-managed process of implementing technology as per the tried and

tested Technology Readiness Levels (TRLs) method. The TRL method systematically assesses the maturity level of a technology and assist in assessing its efficacy. The benefit of following this method is to enable technology adopters to make well-informed decision on the type of technology to choose looking at how it was developed and if it was designed and tested for their particular environment and needs.

There are nine maturity levels, ranked from the lowest at one and the highest maturity level at nine as shown in Figure 2.1 (National Aeronautics and Space Administration, 2012).

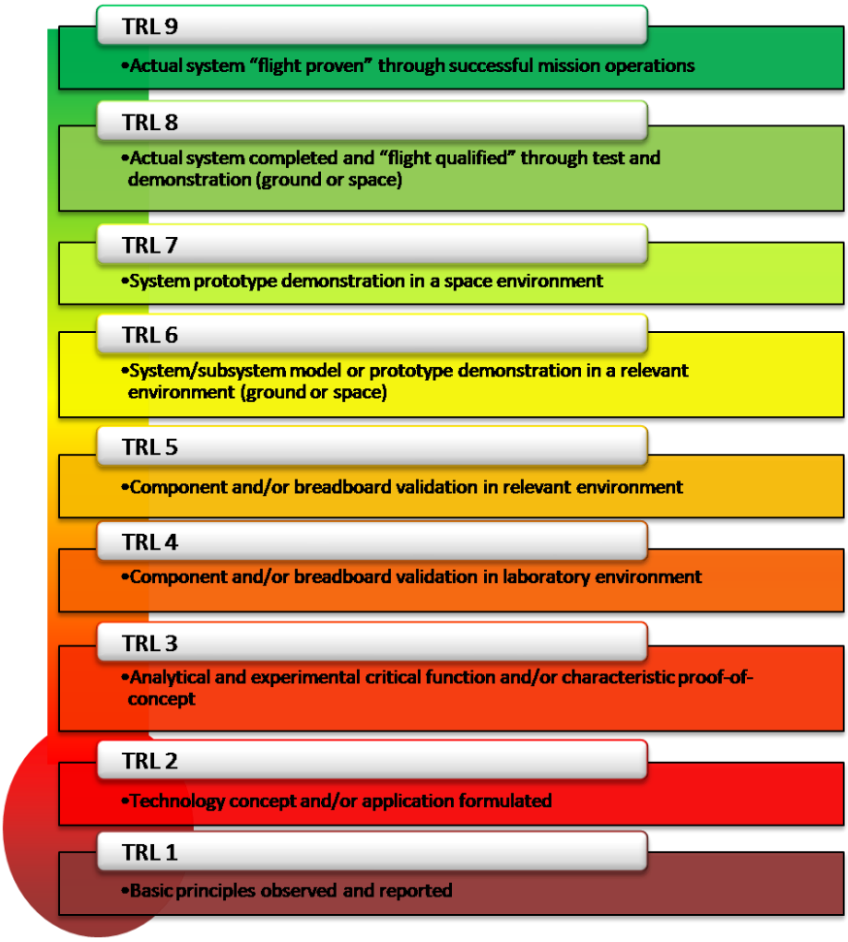

Figure 2.1: Technology Readiness Levels (National Aeronautics and Space Administration, 2012)

Level one is building of the hypothesis, theory or and/or applications of the technology. Level two is about the conceptualisation of the technology and formulating possible applications to prepare for proof of concept in level three as part of its feasibility research. Level four focuses on testing the concept in a laboratory environment to validate the hypothesis and build technical performance criteria. Following the laboratory results, level five tests the concept in a controlled practical environment to validate the hypothesis and build technical performance criteria. Level six and seven are about piloting a prototype or model that can be repeated in similar practical and operational environments respectively. If the prototype delivers demonstratable results and performs as expected in the operational environment, it is then passed as completed and certified in level eight. It is then ready for deployment and can be integrated in the operational process in level nine and ready to be tested in different environments as a complete technology. It is critical for organisations to understand the maturity level of a particular technology before they start using it and consider its benefits, their environment and the solution it brings.

2.3 Mining Industry and Industrial Revolutions

Mining has been an integral part of human existence and survival for ages and this is evident from the history of the Stone Age where stones and other minerals were used to make tools, utensils, paint and many other uses (Kogel, 2013). Methods used to extract these stones and minerals improved with civilisation and industrialisation, from the manual and highly labour-intensive methods to technological and digitalised ones of the current age. The mining industry has grown from the time mining shafts were dug by hand and other primitive tools, to the use of fire and steam and to the introduction of explosives in the Middle Ages (General Kinematics Corporation, n.d.).

With industrial revolution came the development of motorised equipment and machines in mining which improved the safety of mineworkers, extraction methods and productivity. The industry is currently heading into a future of digitisation with reduced human exposure to the risks of mining (General Kinematics Corporation, n.d.). With improving technologies, reliance on mine employees to collect and interpret data to make judgement has greatly reduced. The use of sophisticated systems that integrate the mining value chain and present information for easier decision-making is increasing.

Figure 2.2 depicts how the Internet of Things (IoT) is transforming mining by collecting data from mining equipment and creating dashboards that can be accessed remotely and safely. The figure depicts the mining value chain at the bottom where drilling and other activities take place. Data from these processes is collected and processed in order to analyse it and integrate the processes to give reports on the value chain. The data is integrated from the different activities and reported in a manner in which humans can access it remotely and use it for communication, monitoring performance and making decisions.

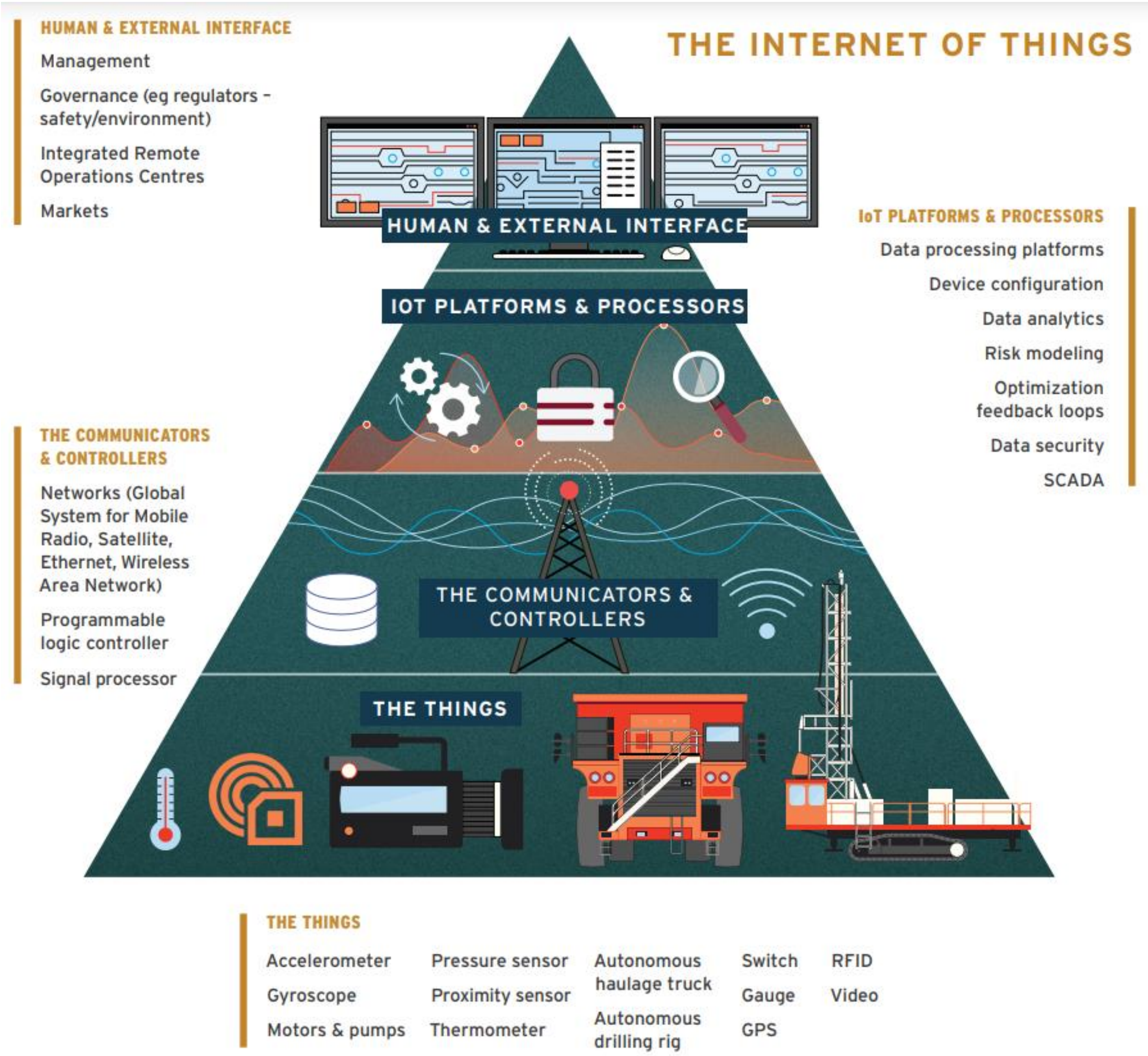

Figure 2.2: The IoT in Mining (Source: Lee and Prowse, 2014)

Other innovations in the mining industry include Rio Tinto's driverless trucks and trains, airborne exploration drones, remote operations centre and autonomous tunnelling and boring machines established as part of their "Mine of the future" program (Lee and Prowse, 2014). Several other operations have implemented automation and the use of drones and according to Sorensen, et al (2020) this will be followed by software components such as cloud solutions, data analytics and 3D imaging and modelling software which will contribute to reduced consumption of fossil fuels, energy and water.

2.4 Key Drivers of Technology in Mining

While there has been technology advancement in the mining industry, the industry still lags behind other industries in innovation and this has contributed to its decline in productivity by up to 30% in the past decade and a half (Crawford, 2018). To add to the strain caused by the decline in productivity, Crawford (2018) adds that the industry is experiencing rising mining costs, higher commodity price fluctuations and declining qualities of mineral deposits and resources becoming more expensive to access. The need for mining companies to remain competitive and maintain their license to operate requires that they continuously innovate and employ advanced mining methods. Key drivers for innovation and technology adoption by mining companies include reduction of operational health and safety risks, reduced environmental footprints, efficiency of mineral deposit exploration, optimised mineral processing and recovery rates and overall cost reduction along the mining value chain (Crawford, 2018).

According to Anglo American Kumba Iron Ore (2021), safety and health, operational performance and managing change are amongst the top risks of several mining companies. Amongst the interventions identified to address the technical challenges facing the mining industry is modernisation and adoption of technology. According to Swart, et al. (2020) the introduction of technology has the potential to transform the mining industry by realising operational efficiency improvements, enhancing productivity, improving safety performance and empowering employees to do more meaningful work.

2.5 Benefits and Challenges of Technology Adoption in Mining

Mining technologies continue to improve health, safety, productivity as well profitability thereby contributing to sustainability of the industry. Crawford (2018) presented case studies from 13 mines that realised operational improvements through the adoption of new and emerging technologies. Some of these improvements were seen in the Western Australia's Rio Tinto Pilbara Iron Ore Mine's autonomous haulage system (AHS), where they ran a trail of a driverless train tested over nearly 100 km in 2017. Another improvement was at B2Gold's 7 MW solar power plant in Otjikoto Mine in Namibia, which reduced the mine's reliance on fossil fuel energy and also improved its license to operate amidst the need to decarbonise. Matthias, et al (2018) reports that Boliden's Garpenberg underground mine in Sweden has connected sensors to robotic equipment to feed data to operators in a control room aboveground. Further benefits of technology can be summarised in different categories as follows:

- **Health and Safety**

The safety of people can be enhanced through the use of light detection and ranging (LIDAR) sensors technology installed on autonomous trucks to measure range and recognise humans within a certain range (Matthias , et al, 2018). This technology can be used to eliminate incidents of trucks driving into people. Collisions of mobile equipment are some of the top fatal risks in surface mining and the use of Collision Avoidance System (CAS) can reduce these incidents (Job and McAree, 2017). Matthias, et al (2018) writes about smart helmets which provide data to the wearer in order to enhance the wearer's vision and give an indication of dangerous areas.

- **Productivity and Efficiencies**

The following technologies improve productivity and efficiencies in mining as reported by Matthias, et al (2018):

  - Autonomous drilling improves drilling precision and efficiency with added benefit of exposing drilling operators to less risk;
  - 3D and 4D printing reduces delivery of equipment spare parts; and
  - Predictive maintenance optimises planned maintenance strategies as well reliability of mining equipment.

Crawford (2018) reported that Rio Tinto's autonomous haulage systems (AHS) can operate for almost 24 hours a day, and this means that more material can be moved than in manned haulage systems.

- **Profitability and Sustainability**

Application of Unmanned Aerial Vehicles (UAE) in surveying processes is relatively low cost and gives easier access to remote and poorly accessible areas (Job and McAree, 2017). Anglo American Platinum is trialling the use of hydrogen powered fuel cell electric vehicles (FCEVs) in order to reduce emission of greenhouse gases as well as creating a new market for platinum for the world's largest platinum supplier (Crawford, 2018).

While technology has brought improvements in the mining industry, there are still shortcomings in terms of the envisaged outputs as they relate to safety performance, productivity and profitability. Yeates (2021) has identified the following factors as challenges to technology adoption in mining:

- The cadence of the mining industry which refers to its reliance on the orebody that depletes over the life of the mine and how the development of mines is highly capital intensive. This is exacerbated by the volatility of mineral commodities which inhibits appetite for technology adoption;
- Proprietary approaches and protection of intellectual property makes it difficult to integrate technologies from different OEMs and this further hinders innovation in the mining industry;
- Organisations not properly defining the roles of technology innovators and technology users and how they can work collaboratively to make technology adoption successful; and
- Operating models and the manner in which mining operations are run, wherein the use of service providers for projects can put technology adoption at risk because of greater focus placed on delivering the projects on time and budget.

In order to determine an industry's level of digital transformation and alignment toward the fourth industrial revolution, Aslanova & Kulichkina (2020) synthesised the definition of digital maturity from different researchers. They defined digital maturity as an adequate reaction of a company on changes in the digital sphere, implementation of digital achievements into business processes as well as development of staff's digital competencies. This definition integrates change management, processes and people which are part of the key factors for successful adoption of technology. Figure 2.3 shows the digital maturity curve and where the mining industry is along the maturity process. The global mining industry lags behind in digital technology advancement when compared to other industries. The mining industry is still developing business models that support technology adoption, coming from an old culture of labour-intensity and primitive mining practices.

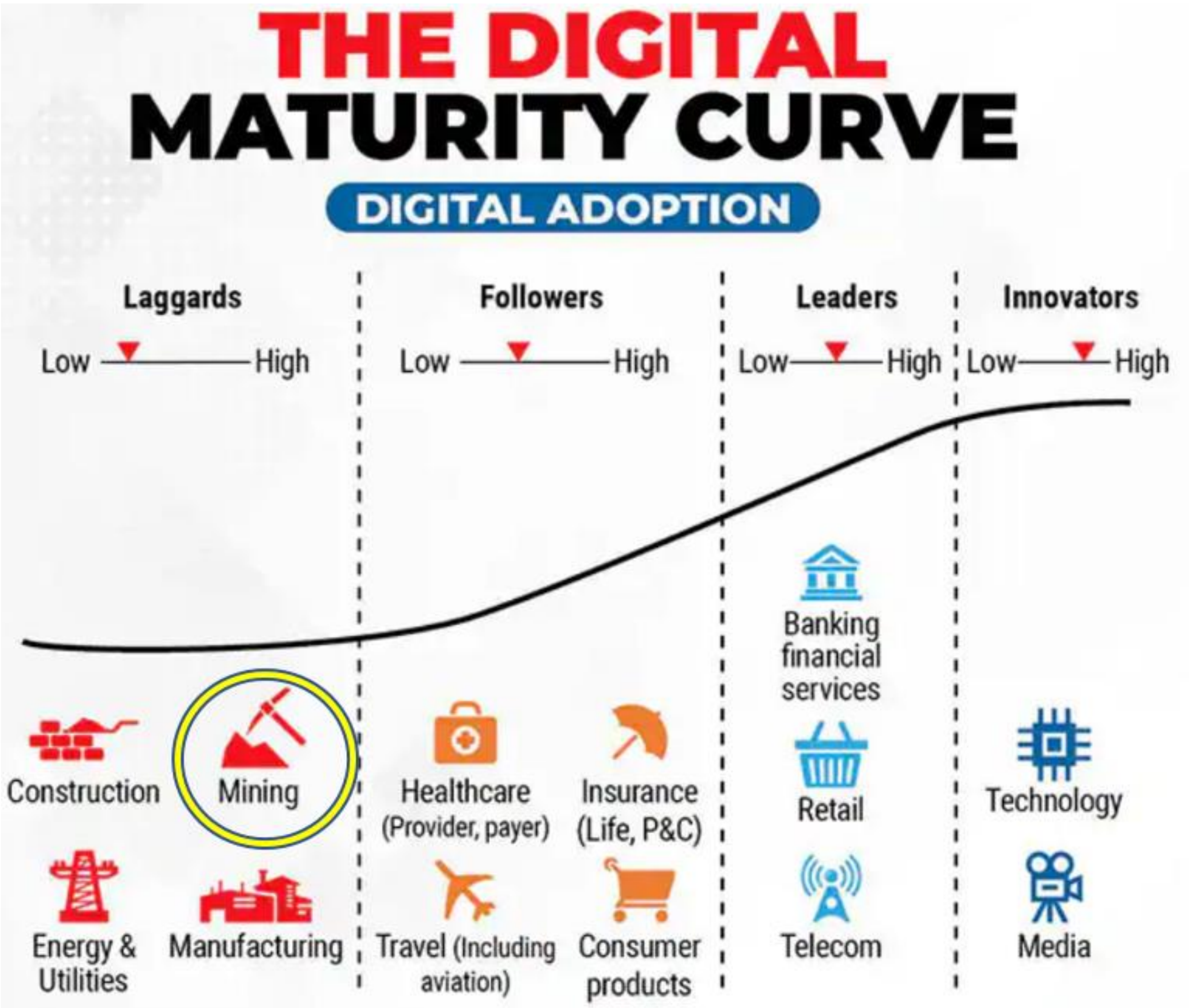

Figure 2.3: Digital Maturity Curve (Source: Majumdar and Raja, 2021)

Majumdar and Raja (2021) describes laggards as industries with rigid processes and designs that are slow to change and mainly focused on cost efficiencies and followers as those that are modernising their core businesses, migrating to cloud services and investing in new-age technologies such as the Internet of Things (IoT) and Artificial Intelligence (AI). Leaders are described as industries that continue to increasingly spend on technology to enhance consumer experience by going direct to customer and enabling more virtual interactions and innovators as leaders in innovation and digital talent who continue to transition their products to Software-as-a-Service (SaaS) and reduce their spending on older products (Majumdar and Raja, 2021). There are several factors that contribute to the slower digital transformation in mining as compared to other industries and according to Lee and Prowse (2014) they include amongst others, the following challenges:

- Culture and workforce in mining historically comprised of older employees with lower literacy levels who relied mostly on physical strength to perform manual labour. They usually see technology as a threat to their jobs and resist the change required for technology adoption. They prefer to keep to the "we have always done it this way" attitude;
- Systems thinking that the mining industry needs to adopt instead of the old way of thinking about independent activities and tools in the value chain. Systems thinking will enable integration of the mining value chain and focus on innovation in order to meet the business bottom lines;
- Industry research and development is not prevalent in the mining industry due to its primary focus of producing raw materials for other industries to turn into usable materials. This inhibits innovation and thinking about new ways of doing things required for technology development and digital transformation. This is also essential to building partnerships with other industries such as suppliers, research institutes and universities;
- Standards and interoperability are not a norm in mining wherein there are competing sets of output along the value chain, hindering collaboration and integration. This is compounded by different OEMs protecting their intellectual property and not allowing integration of systems for simplification and ease of digital transformation; and

- Technology retrofit is one of the challenges in an industry which is highly capital intensive and operate heavy equipment designed without the technology. Retrofitting of technology comes at a cost and occasionally with the risk incompatibility.

Given the abovementioned challenges and shortcomings, the mining industry would need to undergo extensive change management in order to improve innovation and technology adoption. In consideration of other factors such as stakeholder engagement for buy-in, contextualisation of change and organisational culture change to support the industry's transition, human factors are crucial in order for change management to take place successfully. Psychological factors have been identified as being important to technology change management. According to Roberts, et al. (2021), there appears to be a lack of integrated framework which outlines the potential psychological variables for technology adoption and this is valuable for industries such as mining that need to embrace technology for their sustainability.

2.6 Conclusion

Considering the history of human existence and industrial revolutions, the mining industry has played a significant role in human civilisation. The industry has transformed from how it used to operate in the first industrial revolution to the current times of IoT where technology is a big enabler for the industry's growth. There have been some benefits of technology advancements in safety and productivity but the industry still lags behind other industries in innovation and digital transformation due to a number of factors including the slow-to-transform culture and workforce.

CHAPTER THREE: SOUTH AFRICAN MINING INDUSTRY AND TECHNOLOGY ADOPTION

3.1 Introduction

In this chapter, the history and landscape of the South African mining industry (SAMI), its performance in health and safety and contribution to the economy are discussed. This chapter also focuses on challenges that the SAMI is faced with, issues with technology adoption and directs attention to the opportunities that technology can bring to the industry.

3.2 The History and Landscape of Mining in South Africa

Mining in South Africa started in the 1850s when the first copper mine was established, followed by the discovery of diamonds in Kimberley in 1867 in the Northern Cape and gold in 1870 in Limpopo (Mining Africa, 2017). The discovery of other economical minerals followed with the very first diamond discovered in Hopetown on the banks of the Orange river and the mining of the alluvial diamonds led to the founding of De Beers in 1888 by Cecil Rhodes. South Africa is endowed with the world's largest gold resources located in the Witwatersrand Basin, spanning over 400 km and was discovered in the 19^{th} century together with coal and followed by Platinum in 1924 (Mining Africa, 2017). Mining operations were conducted by means of hard physical labour, including migrant labour and "cheap black labour" between 1890 and 1986. It took up to 50 000 mineworkers to dig diamonds up to 215m depth, creating the deepest excavation by hand which is known as the Big Hole in Kimberley (Mining Technology, 2019).

Key commodities mined in South Africa are Platinum Group Metals (PGMs), gold, coal, diamond, iron ore, manganese and chrome which contribute largely to the country's economy. The PGMs, which include platinum, palladium, rhodium, iridium, osmium and ruthenium account for 75% of the world's reserves, the Witwatersrand gold basin is the largest gold resource, contributing about 4.2% of the global gold production and the largest known manganese deposit is found in South Africa and is also the leading producer globally (South African Government, 2023). According to the South African Government (2023), the country is ranked amongst top ten diamond producers contributing about 10% to the global production, the largest producer in the country being Venetia mine owned by De Beers and followed Finsch mine owned by Petra Diamonds group.

3.3 Performance and Contribution of Mining to South Africa's Economy

The South African mining industry is a significant contributor to the economy. The industry contributed about R493.8 billion to the country's Gross Domestic Product (GDP), about R73.6 billion to taxes and employed about 475 561 workers in 2022 (Minerals Council South Africa, 2023). The industry's contribution is driven by a number of factors, including the industry's production performance as well as macro-economic factors like commodity prices and currency performances. Figure 3.1 shows a comparison of the industry's contribution between 2022 and 2021.

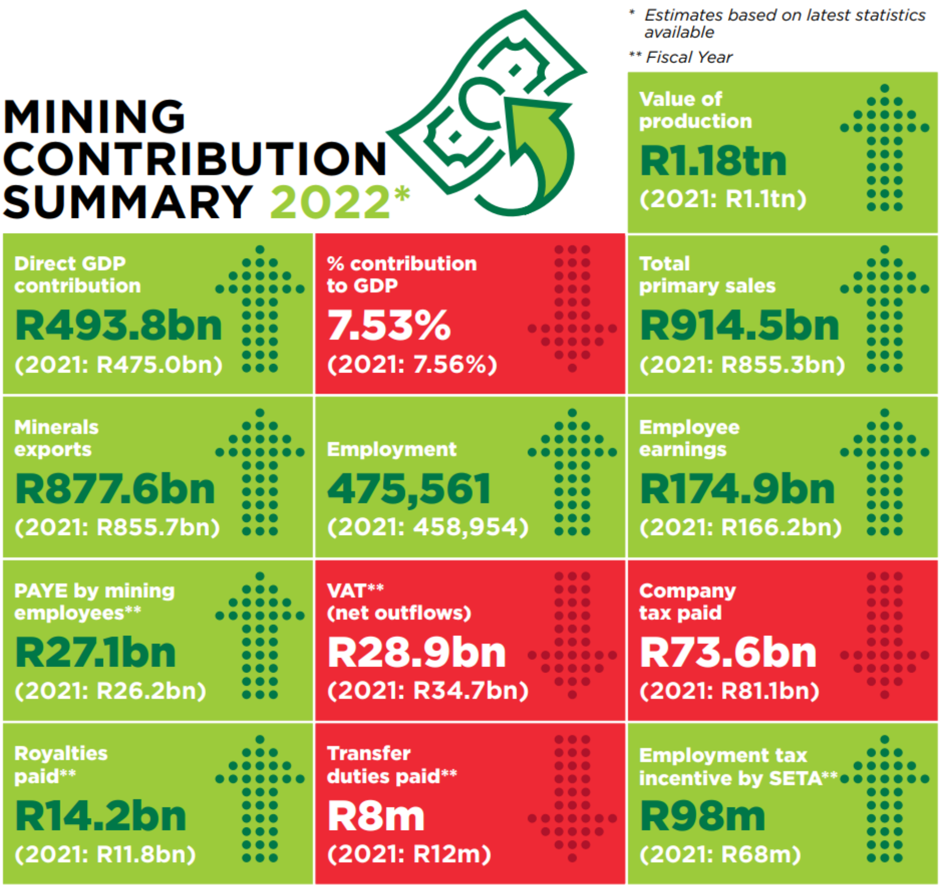

Figure 3.1: SAMI contribution to SA economy 2022 vs 2021 (Minerals Council South Africa, 2023)

There is an overall increase in performance and contribution driven by the increase in the global commodity prices and rand-dollar exchange performance. The industry's production revenue is reported at about a trillion Rands for the second year in row and Table 3.1 shows the different commodities' performance and contribution in royalties for 2022 (Minerals Council South Africa, 2023).

Table 3.1: Commodities Contribution and Performance (Source: Minerals Council South Africa, 2023)

Commodity	Direct Employees	Production Tonnages (t)	Export %	Royalties (million Rands)	Total Sales (Billion Rands)
PGMs	172,159	242	92.7%	5,700	287.4
Coal	90,977	231,000,000	56.7%	1,970	252.3
Gold	93,841	84	93.2%	608	88.8
Iron Ore	22,976	66,330,000	95.8%	4,190	104.1
Manganese	12,983	19,000,000	95.6%	158	48.1
Chrome	18,969	19,410,000	46.1%	N/A	33
Diamonds	14,577	10.2 carats	54.7	29	27.7
Industrial Minerals	12,084	51,300,000	30.3%	596	21.3

3.4 Challenges in the South African Mining Industry

Given the overall improved performance of the industry in 2022, there are still challenges facing the industry as discussed below:

- **Technical Challenges**

The technical challenges faced by the South African mining industry include old orebodies that have become deeper and more complex to mine, declining orebody qualities and old infrastructure requiring innovative ways of mining safely and economically. The mining industry's overall input cost increased by about 15% on average in 2022 (Minerals Council South Africa, 2023). The industry's GDP contribution and production output decreased by approximately 6% each between 2021 and 2022. Most of the mineral resources are exported to international clients such as Asia and Europe and this requires reliable logistical services to take the materials to the coastal export facilities which were greatly challenged in 2022, showing a 20% decline in volumes (Minerals Council South Africa, 2023). For the industry to remain sustainable, is also requires reliable power supply, which is a challenge with over 90% of electricity produced from struggling coal power stations and rising cost of electricity. The deepening gold reserves cause an increase in energy demand for ventilation, subsequently increasing the energy cost. The mining industry is further affected by high commodity volatility exposure, declining productivity and risky cost position with 42% of the industry's revenue in the bottom quartile of the global cost competitiveness (McKinsey, 2019).

- **Health and Safety Challenges**

The mining industry has significant health and safety risks that have caused a lot of mine fatalities historically. Some of the main causes of these fatalities are fall of ground, interaction of people and machinery and mobile equipment and electrocution. In an effort to regulate the industry and manage health and safety of mine workers and everyone else who may be affected by mining activities, the Mine Health and Safety Act (MHSA) was drawn up in 1996 (Minerals Council South Africa, 2020). This was followed by the establishment of the Mine Health and Safety Council (MHSC) which plays an advisory role to the Minister of Mineral Resources and Energy. Part of the MHSC's role include advising the Minister on occupational health and safety legislation, conducting research and promotion of safety culture transformation. These and other initiatives helped in reducing fatalities in the past three decades as can be seen in Figure 3.2.

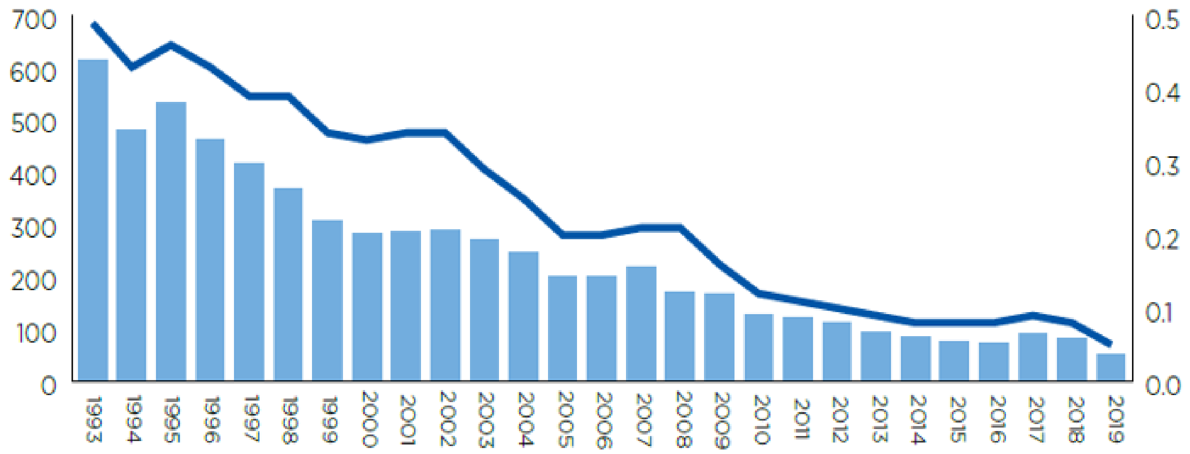

Figure 3.2: Fatalities and frequency rate (Minerals Council South Africa, 2020)

The number of fatalities in industry continued to decrease and was reported at sixty in 2020, seventy-four in 2021 and forty-nine in 2022, the lowest it has ever been in the history of the SAMI (Minerals Council South Africa, 2023). This is a great feat in safe guarding of lives and livelihood of mine employees. The Minerals Council South Africa (2020) reported that the almost half a million of the industry's employees are responsible for about five to ten dependents who usually suffer emotional as well economic impact at the loss of their breadwinners. Even with this decline, it is unacceptable to have any employee die at work. Figure 8 shows that the South African mining industry is still lagging behind in terms of safety performance when compared to other international mining countries, despite its improvement in safety performance (Minerals Council South Africa, 2020). This depicts the total fatality rate, which is the total number of employees who are fatally injured over the total hours worked from 1993 to 2018 in the various countries.

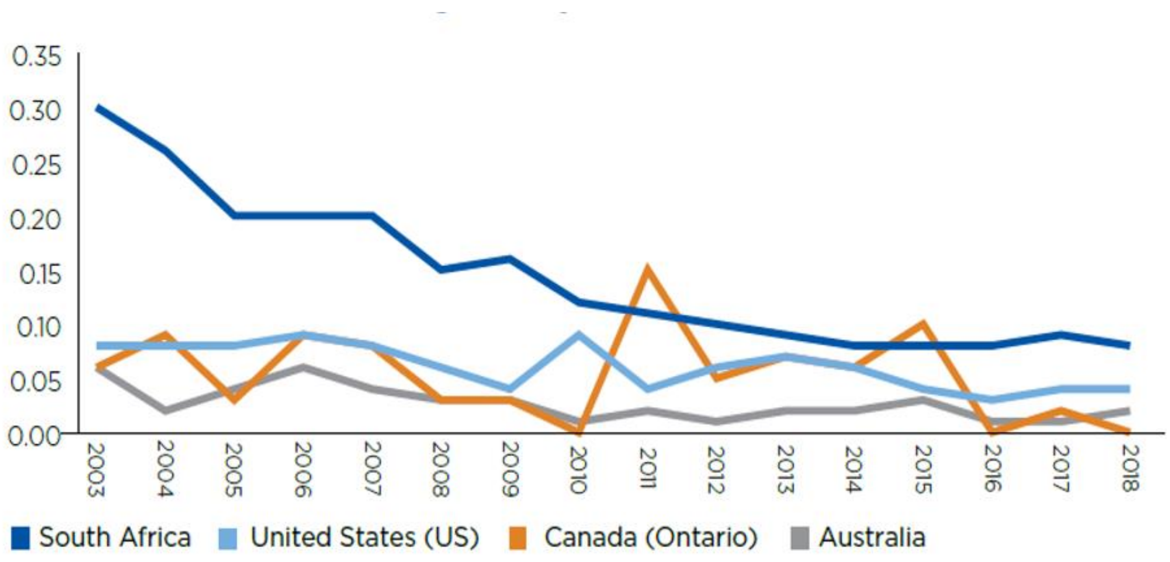

Figure 3.3: Fatalities: SA vs International Mining Industry (Minerals Council South Africa, 2020)

- **Socio-economic Challenges**

The industry is still very labour-intensive and is one of the biggest employers and contributors to the economy of the country. The country's socio-economic challenges such as the high unemployment rate are additional challenges, forcing the industry to keep the current workforce and continue to create more jobs. This is adding to the spiralling operational costs which put its financial performance under pressure, especially the gold sector which needs to consider adoption of digital technology for the safety of their employees and continued foreign investment (Mining Review Africa, 2020). Other challenges that the industry has to deal with in order to improve its competitiveness include network connectivity issues in deep underground mines and a lack of required digital skills for technology transformation (McKinsey, 2019).

3.5 Technology in the South Africa Mining Industry

As a global exporter of mining commodities, the SAMI also follows trends of digital and technology transformation to ensure that it remains competitive and sustainable. Given the country's socio-economic challenges, the industry continues to ensure that digital and technology transformation is people-centric and not threatening to the livelihoods of the citizens. Minerals Council South Africa (2023) reported that the industry has formed a five-year strategic partnership for people-centric modernisation with the Research Institute for Innovation and Sustainability (RIIS) to work on the following aspects in order to drive innovation and technology transformation:

- Technology innovation for improved security in mining;
- Improved data collection and analysis of Research and Development (R&D) expenditure trends in mining
- Policy advocacy for R&D tax incentive renewal and amendments
- Innovation ecosystem review
- Hydrogen

Mining Weekly (2023) reported that MTN business, Huawei, Minetec and Miniandate Mining Company signed an agreement for provision of 5G technology equipment and connectivity. This agreement and partnership have led to a successful proof-of-concept of an integrated 5G mine and South Africa's first connected coal mine: Canyon Coal's Phalanndwa colliery in Mpumalanga in December of 2022. It is further reported that provision of advanced 5G solution enabled guaranteed connectivity across the mine for real-time vehicle collision avoidance monitoring in the pit, video surveillance and analytics at the mine's entrance for improved safety and security.

Anglo American (2022) unveiled a prototype of the world's largest hydrogen-powered mine haul truck at its Mogalakwena mine in Limpopo, South Africa. This 2 Megawatt (MW) hydrogen-battery hybrid 290-tonne payload truck is capable of generating more power than its diesel-powered counterpart. The truck was launched as part of Anglo American's nuGen Zero Emission Haulage Solution (ZEHS) to support their commitment to carbon-neutrality across their operations by 2040.

3.6 Issues with Technology Adoption in the South African Mining Industry

Amongst the global challenges to adoption of technology, the following are prominent in SAMI according to PwC and Minerals Council South Africa (2021):

- Low data management maturity;
- Low workforce digital skills;
- Concern over data and cyber security;

- Uncertain return on investment;
- Resistance by labour unions;
- Lack of trust and transparency;
- Technologies that are not mature yet;
- Regulatory hurdles;
- Cost of compliance; and
- The need to review and/or change operating models.

3.7 Conclusion

The South African mining industry plays a significant role in the country's economy. Mining in South Africa started in the late 1800s and is forecasted to remain a significant contributor to the economy. The industry's performance in both safety and production continues to improve amidst challenging local and macroeconomic challenges such safety in the mines, supply chain, logistics and power supply constraints. High commodity prices and rand-dollar performance continue to impact the industry's financial performance. Technology is an emerging solution to some of the challenges that that industry continues to battle with, including safeguarding of its employees' lives and livelihoods.

CHAPTER FOUR: HUMAN FACTORS AND TECHNOLOGY ADOPTION

4.1 Introduction

In this chapter, human factors and their related theories focusing on human behaviour and motivation are discussed. These human theories are discussed to build an understanding of how psychological, social and emotional factors drive human behaviour. The impact of these human factors in terms of how human beings perceive and respond to change is also discussed. This is done in order to understand how they impact change management and adoption of technology.

4.2 Human Behaviour Theories

In order to understand human behaviour, it is essential to study the psychological factors that make up their personality traits and theories that explain these factors. Fatima (2021) defines human behaviour as the actions or reactions of a person in response to external or internal stimulus situation. Human behaviour is influenced by culture, attitudes, emotions, values, authority, ethics, rapport, hypnosis, persuasion, coercion, and genetics (LeadershipTheorist, 2021). Employees who work for an organisation usually come from different backgrounds and usually bring forth diversity in the above-mentioned factors which will influence how they behave in the workplace. It is therefore crucial for an organisation to implement systems to manage the diversity for the employees to work together to achieve the organisation's goals.

In explaining human behaviour, Kamil & Abidil (2013) refers to human's unconscious mental and behavioural processing which drive several psychological factors such as mood, memory, feeling, mannerisms and perceptions. These psychological factors are not physical and can only be seen through the expression of certain behaviours. The unconscious behavioural guidance system is meant to explain how environmental stimuli determine human behaviour which is driven by motivational stimuli shown in Figure 4.1. Step 1 depicted by the solid lines refers to the automatic activation of distinct internal information processing systems and step 2 in dotted lines, refers to automatic influences of these activated systems on behaviour (Bargh & Morsella, 2009).

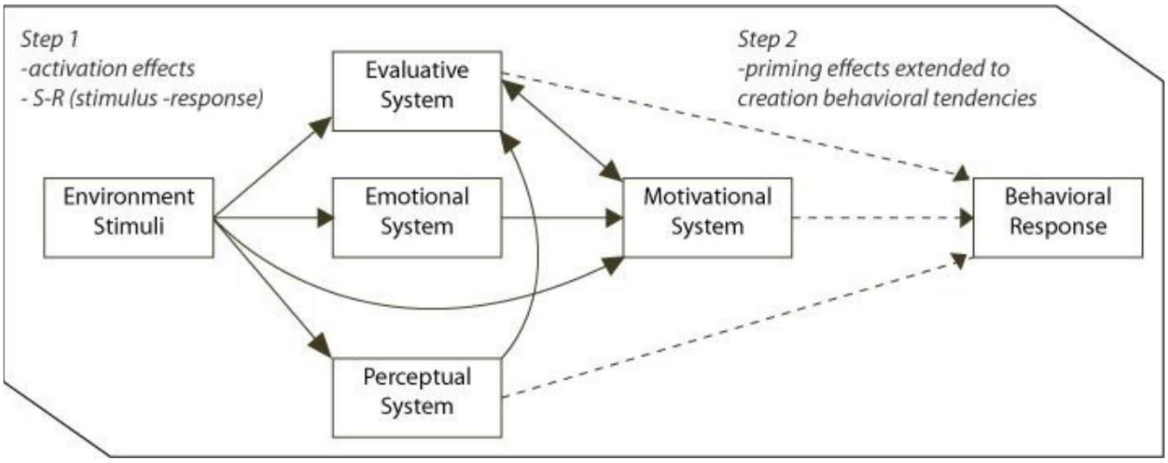

Figure 4.1: Unconscious Behavioural Guidance System (Source: Kamil & Abidil, 2013)

This model explains how humans unconsciously make decisions mentally which will be exhibited as behaviours that can then be observed physically. The environmental stimuli can be defined as the external conditions or surroundings which elicit sensory response or reaction from humans through one or a combination of their five senses (Study.com, 2022). The environmental stimuli trigger a person's evaluative, emotional and/or perceptual system used to determine the value of something based on actual or desired feelings. Based on the interpretation of the stimuli from the three systems, the individual decides on a behaviour driven by internal values and the desired consequences of that behaviour.

In addition to the theory of mental processes and how they influence human behaviour, Freud's view of the human mind shows that a big portion of the human mental processes happen in the unconscious level as shown in Figure 4.2. These unconscious mental processes influence the conscious level process which is usually observable in the form of expressed actions and/or behaviours arising from thoughts and perceptions. This Mental Iceberg seeks to explain that thoughts and perceptions are driven by a bigger part of the unconscious level factors such as fears, shameful experiences, irrational wishes and others.

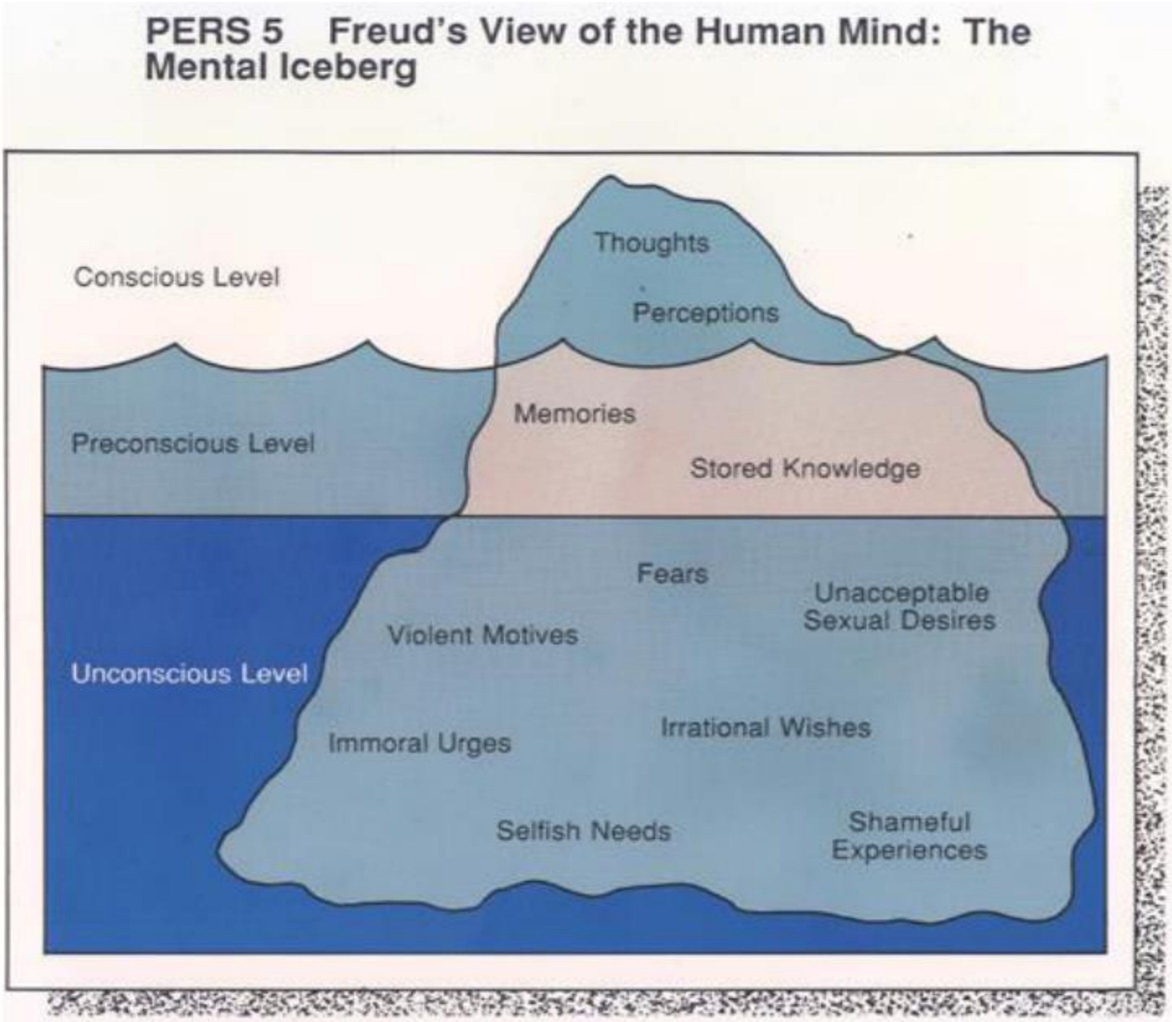

Figure 4.2: Freud's iceberg of unconscious, pre-conscious and conscious levels (Source: Kamil & Abidil, 2013)

According to Benitez (2021), cognition is a very prevalent human behaviour theory which maintains that humans behave according to individual thoughts, inner judgement and personal motivation. Cherry (2020) defines cognitive psychology as the field of psychology that investigates how and why humans think the way they do, through the study of the interactions amongst human thinking, emotion, creativity, language, planning, imagination, perception, remembering, judging and problem-solving. Cognitive psychology emerged in the 1960s as part of "cognitive revolution", following other fields of psychology dominating this field of study from prior years. Cognitive processes are complex and largely include the following factors as described by Cherry (2020):

- **Attention** which is a cognitive process that allows humans to focus on a specific external stimulus. Cherry (2020) defined attention as the ability to actively process specific information while tuning out other details and it is limited in both capacity and duration. There are different types of attention, and they include sustained, alternating, selective, focused and limited attention;
- **Language** is the ability to understand and express thoughts through spoken and/or written words and is used to communicate with others and plays a critical role in human thought. Mirolli & Parisi (2009) wrote about the importance of language in memory and its use for both mediating social communication and to talk to oneself as private or inner speech, which is also important for other coginitive processes;
- **Memory** is a cognitive process that allows humans to encode, store and retrieve information. It is an important part of the learning process, and it allows humans to retain knowledge about the world and their personal histories;
- **Perception** is the process humans use to take in information through their sense and use the information to interact with and respond to the world;
- **Thought** is an essential part of the cognitive process used to enable humans to engage in decision-making, problem-solving and higher reasoning; and
- **Learning** is the process of taking in new things, synthesizing information and integrating it with previously acquired knowledge.

According to Valamis (2021), there are three fundamental aspects of cognitive learning, namely: comprehension, memory and application. Figure 4.3 shows the congnitive learning loop. The comprehension component defines how humans think about how a topic fits into a larger picture and why learning it would matter. The memory component is about building knowledge by relating new information with past experiences. The last component is application of knowledge or skills to real life situations and reflecting on topics one is learning.

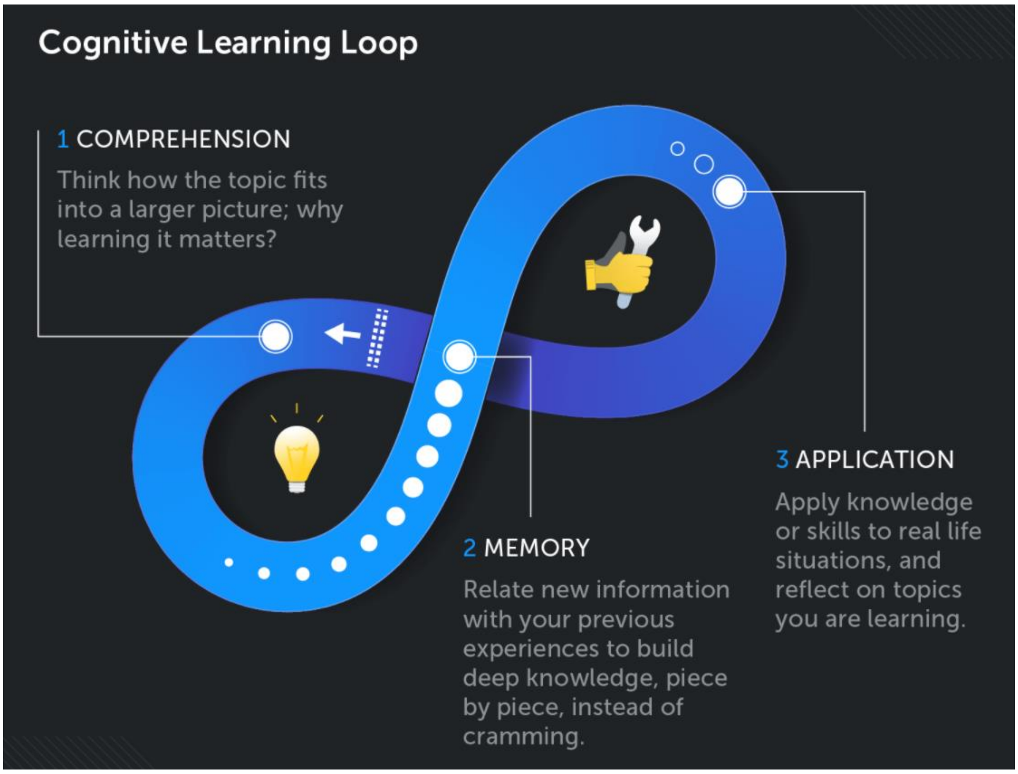

Figure 4.3: Cognitive learning loop (Source: Valamis, 2021)

Valamis (2021) explains that is it important to train employees on cognitive learning in order to build successful organisations because employees who are capable of learning quickly are highly productive and can handle complex tasks with minimal supervision.

It is crucial to understand the factors influencing human behaviour and incorporate these in the development of mining technology and how it is introduced in the industry to improve the level of adoption. The mining industry is diverse and in order to ensure successful adoption of technology, mining organisations need to work more at creating a learning and transformative culture.

4.3 Human Motivation Theories

For an organisation to achieve its goals, these need to be defined and communicated to the organisation's employees. Due to the diversity of the mining workforce, it is important to consider motivational factors that will influence employees' behaviour and use these factors to motivate employees to work towards the desired goals. Motivation of employees is defined as cognitive decision-making process which drives behaviour that is aimed at achieving a certain goal through initiation and monitoring in the workplace (Badubi, 2017). This is done through various means such as performance reviews by means of appraisals which have predetermined standards and the outcomes of these reviews may provoke emotional reactions of satisfaction or dissatisfaction, thereby influencing certain behaviours. Motivational factors differ across employees and may be either outside (extrinsic) such as rewards or within (intrinsic) such as the desire to do better (Badubi, 2017).

Due to varied human personalities, traits and needs, motivational factors can result in different impacts and feelings of satisfaction or dissatisfaction. There are a number of theories that explain motivational factors and the following are discussed by Badubi (2017):

- **Maslow's hierarchy of needs** defines the hierarchy of human needs and factors that bring them satisfaction, with basic needs at the bottom and being the most important as shown in Figure 4.4. The first category at the bottom of the pyramid is physiological needs such as shelter, food and clothing. The second category is safety and security needs such as physical protection. The third category is social needs in the form of associations with other people. The fourth category is esteem needs wherein people receive acknowledgement and recognition from others and the last category is self-actualisation needs in the form of a desire to accomplish or leave behind a legacy. The Maslow's theory of hierarchy of needs forms the basis of several theories that are used to explain employees' job satisfaction such as the Hertzberg's two-factor theory.

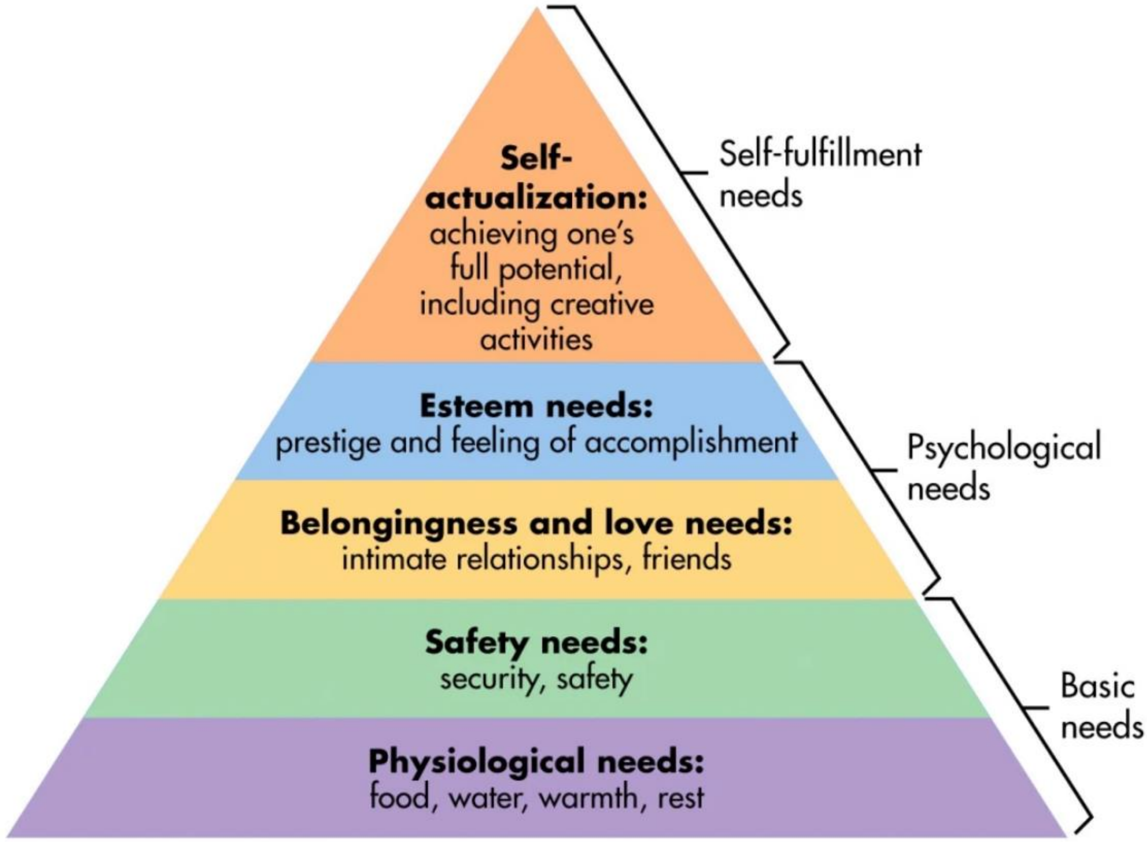

Figure 4.4: Maslow's hierarchy of needs pyramid (Comberg, 2011)

- **Herzberg's two-factor theory: Motivator-hygiene** comes from a study meant to determine factors that can influence motivation in employees and cause feelings of job satisfaction or dissatisfaction in the workplace. Figure 4.5 shows a summary of the Herzberg's Motivator-Hygiene theory.

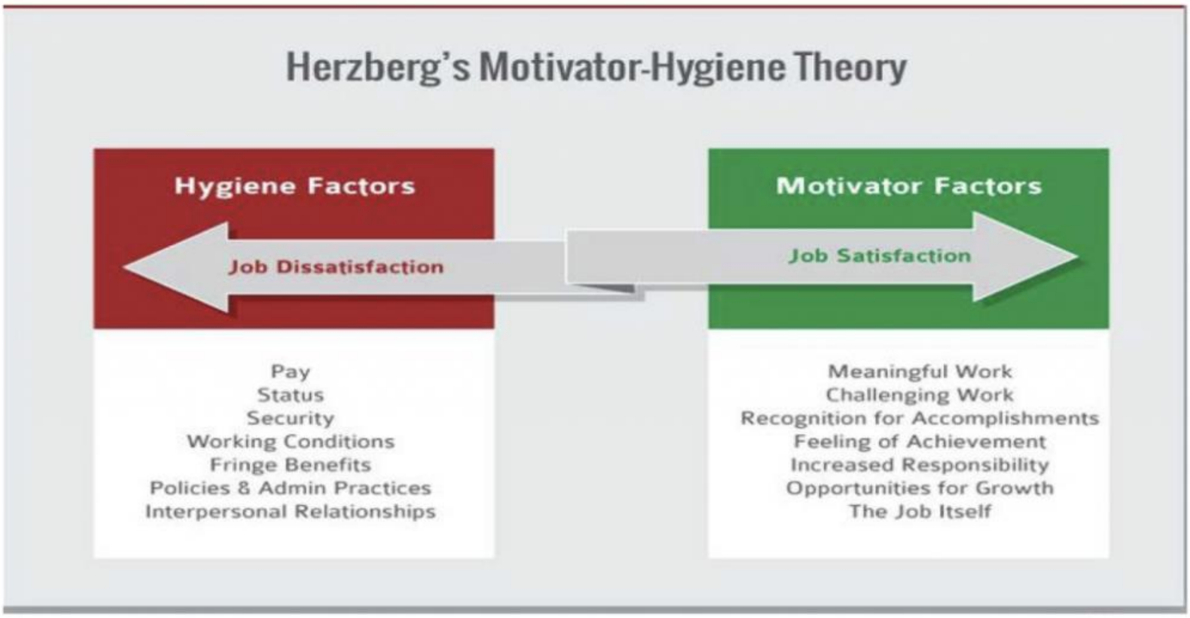

Figure 4.5: Motivators and hygiene factors (Source: Kurt, 2021a)

Kurt (2021a) explains that motivation factors are related to workplace satisfaction and cover intrinsic human needs such as achievement, recognition and advancement. Hygiene factors are not key drivers of job satisfaction but can cause job dissatisfation if they are not considered. These factors cover extrinsic human needs such as salary grading, status, workplace policy and relationships with peers. In order to motivate employees, it is important to create a working environment wherein they feel that their work is meaningful, challenges them to grow and accomplish specific goals and they get recognised for that work.

- **McGregor's X and Y Theory** is used to describe two types of employees and their typical behaviour in the workplace. Kurt (2021b) describes theory X employees as unmotivated to work and their managers usually perceive them as inherently lazy and employees who dislike their jobs. They are assumed to have very little motivation to work and need to get direction from their supervisors. These employees need constant reward and/or punishment in order to complete their tasks and do not have the desire to grow or achieve any personal and professional goals.

Kurt (2021b) describes theory Y employees as those who are motivated to do their jobs and are willing to take up challenges. They are perceived to be proud of their work and usually self-directed and do not need to be micromanaged. These employees are eager to participate in decision-making and are happy to contribute to their work and feel internally satisfied by the work they do.

McGregor's X and Y theory is important for organisational and leadership culture development. Organisations which are growth-orientated and transformative adopt the Y theory as opposed to the X theory type of management which is not very transformative in nature but more punitive.

4.4 Human factors on Technology Adoption

While equipment, infrastructure and technical competencies are important to technology implementation, they are not sufficient to ensure the success of technology adoption. Roberts, et al. (2021) identified six psychological categories which affect the adoption of technology, and these are personality, cognitive, motivation, attitude, social and organisational factors. A brief description of each category is provided below. According to Roberts, et al. (2021), these factors affect the decisions of people who interact with technology and have the potential to support or hinder technology adoption.

- Personality factors - personality factors encompass innovativeness. This refers to individuals' inclination to trying new technologies, embracing change and their preference to accepting relatively lower-risk alternatives (Roberts, et al. 2021).
- Cognitive factors - Prasad & Agwaral (1999) define cognitive factors as previous positive and negative experiences that individuals have with technology and new ways of working. Cognitive factors include aspects related to risk perception which refers to the way individuals identify and respond to hazards that pose risks to them and their technical knowledge which is the process of individuals recalling their domain-specific knowledge which contribute to their performance (Prasad & Agwaral,1999). Cognitive factors also relate to the perception of certainty by individuals for a sense of surety on how current or future events will turn out and their level of confidence in the outcome of that prediction (Johnson & Slovic, 1995).

- Motivation factors - motivation factors include personal incentives that determine individuals' behaviours to perform work and are driven by perceived rewards or punishments. Another factor that falls into this category is the fear of technology failure by decision-makers. This creates uncertainty on the outcome of newly introduced technology and its potential failure relating particularly to operational consequences than personal implications on the individuals (Roberts, et al. 2021).
- Attitude factors - refer to individual evaluations made about the people, objects, events and ideas associated with the adoption of new technology products. They also include individuals' beliefs on the ability, reliability and truthfulness of the people involved in the adoption of new technology (Roberts, et al. 2021).
- Social factors - refer to the change to individuals' thoughts, ideas, feelings and behaviours towards new ways of working that is caused by other people and subjective norms such set morals and normalised behaviours. These individuals' behaviour is influenced by their perceived expectation of them by people who are important to them, such as supervisors/managers (Ajzen, 1991).
- Organisational factors - include aspects of leadership defined as organisations' values, behaviours and attitudes of people in leadership roles. It also includes how those aspects of leadership influence the organisational culture and behaviours of employees (Roberts, et al. 2021).

At a conference in Dublin, Patel and Connolly (2007) presented a paper on factors that influence technology adoption, and they identified the following sociological factors:

- Relative advantage which is defined as the degree to which a new idea is perceived to be better than the one it precedes. Patel and Connolly (2007) suggest that the greater the perceived relative advantage of a new idea, the more rapid its rate of adoption;
- Compatibility is described as the degree to which a new idea is perceived to be compatible with the value system, past experiences and the needs of the potential adopters. The innovation is more likely to be adopted if the potential adopters think it is compatible with their values and job responsibilities;
- Complexity is the degree to which an innovation is perceived to be difficult to understand and use. Innovative ideas which are perceived to be simpler to

understand and use tend to be rapidly adopted than those that may require new skills;

- Trialability is the extent to which new ideas can be experimented on and tested prior to potential adopters committing to full adoption and usage. This is suggested to minimise unknown fears and also make end-users feel more comfortable using the innovation; and
- Observability is the degree to which benefits of new innovative ideas are visible and tangible to the potential adopters. The more the perceived visibility of results and benefits, the more rapid the adoption of the ideas.

In studying the relationship between human factors and technology adoption, Koul and Eydgahi (2018) used the technology adoption model (TAM) as depicted in Figure 4.6. TAM shows how external variables comprising of perceived usefulness and ease of use of technology determine behaviours that influence usage of technology.

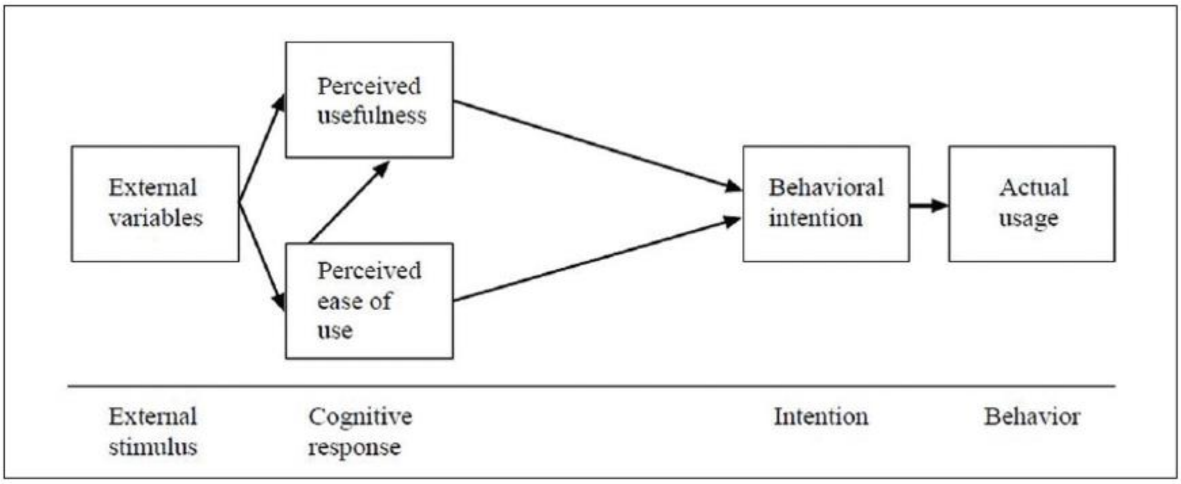

Figure 4.6: Technology adoption model (TAM) (Source: Koul & Eydgahi, 2018 adapted from Davis and Venkatesh 1996, pg.20)

According to Patel & Connolly (2007), TAM has been used in the field of information system to predict and explain user acceptance of various information technologies. In the case of mining technology, when technology users perceive it to be useful in enhancing their safety and/or productivity performance, there is increased chance of them adopting it. The level of adoption is enhanced when technology users feel that they are competent to use the technology without needing to acquire new skills.

Figure 4.7 shows the three levels constituting the emotional design theory which focuses on the emotions of technology users on new technology. Kamil and Abidil, (2013) define the first level is instinctive and it is captivated by the sense stimulations such as hearing, seeing, touching, smelling and tasting. In this level, the sensory stimuli cause pleasurable emotional experiences that can make technology users unconscoiusly want to experience more of those emotions.

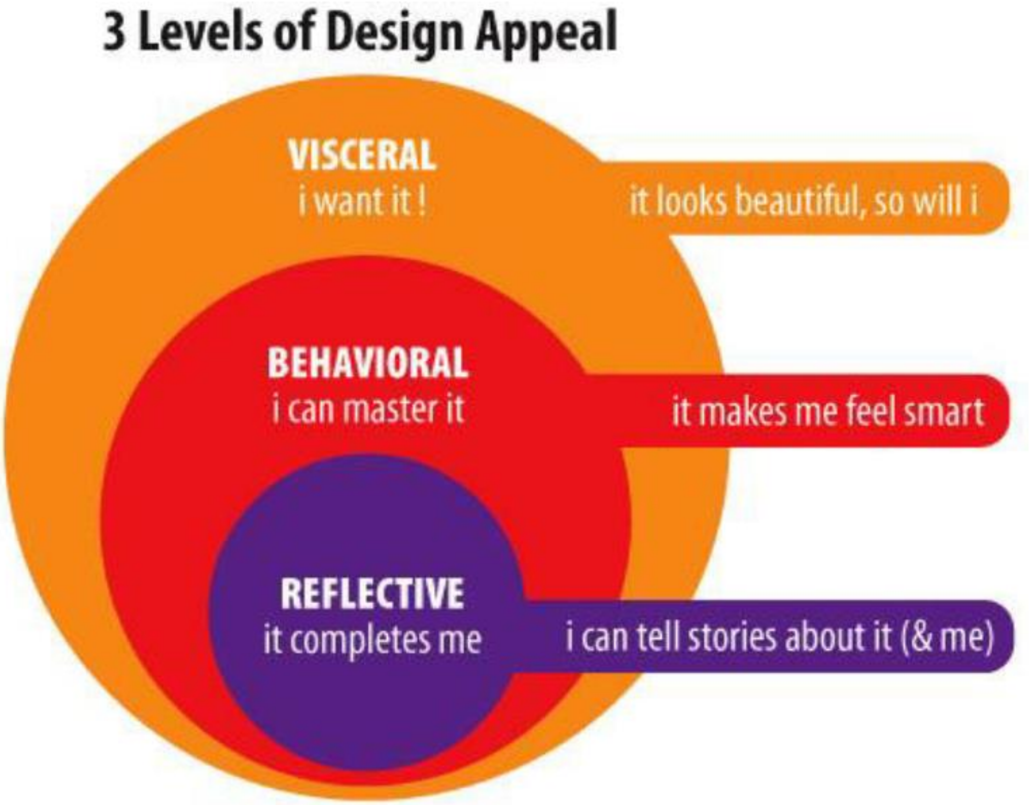

Figure 4.7: Don Norman's 3 levels of design (Source: Kamil and Abidil, 2013)

The second level is the behavioural design which covers emotions that users experience when they use a technology. These emotions are determined by the user's perceived usability, performance and effectiveness of the technology. The last level is the reflective design level which includes emotions experienced by users after they have used the technology. This level determines the full user experience and may influence what the user shares as a way to represent the technology.

4.5 Conclusion

Human factors encompass psychological, social and emotional factors which are defined by a number of theories to explain human behaviour. These theories explain the origin of human behavior and why they express their thoughts and emotions they way they do. The theories explained how and why employees are motivated to do their work in the manner that they do and factors that can be used to drive certain outcomes. Adoption of technology by human beings is determined by psychological, social and emotional factors which influence the experiences that the use of the technology brings about. In order to ensure that technology change management is successful, it is crucial to consider these human factors and address the challeges they may bring to the process.

CHAPTER FIVE: RESEARCH METHODOLOGY

5.1 Introduction

The purpose of this chapter is to give an overview of the research approach and design, description of the case study, the methodology employed in investigating the relationship between human factors and the adoption of technology at Sishen Mine. The chapter also outlines the framework of the study, methods used to analyse the data, ethical considerations as well as research limitations.

5.2 Research Approach and Design

The research was conducted through qualitative research methods which Roberts (2023) defined as the naturalistic study of social meanings and processes, using interviews, observations and the analysis of texts and images. This method is focused mainly on the understanding of experiences of humans through structured and open-ended interview questions with the aim of collecting data from individuals (Jackson et al, 2007). The research used a case study and data was collected using both structured and semi-structured interviews with individuals.

According to Queiros et al (2017), advantages of using structured interviews include structure that enables easier comparison of answers amongst participants, ability to reach a large sample, easy to replicate and interviews being fairly quick to conduct. Semi-structured interviews allow for in-depth discussions to be had in a set of pre-defined questions as well as an opportunity for follow-up questions, justifying of answers and establishing of connection/s between topics (Queiros et al, 2017). This type of interview style creates a more open and comfortable atmosphere for conversations to take place. Queiros et al (2017) added that the disadvantages of structured interviews are rigidity, low flexibility in responses, difficulty in obtaining detailed data and the time required to prepare the interview questions. Disadvantages of semi-structured interviews are that they are time-intensive, gives additional information that is not always generalisable (Queiros et al, 2017).

A combination of structured and semi-structured interviews was appropriate for the research to ensure that sufficient information is gathered to be able to get comprehensive insights from the participants and still be able to establish correlation and links between different responses. This is important for creating themes that can be used to compare and distinguish the participants' views.

5.3 Description of the Case Study

Starman (2013) defines a case study as a comprehensive description of an individual case and its analysis. The advantage of using the case study method is its suitability to provide detailed information on the subject and its disadvantage is the difficulty to gneralised and the risk of sharing confidential information (Queiros et al, 2017). The case study for the research is Sishen iron ore mine, located near the town of Kathu in the Northern Cape of South Africa. The mine is about seventy years old and employs approximately 10 000 employees across the mining value chain, including contractors.

The mine is one of the largest open pit mines in the world and is approximately fourteen kilometres long and nine kilometres wide and exports most of its iron ore to the global steel making industry (Anglo American Kumba Iron Ore, 2015). The mine employs several technologies across the value chain and the focus for the research is on four technologies, namely: Mine Integrated Control Centre (MIOC), Fuel Management System, Fleet Management System (FMS) and Autonomous Drilling Systems (ADS). The reason for the four technologies was to take a sample of technologies that cover safety, production, cost and integration of the mining processes.

5.4 Data Collection Methods

The participants in the research were employees of the mine as well technology OEMs representatives. A total of seventeen interviews, thirteen mine employees and four technology OEM employees, were conducted both face-to-face and using online communication platforms. The interviews conducted consisted of prepared questions on the subject under research, divided into different categories with questions linked to a specific category. The questionnaire for the research is attached to this research report as Appendix C. The interviews took a duration of one hour on average, with the shortest being 35 minutes and the longest one and a half hours. All the interviews were transcribed, and responses recorded during the interviews on a Microsoft Excel spreadsheet and in some cases, used a voice recorder for back up and reference.

The participants were comprised of four representatives of technology OEMs, viz. Mining integrated operations centre (MIOC), Fleet Management System (FMS), Fuel Management System and Drill Automation employed at the mine and thirteen mine employees occupying the following roles: Shovel Operator, Diesel Truck Operator, Employee Relations (ER) Officer, Drill Operator, Haul Truck Operators, Dozer Operator, Waterbowser Operator, Drill Operations Controller, Dispatch Systems Specialist, Primary Dispatcher, (MIOC) Shift Supervisor and Section Manager.

5.5 Framework for the Study

The study was structured into two sets of interview questions, one for mine employees and the other one for technology OEM representatives employed in the mine. The mine employees' questions were structured under the following topics to explore the participants' experience on the subject:

- Management of change - The management of change theme was aimed at investigation the level of employees' understanding of the use of technology in their work and the way new technology was introduced to them. It also investigated whether the participants had any experience in their current roles prior the introduction of technology.
- Personality factors – this was used to investigate how individuals respond to change and new ways of doing things at a personal level.
- Cognitive factors – this theme was aimed at investigating the perceptions that the participants have about the technology in their work and how it has changed the way they do work. The focus was on perceived benefits and threats as well as on best and worst experiences in the use of technology in their work.
- Motivational factors – this theme aimed to understand factors that encourage and/or discourage employees to adopt the use of technology and their level of trust of the technology. The aim was to determine whether trust plays a role in the decision to adopt technology or not.

- Attitude factors – attitude factors theme was meant to investigate employees' self-perceived role in adoption of technology.
- Social factors – this theme was aimed at understanding the way technology has impacted the attitude and behaviour of employees as individuals as well as groups.
- Organisational factors – the organisational theme was to investigate the role of organisational leaders in adoption of technology.

The technology OEM representatives' interview questions were structured in a descriptive as well as open-ended manner to allow them to share their views in a broader manner as opposed to asking more leading questions. The interview questions for the mining technology OEMs were designed to cover the following areas:

- The description of the technology;
- Key benefits of the technology;
- When and how the technology was introduced to Sishen mine;
- Stakeholders of the technology and the OEMs' roles during both pre- and post-installation; and
- Factors that hinder and those that support the adoption of the technology.

5.6 Data Analysis Methods

To analyse the interview data, thematic analysis which Braun and Clarke (2006) described as a method for identifying, analysing, organising, describing and reporting themes found within a data set was used. According to Nowell, et al (2017), this method creates flexibility for data analysis in many studies and allows for examination of perspectives of different research participants, highlighting common ideas and drawing of differences to generate insights. Nowell, et al (2017) added that the flexibility offered by this method could lead to inconsistency and incoherent themes from the data when not applied vigorously.

Responses to the interview questions were recorded for each interview and key words used to determine common and/or contradictory themes per subject. Different categories of the interview questions were used to find correlation between the topics and the experiences of the participants. This data was them formed into information sets to describe themes that came out.

5.7 Ethical Considerations

The mine has granted permission to conduct research and collect data at the mine. The permission letter is attached to the report. Application for ethical clearance was submitted to the University of the Witwatersrand's ethics committee before the interviews were conducted and permission granted with protocol number EMINN/2021/18. All participants completed consent forms prior to the interviews and gave permission for their contribution to be used for the purposes of this research. Their responses are used without revealing their identity to preserve anonymity.

5.8 Reliability and Validity of the Research

The primary data was collected from interviews which were guided by literature on the subject, observations and lived experiences. For the research findings to be considered credible, Nowell, et al (2017) recommend conducting trusworthyness thematic analysis in order to ensure credibility, confirmabiliity, transferability and dependability of the data. They described credibility as the testing of the different participants' responses against one another and literature reviews through triangulation. Transferability is described by ensuring that the interview questions are not limiting and can be used to conduct similar research in other areas outside the current case study. Dependability is described by a structured process followed in conducting research which can be audited.

This was done in the research by asking about the use of technology in other industries in order to check transferability. The questions were open-ended and not leading to allow the participants to give more information and all of them were asked if they had any information they wanted to share in relation to the subject that may not have been asked. Following a qualitative research methodology, validation of the research conformed to Sousa's (2014) three major concepts of knowledge assessment, namely: validation, reliability and generalisation.

5.9 Research Limitations

The interviews were all conducted in English to avoid translation were context might be lost but this was not easy for some participants because they are second language English speakers. This was addressed by sending them the research information sheet in advance to give context so that they can prepare for the interview. The participants were also given an opportunity to ask questions to ensure clarity. The subject of mining technology is quite popular, but it is understood differently by different groups of people and their experience may also vary from that perspective. Some of the participants' educational background limited their understanding of subject and required that the questions be further broken down to their level of understanding, accompanied by use of examples in their work and life experiences.

5.10 Conclusion

The research method employed is qualitative in order to understand the experiences of the participants on technology adoption and how they contribute to its adoption at Sishen mine. Thematic analysis methodology was used to create themes for presentation of correlations or differences in the participants' responses. The description of the case study as well as the research framework were conducted to give context in relation to literature review and the data. Ethical consideration and research limitations were also discussed to further give perspective on how and why the data collected was used in the manner it was.

CHAPTER SIX: RESULTS AND ANALYSIS

6.1 Introduction

The purpose of this chapter is to present the research findings and analyse them in relation to the research questions and research aims and objectives. The chapter discusses technologies under study and their performance at the mine, overview of benefits of technology introduction and factors hindering full benefits of technology at the mine. It also focuses on factors supporting full performance of technology and mine employees' uptake of technology to better understand the impact of human factors on technology adoption.

6.2 Overview of Technologies Under Study

Anglo American in one of the global mining organisations that are leading in technology. Sishen Mine has a number of technology applications across the business value chain and the mining technologies in this research were introduced at the mine between 2007 and 2021. The key drivers of technology adoption at Sishen Mine is to improve safety as part of the Anglo American's drive to eliminate fatalities and optimise the operation as it works towards a more sustainable mine. The types of technologies under research are as follows:

- Mining Integrated Operations Centre (MIOC) for centralisation of mining operations control systems, such as fleet management, fatigue management systems, autonomous drilling operations, etc. This technology was introduced in April of 2021 and fully implemented by end of June of 2022. The technology is used in other industries such as mobile phone network providers and processing plants and serve as centralised control rooms and integrated systems in a value chain.
- Fuel Management System used for managing how fuel is dispensed from the fuel stations in the mine directly into tyre-based TMMs and diesel bowsers which refuel track-mounted and other mining equipment. It was first introduced at Sishen Mine in 2007 and has undergone a number of developments for further improvements. The technology comprises of a number of uses including key control on TMMs to prevent uncontrolled/unauthorised use of mining equipment, monitoring of TMM locations and speed for monitoring of operators' behaviour and electronic fuel

logbooks to measure and reconcile fuel consumption which is also a compliance requirement from the South African Revenue Services (SARS). The technology is used in other industries for driver behaviour monitoring and electronic logbooks used in farming for fuel management.

- Fleet Management System (FMS) developed by one of the largest international mining equipment manufacturers to remotely manage and optimise mining operations. This is done through monitoring and controlling of TMM locations in the pit and dispatching equipment to ensure efficient task completion and optimising the mining value chain. The system is used to control loading and hauling activities, optimising the fleet to move more material safer, faster and efficiently. It is also used for maintaining mining equipment health by measuring operational parameters on equipment for optimised maintenance interventions. This technology is currently only being used in the mining industry and was introduced at Sishen Mine between 2015 and 2016.
- Autonomous Drilling Systems (ADS) conversion kits to convert from manual to autonomous drilling operations. The technology is used in construction industries in European countries and United States of America. It was introduced at Sishen Mine in late 2016 and early 2017 and was put on hold in order to allow other operations to test and implement first, before rolling it out further in mid2021.

6.3 Performance of Technologies at Sishen Mine

The four technologies were implemented for various benefits and at the time of the interviews, some had not shown their full benefits because they were still under implementation. The Fleet Management System installed is standardised between a number of Anglo American surface operations globally. The site teams seem to have a good understanding of how it operates and the benefits it brings to the operation. Some of the features installed on the loading and hauling mining equipment are part of the TMM pre-use inspection No-Go items in order to ensure that no equipment operates when the technology is defective or dysfunctional. The technology OEM sees the decision to put the technology on the pre-use inspection as a sign of how important the system is to the mine.

The fuel management system and MIOC were not showing results yet in order for their performance to be assessed fully as they were not yet fully implemented at the time of the study. The autonomous drills were starting to show some benefits and the management of change was still underway at the time of the interviews. Immediate benefits realised were on the safety of drill operators working remotely from a control centre and not exposed to physical health and safety hazards present in the mine. The cost benefit from the conversion (i.e. manual to autonomous) was not realised yet due to training of operators and other processes still in progress.

6.4 Benefits of Technology Introduction

Technology introduction is generally beneficial to human beings by making communications, travelling, access to data and information, record-keeping and other processes easier, effective and efficient. In mining, these benefits are in safety improvement by reducing risk exposure of mine employees and improving morale, reducing cost of operations through improved efficiencies and quality of work. Technology adoption also ensures that orebodies with declining qualities are mined efficiently and economically using advanced mining and ore processing technologies.

At Sishen mine, some of the key benefits of centralising mining control centres include improved and timeous communication between employees in different processes, collaboration and safer working environment where there is open and transparent sharing of information across the value chain. The fuel management system's key benefits are accurate fuel records to avoid misuse or loss of fuel and to improve record-keeping for claiming SARS rebates, monitoring of operators' behaviour through speed monitoring and prevention of unauthorised operation of mining equipment through key control which if not managed, could lead to serious safety incidents.

Autonomous drills immediately remove operators from the drills to a safer working environment in a control room as can be seen on the picture in Figure 6.1. This improves the safety of the drill operators significantly as their exposure to hazards becomes very minimal. The setup of autonomous drills allows one operator to operate three or more drills at a time, thereby reducing the cost of operation. The drills require less human intervention, and this improves uptime, productivity, accuracy and efficiency of drilling by over 90%.

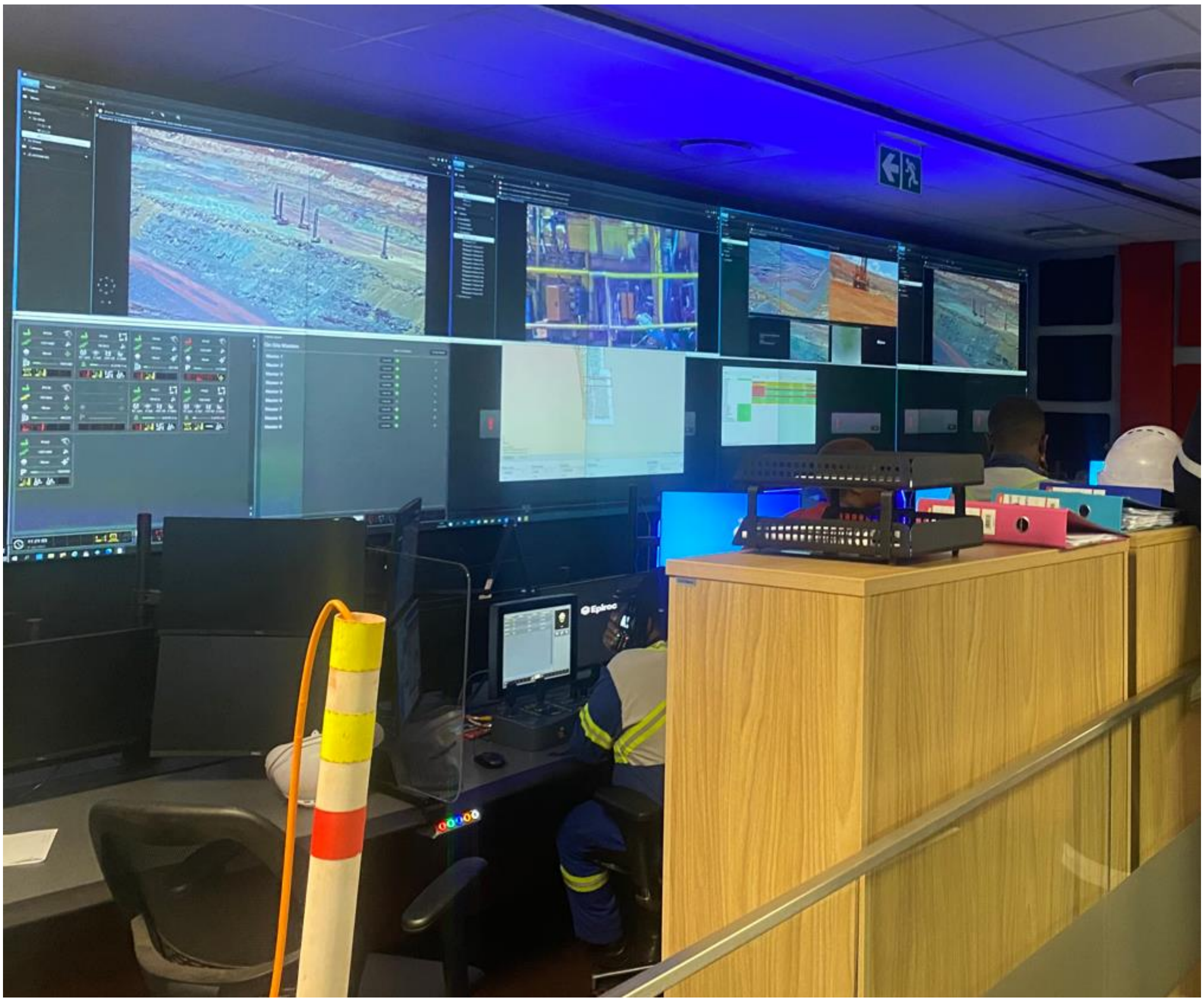

Figure 6.1: Autonomous drills setup at Sishen Mine (Source: Author's own, 2023)

6.5 Factors Hindering Full Technology Benefits and Performance at Sishen Mine

The reliance of the mining industry on depleting mineral resources, found mostly in remote locations with high development capital requirements makes it difficult for the industry to realise full technology benefits with ease as compared to other industries such as the financial services industry. Sishen mine is not an exception, mining an iron ore deposit found in the remote and semi-arid parts of the Northern Cape province, far from ports and other industrial areas in South Africa. Another factor that hinders full benefits of technology is socio-economic conditions of the labour-sending environments with high poverty and low literacy and skills required for technology adoption. Below is discussion of factors discussed during interviews with the technology OEM representatives:

6.5.1 Unreliable electricity power supply

MIOC requires reliable power supply for the systems to operate continuously and efficiently. Power interruptions threaten data integrity which is a measure of performance for the fleet management system. It is also a risk to autonomous drilling which requires reliable network availability for the drills to work.

6.5.2 Misalignment between product capability and expectations

The MIOC OEM representative mentioned that when decisions were made around the choice of technology, it was important to understand how the technology worked and factors that affected its performance. The OEM gave an example of a system that was procured to assist with auto-breaking of haul trucks to prevent collisions, with limited knowledge of the speed parameters within which the system operated. According to the OEM, “this discovery was made during a TMM collision incident investigation, wherein end-users of the technology found out that it only works in certain truck speeds” (MIOC OEM, interview, 2022)

The misalignment between product capability and expectations created low confidence on the capability of the system and what it was intended for. The OEM representative added that “this is because some of the technologies were implemented on instruction from senior leaders in the organisation without spending enough time explaining how they work and researching on the maturity of the technology to ensure that it has been tried and tested in similar environments” (MIOC OEM, interview, 2022). In addition to the above, the newest product in the FMS was used to assist with reducing truck spotting time and it was still undergoing development at the time of the interview in the beginning of 2022. Its performance was not yet measurable, but the OEM said that it had a slower uptake and poor buy-in from truck operators due to poor engagements and intervention from site leadership.

6.5.3 Inadequate training and lack of skills

Despite the introduction of the FMS, features such as the one used for predictive maintenance were not yet utilised fully and optimally. Equipment maintenance planning was still done manually based on machine hours, as opposed to using features on the FMS to predict maintenance requirements based on machine condition and health status. The OEM said that this was due to shortage of highly skilled reliability engineers required to understand how the features were configured to operate and ensure that the system was customised to suit the mine.

The fuel management system OEM representative attributed its past poor performance at Sishen Mine to lack of training of end users. The OEM mentioned that the reason that Sishen Mine was still not getting full benefits of the system was due to lack of education and knowledge from diesel bowser operators who were not trained on the system. The OEM said, “that had resulted in end-users’ expectations of the system not getting met and compromised their buy-in into the system” (Fuel management system OEM, interview, 2022). Inadequate training also hindered enforcement of procedures due to misalignment between technology capabilities and how it was actually used on site. An example of this was end-users not enforcing the installation of diesel tags on equipment and continuing to allow refuelling of equipment without diesel tags.

6.5.4 Lack of accountability

The FMS OEM representative mentioned that unclear lines of responsibility and lack of accountability were some of the factors hindering the performance of their technology. The OEM further mentioned “that was as a result of not having an accountable individual person responsible for the implementation and adoption of technology from the client” (FMS OEM, interview, 2022). The ADS OEM representative added to this point by saying “by not allocating responsible individuals to the automation project, there is no single point of contact, and this makes it difficult to get client support and ensure that the project timelines are met” (ADS OEM, interview, 2021).

6.5.5 Inadequate management of change

ADS conversion was still in project implementation phase during the interview and some of the issues that were already impacting their performance were instability in the Wi-Fi network due to poor network infrastructure, poor quality of block preparation for drilling leaving undulations and loose rocks on the floor which might cause drills to stop, poor control room set up, lack of OEM site support in embedding best performance practices, lack of understanding of inputs for optimal autonomous drilling, fear of job losses and inadequate training of drill operators and support teams. The OEM is critical in assisting the mine develop standards, procedures and process to enable safe and optimal operation of the drills. This was supposed to have been done as part of a service level agreement until autonomous drilling was fully imbedded in the mine's operating model.

The fuel management system was installed in 2007 with very little management of change. The OEM representative mentioned that the KPIs were not clarified from the beginning and as a result not much success came out of the system. Another factor that contributed to the lack of benefits from the fuel management system, such as accurate fuel consumption records, was that some of the features were bought by Anglo American group leadership on behalf of the sites. Site teams were as a result not very optimistic about the products and their application.

The OEM also mentioned that "in 2021, there were upgrades made on the system and the OEM participated actively in managing the change in collaboration with the client. KPIs were clarified and the system performance improved" (Fuel Management System OEM, interview, 2022). This was said to be driven by the Sishen Mine leadership team in order to stop suspected diesel theft and ensure optimised diesel consumption in order to reduce costs. The autonomous drills OEM representative mentioned that the management of change in 2017 was difficult due to limited autonomous drilling benchmarks which would have helped in managing the change.

6.6 Factors Supporting Full Performance of Technologies

For mining technologies to work and yield full performance, the following factors are crucial according to the OEMs interviewed in this research:

6.6.1 Training

The teams working in MIOC must be trained on how the screens and dashboards were configured and commissioned as well as how the videowall was set up to work. The fuel management system OEM emphasised that end users must be trained on the system and how it worked. The first step in training on the autonomous drills was to ensure that the right stakeholders were identified and trained on the what, how and why to build trust, confidence and get buy-in before the technology was installed. The stakeholders include but not limited to operators, maintenance teams, supervisors, managers, trade union representatives, site technology champions and support services teams. According to the OEM representative, this will alleviate fears and uncertainty around the technology.

6.6.2 Proper installation and configuration

The MIOC OEM had a duty to ensure that the videowall was installed and configured correctly and the different systems in the control centre were integrated well in collaboration with other OEMs. The sound and acoustics in the facility were of a particular standard and the construction work needed to be suitable for that. Manual drills were converted to autonomous drills and appropriate components needed to be installed to ensure successful autonomous drilling. For the FMS to function well, the system was installed on the mine equipment and configured for the specific pit conditions and equipment matched correctly, an example being the trucks being matched to the suitable loading equipment. The fuel management system required installation of diesel tags on the TMMs to be able to read and record diesel during refuelling.

6.6.3 Defined stakeholders and site champion

For all new technologies, it was crucial to have a well-defined stakeholder map and dedicated implementation, adoption personnel and an adoption roadmap. The benefit of this was for all stakeholder, especially the end-users to embrace the technology and build a level of ownership for easier adoption. The Fleet Management System OEM said that a site champion must be clearly identified to assist with support and accountability on site. This individual must be in a role that has power and authority to make decisions to avoid delays in decision-making and progress of projects.

The other reasons of having this site champion were for him/her to engage stakeholders and keep them updated on the progress and garner support for the technology OEM during the implementation phase. The importance of having a site champion is to also ensure timeous escalation of matters to senior leadership and ensure that the technology was customised as may be required. The site champion must be suitably qualified in the field and be resourced to carry out duties as may be agreed upon in order to ensure successful implementation of technology, varying from leading engagements amongst stakeholders to gathering information from the front-line teams. In the case of Sishen Mine, the FMS OEM recommended a site champion who was in middle management with access to both senior leadership and teams in lower roles in the mine. The OEM identified everyone working in mining operations as key stakeholders for ensuring that the technology was a success.

The fuel management system OEM mentioned that their key stakeholder was the finance team followed by the end-users of the equipment installed with the system. The MIOC OEM said that their key stakeholders were the teams working in the MIOC, General Manager, Sishen Leadership Team (SLT), Mine Managers (MMs), Section Managers (SMs) and Mine Overseers (MOs). The MIOC OEM further mentioned that "if technology decisions are made only top-down and there is little consideration for technology echo system and the number of systems operators have to deal with, we might never fully understand the impact of technology on end-users and vice versa" (MIOC OEM, interview, 2022)

The ADS OEM said that their key stakeholders were "all employees from the CEO to the operator of the drill in order to ensure that the organisation's strategy and operational processes support the technology" (ADS OEM, interview, 2021). The OEM went on further to say that "the mine planning teams must be able to produce correct drill plans timeously, engineering teams to ensure proper maintenance of the drill and technology system and mine managers and drill and blast section managers to engage with drill operators to alleviate fear and uncertainty around automation of drills" (ADS OEM, interview, 2021).

6.6.4 Site infrastructure, processes and systems

The MIOC was designed and constructed to ensure that Sishen Mine's mining activities are centralised and managed from one location. The old mining control room setup with processes scattered in different locations was demolished and replaced with MIOC. For autonomous drilling to be successful, the drills, field conditions, office environment setup, network infrastructure, reporting systems and data flow were set up to support the technology. Some processes linked to drilling were reviewed, such as the quality of drill block preparation to ensure flatter and cleaner blocks for autonomous blocks. There were additional resources allocated to prepare drill blocks for autonomous drills whilst the current process was under review to suit autonomous drilling requirements. The reporting and monitoring dashboards were also adapted for autonomous drilling. Operational procedures were amended to support the implementation of the technology systems.

6.6.5 Governance and performance monitoring measures

With the review of procedures and processes, new governance documents were put in place to ensure proper measuring and monitoring of processes and people's performance. There were also measures of compliance put in place to ensure that the right KPIs were measured and achieved. This was crucial to ensure that all the changes were incorporated in the operating model for compliance to governance requirements.

6.6.6 Management of change

Management of change is crucial for successful technology implementation and adoption. This process runs before, during and after the technology installation in order to ensure that every step of the process is done correctly. The MIOC OEM reflected on how the management of change for MIOC was run by the responsible section manager and the OEM's scope was focused on control room design and installation. The OEM said that assisted with the implementation and adoption of the technology because there was site ownership and continuous engagement with different stakeholders.

The fleet management system OEM mentioned that the management of change was the reason the system upgrade was completed successfully. This was done in collaboration with the MIOC section manager, Information Technology (IT), engineering teams and technicians. The FMS OEM said that this change took place over a two-months period, during which a gap analysis was conducted, and actions put in place to come up with customised fleet management solutions. The OEM was involved in the process and continues to support the client post installation as part of their Customer Care Agreement (CCA).

Management of change for autonomous drilling was championed by the OEM in collaboration with end-users to pro-actively share knowledge on the technology, address fears around job security and build trust with the support of the Regional Automation Centre (RAC). The role of the RAC was defined in the CCA to include monitoring of the change and ensuring that the client complied to implementation protocols and was kept updated on the progress and any gaps that occurred. This was done by openly sharing information about the technology and engaging with drill operators and offer support to all stakeholders on site. The OEM representative mentioned that they “pride themselves with supplying not just a product but a solution” (ADS OEM, interview, 2021).

6.7 Employees’ Uptake of Technologies

6.7.1 Background of respondents

The thirteen mine employees who participated in the interviews had working experiences ranging from one to twenty-seven years at Sishen Mine and occupied the following roles:

- MIOC Supervisor – responsible for coordinating activities in the mining control room to ensure safe and efficient mining activities. The activities include fleet management, fatigue monitoring of operators, safety berm monitoring technology and autonomous drilling. The MIOC supervisor is a professional with a university degree and over five years’ experience in the mining industry.
- System Specialist – responsible for the maintenance of the technology system in MIOC and responding to any system and/or IT-related issues that affect the operation of MIOC. The primary focus of this role is to ensure that the fleet management system is always operational and that risks associated to the network and IT are prevented and/or mitigated when they occur for safe and productive mining operations. The dispatch system specialist is qualified in the IT profession with over ten years of experience in the IT field in different industries.
- Section Manager (SM) – responsible for overseeing activities of the Mining Integrated Operations Centre and ensure that all mining systems operate optimally and are integrated. The section manager is also responsible to ensure compliance to the Mine Health and Safety Act (MHSA) and regulations to ensure health and safety of all employees working in the MIOC section. The section manager is an engineering professional with a total of seven years within the organisation in different roles.
- Rope Shovel Operator – responsible for safe operation of the face shovel to load trucks with ore material from stockpiles to tip into the primary crusher. The operator is also responsible for ensuring that the shovel is operated optimally and respond to technological systems installed on the shovel in order to manage safety and

production. The shovel operator has over 12 years operating experience at Sishen Mine.

- Employee Relations (ER) Officer – responsible for managing relations between the employer and employees and facilitate engagements with employees' trade unions and other organised labour organisations. The ER officer is also responsible for ensuring compliance to the Labour Relations Act (LRA) in dealing with all labour issues such as wage negotiations, working conditions, disciplinary cases and others. The ER officer has about ten years working experience at Sishen Mine occupying different roles.
- Water bowser Operator – responsible for the safe operation of the water bowser to suppress dust on haul roads by watering down with water and dust suppression product. The operator is also responsible for responding to all safety and production technology systems installed on the water bowser. The operator has a matric certificate and about 15 years working experience in different roles as an operator.
- Diesel bowser Operator – responsible for safe operation of the diesel bowser used to refuel mining equipment in the pit with diesel. The operator must ensure safe handling of diesel to prevent any health, safety and environmental risks associated with diesel and refuelling activities. The operator has a matric certificate and about four years working experience as an operator at Sishen Mine.
- Pit Viper (Autonomous) Drill Operator – responsible for the safe operation of the drill rig to drill holes to the required depth for blasting purposes. The operator drills with manual and autonomous drill rigs operated inside a cab and remotely from a control centre respectively. The drill operator is also responsible for operating and responding to the technology installed on the drill rig for safety, production and efficiency purposes. The operator has a matric certificate with about fourteen years of working experience which includes working as a drill assistant at Sishen Mine.
- Drill Operations Controller – this employee is responsible for coordinating activities in drilling to ensure that drills operate optimally. The operations controller is also responsible for assisting the shift supervisor with some of the supervisor's duties and responding to the operators and supervisor's requests. The Controller has a matric certificate with fourteen years working experience including drill assistant and drill operator at Sishen Mine.

- Haul Truck Operator – the haul truck operator is responsible for the safe operation of a haul truck loaded with material to be hauled to the waste dumps and/or ore stockpiles. The operator is also responsible for responding to all safety, production and efficiency technology systems installed on the truck. These systems include collision avoidance system, fatigue management system, vehicle intervention system, fuel management system, FMS and others. The operator has a matric certificate and about seven years working experience.
- Dozer Operator – the dozer operator is responsible for safe dozing of material in loading areas, waste dumps, ore stockpiles, haul roads and clearing bushes in vegetated working areas. The operator is also responsible for responding to all safety, production and efficiency technology systems installed on the dozer. The operator has a matric certificate and about eight years working experience as an operator at Sishen Mine.
- Primary Dispatcher - responsible for ensuring that the load and haul fleet is optimised for safe, cost-effective and productive operations. The dispatcher must ensure that trucks are allocated to the shovels in a manner that is optimised to avoid poor productivity and safety risks. Other responsibilities in this role are to report health and safety incidents happening in the mining operations, call operators when equipment is handed back to operations from maintenance, call maintenance teams when machines need unplanned maintenance and respond to all other issues reported to the mining control room. The dispatcher has a matric certificate and about twenty-seven years working experience including operating a number of equipment in mining at Sishen Mine.

6.7.2 Employees' insights on human factors and technology adoption

The mine employees were interviewed under the six categories, namely: management of change, personality, motivational, social, attitude and organisational factors. Each category had a number of questions to gather insights on their experiences on these aspects in relation to technology adoption at Sishen Mine.

6.7.2.1 Management of change

All the mine employees interviewed indicated that they work with technology in their jobs. All of them said that they use technology for production-related purposes and twelve of the thirteen added that they use it for safety as well. Amongst the thirteen employees, they listed sixteen different types of technology applications that they have used for both production and safety purposes. The respondents were able to name and describe the technology applications in their jobs with varying levels of knowledge and understanding. The Fleet Management System (FMS), Collision Avoidance System (CAS) and fatigue monitoring system were listed by eight, six and five employees respectively and the other technologies listed by three or less employees.

Eight of the thirteen employees started working in their roles before introduction of some of the technologies. The respondents mentioned that the technologies under study were introduced between the years 2010 and 2021 and mostly introduced for the first time in the start of shift meetings and induction training. This introduction was followed by formal training which included theoretical and practical training.

Two employees mentioned that they did not receive formal training as the expectation was that they are familiar with the systems when they started in their roles given their experience and educational background. One of the employees said that “I learnt the system through exploration and self-learning” (SM, interview, 2022). The drill operator mentioned that prior to autonomous drilling technology, “management engaged them on the technology and why they are introducing it” (Drill operator, interview, 2021). Some of the reasons mentioned were safety of drill operators who were removed from drill cabs to safer control centres that are located out of the pit and productivity of drills due to increased uptime with less operator-related delays. The autonomous drilling operator and operations controller also mentioned that the OEM was also involved in their refresher training annually.

The shovel operator said that prior to the shovel tooth detection technology installation, they were called in for training and an engagement on why it was important to install the technology. The shovel operator stated that the technology was introduced because “Crusher blockages due to foreign metals such as shovel teeth, drill bits and scrap metals had caused a lot of production time losses and posed safety risk to the team working in the crushers to remove them” (Shovel operator, interview, 2021). The shovel tooth detection technology application installed on primary shovels detects missing tooth and notifies the shovel operator and also sends a notification to the control room operator. The operators can then respond timeously by stopping the shovel and the last truck loaded to find the tooth and prevent it from getting tipped into the primary crusher with ore.

6.7.2.2 Personality factors influencing technology adoption

When the employees were asked to rate themselves on a scale of one to ten on how much they liked trying out new things, the lowest score was four, highest ten and the average score was eight point five. The haul truck operator scored four out of ten mentioned that these technologies partially made them feel safe. The haul truck operator added that some of the safety systems were not installed on all mining equipment, but everyone lost the safety incentive when there was a recordable safety incident. The safety incentive is paid out for predetermined days without recordable injuries with the aim of motivating employees to work safely. Six out of the thirteen employees said that the change made them feel excited and the ER officer continued on to add that “I have great love for technology and learning of new things” (ER officer, interview, 2022). The section manager remarked that “change gives me energy and I do not like routine and monotonous work” (Section Manager, interview, 2022).

Five out of the thirteen employees answered that new things made them feel okay because they understand that the change is necessary, and it is for their own good. The primary dispatcher said that it made them feel comfortable knowing that data was captured, making their job easier as opposed to capturing data manually with higher chances for human error. Two employees said that change can be frustrating if it was not managed correctly and they referred to some inconsistency in the application of rules around technology in safety and production, such as when to stop TMM or not when the technology applications are not functional.

6.7.2.3 Motivational factors influencing technology adoption

On a scale of one to ten with one being the least and ten the most, the thirteen employees scored an average of eight point three (8.3) on how much they trusted the technologies and benefits they bring. The lowest score was four from one employee and the highest was ten from six employees. When these employees were asked what factors encouraged or discouraged them about the technology, most of their responses were focused on perceived and/or experienced individual benefits and losses. Of the thirteen employees interviewed, one employee mentioned that there is nothing encouraging about technology. The twelve employees listed the following encouraging factors about technology:

- Ease of work – the dispatcher remarked that the work had become so much easier because they do not do manual equipment bookings. The waterbowser operator mentioned that filling up a waterbowser at water filling points was less labour-intensive and spraying water on the haul roads had also become easier. They mentioned that pressing a button was all they needed to do to fill up the bowser. They emphasised how easy it had become to comply with the safety requirement of staggered dust suppression on ramps with the aid of technology.
- Improved safety and productivity – the drill operator said that drill operators were now operating from a much safer control centre and not exposed to hazards and risks on the drill blocks such drilling into misfires, dust, blasting activities and adverse weather conditions. The operator further added that "we are not exposed to dust anymore, we knock off with clean clothes" (Drill operator, interview, 2021). The drill operator also mentioned that drills operating time, drilling sequence and accuracy had started to improve with autonomous drilling.
- Safety alarms – the section manager mentioned that with technology, they were better enabled to quantify risk and respond to the alarms to prevent safety incidents. One of the operators also added that with the alarms, they were able to mitigate the risk and prevent damages and injuries.
- Access to information - The ER officer said that technology has improved the speed at which they did their work, with easier access to information, decision-making takes place faster. The operations controller said, "with the pit cameras, I can see what is happening in the whole mine and make more informed decisions that support whole mining value chain and not just the drilling process" (Drill operations controller, interview, 2021).
- Integration of systems – the section manager said that they were greatly encouraged by the opportunity to integrate different technologies for improved efficacy as well as user-experience.
- Recognition by managers using data – the operator mentioned that they were greatly motivated by getting recognition from managers as a result of performance measures, aided by technology and not the old unfair and subjective ways of recognising performance without transparency of the results.

- Digital transformation and continuous learning – technology has introduced continuous learning by changing how work used to be performed and continuous improvements as the technologies upgrade. The MIOC supervisor said that she was working on some technology upgrades which excited her to keep learning on automation and digitisation.

The factors which the thirteen employees described as discouraging about technology are as follows:

- “Inaccurate” data used against operators – the shovel operator mentioned that “managers sometimes use incorrect data from technologies to discipline operators without verifying the information with the operators’ experience” (Shovel operator, interview, 2021).
- No response to concerns raised about technology – One of the haul truck operators interviewed said that they were completely discouraged by the non-response to the complaints they raised over false fatigue alarms and the body strains caused by harsh breaking from the Vehicle Intervention System (VIS). The operator said, “I get irritated when it says that I am fatigued when I know that I am not and I have to follow the fatigue management procedure up to the health care consultations” (Haul truck operator, interview, 2021).
- Poor/slow network/signal – a number of the employees who use data in their work mentioned slow and poor network/signal as discouraging factors. They also mentioned that this was made worse by recurring load shedding, inadequate network infrastructure in the pit areas and the amount of data getting processed at times, further affecting the speed at which data is processed.
- Loss of production – when there is no wi-fi or there are other network-related issues on drills, they cannot continue operating. The drill operator expressed this as a disruption to production and “if all drills are converted to autonomous, there will be major production losses” (Drill operator, interview, 2021).
- Complexity in technology requiring specialised skills – the MIOC supervisor said that they were discouraged by the complexity in the technological systems in the control centre and their limited prior experience and skills. They further mentioned that this also encouraged them to learn fast and continuously so that they built more skills.

- Lower literacy levels – the drill operator said that the autonomous drill project required computer proficiency, a skill which majority of the older drill operators did not have. The previous minimum requirements for drill operators were lower than the current requirements and this discouraged them and threatened their career progression as a result. The waterbowser operator added that “technology requires too much energy to learn and try out new ways of work, which the older operators do not always have” (Waterbowser operator, interview, 2021)
- Multiple subdivisions in Information Management (IM) – according to the dispatch system specialist, there are too many divisions in the network support structure within the organisation as opposed to what was previously known as IT. This has created complexity and the specialist also said, “complexity delays resolution of issues as different teams are responsible for different areas within the department” (Systems specialist, interview, 2022).
- Competing responsibilities to technology implementation – the section manager said that one of the biggest discouraging factors was competing responsibilities between technology implementation and operational responsibilities for legal appointees. Legal responsibilities usually weigh more and take priority over technology implementation.

6.7.2.4 Attitude factors influencing technology adoption

During the research, the participants were asked how much they felt involved in adoption of technology, eleven of the thirteen said they felt involved and two did not feel involved. The truck and drill operators said that they did not feel involved at all because they were only notified about technology when it was time for training. They added that operators had experiences which could be invaluable in the development of some of the technologies if they were consulted before the technologies were installed.

The ER officer and waterbowser operator said that they felt involved from the onset because there were engagements with employees’ trade unions to discuss some of the technologies. They emphasised that this was also influenced by their individual interest in technology transformation which motivated them to engage and understand decisions made as far as technology was involved. The shovel and diesel bowser operators felt that they were adequately involved and were satisfied with the information shared and training they received on the technologies they work with. The primary dispatcher's response was based on how they were involved in the execution stage of the technologies and expressed how satisfied they were with their understanding of how the technologies were applied.

Following the discussion around how involved the employees felt in technology adoption, there was a discussion on what they thought were the best ways to ensure that technology adoption was successful in their work. They mentioned the importance of prior engagement and consultation with all stakeholders on innovation and adoption of new technologies in order for them to make input and share their experiences. They emphasised that engagements would drive buy-in from all stakeholders and enhance ownership. One of the employees who said that they did not feel involved in the adoption of technology mentioned that they only got involved when they needed to go for training and did not get the opportunity to make input. This particular employee said that they rated their trust in technology and the benefits it brought four out of ten because of not having been involved beforehand.

The other employees suggested that for successful adoption of technology, feedback from end-users such TMM operators reporting deviations and what worked was crucial. The section manager proposed that having a site-based implementation champion was important and one of the roles of this individual would be "to promote the technology and keep users informed on the implementation" (Section Manager, interview, 2022). They also added that onsite technical support is required to support all stakeholders through the implementation champion who would need to be in role that has power and authority to engage stakeholders across the organisation and make decisions.

The employees also mentioned that technology should not be used as a punitive tool against operators but instead as an opportunity to upskill and improve their competency levels by offering OEM and customisable training. The ER officer added that this would allow everyone to come to a common understanding of technology and "provide information and curb frustration" (ER officer, interview, 2022). It was also emphasised that full leadership buy-in, support and continuous engagements were all important in making technology adoption successful.

6.7.2.5 Social factors influencing technology adoption

Social factors focused on individual and group behaviours relating to changes brought about by technology in the workplace. The employees were asked how technology changed their behaviour and that of their close colleagues and eleven out of thirteen said that it had positively changed their behaviour and two said that it had changed it negatively. One of the two employees who felt that technology negatively influenced their behaviour added that as a truck operator, they had to use an override button to deactivate the technology installed to bring trucks to an abrupt stop when they are in close proximity to other TMMs. The operator continued to say, “this is against the rule of tampering with safety devices but I sometimes have to do it in order to be able to drive past other TMMs next to the road” (Haul truck operator, interview, 2021). The operator also added that the fatigue monitor did not allow them to make adequate observations when driving because the alarm comes on the moment their eyes were not looking directly into the fatigue monitor. The diesel truck operator said that the negative impact that the technology had on their behaviour was that they “have a higher risk tolerance and sometimes drive too close to other TMMs with the belief that technology will automatically prevent collisions by stopping the trucks” (Diesel truck operator, interview, 2021).

The eleven employees who said that technology had changed their behaviour positively reflected on how easy their jobs had become and that created positivity in them and their close colleagues. The shovel operator commented that they would not have produced as many safe tonnes (i.e. production without safety incidents) as they have if it was not for safety technologies. The operator also said that their attitude was much more positive, and they were motivated to perform better because technology kept them updated on their performance and they knew if they were reaching their targets or not. The drill operator said that their behaviour has changed because of technology as there was improved compliance to traffic rules driven mainly by alarms and cameras used for operator monitoring. The operator however added that this was also accompanied by overreliance on technology by operators who did not use own discretion and judgement because of technology. The drill operator further mentioned that some drill operators felt distracted by alarms in the drill cab that they would tamper with the technology to avoid getting alarms.

The ER officer and waterbowser operator said that technology has made them more responsible and used the wearing of safety belts and following traffic rules as examples of how their behaviour has changed for the better. They said that it started as a compliance issue which has resulted in safer behaviours beyond compliance.

When the employees were asked about how technology had changed the mine's performance in term of safety and production, nine out of thirteen said that the mine’s safety and production had improved, and they referred to the safety milestone of six fatality-free years that the mine had achieved. They said that this was attributable to technologies used for fatigue management, collision avoidance and operator behaviour monitoring. The other four employees said that there were no significant improvements, reflecting on the types of safety incidents still experienced in the mine, such as TMM collisions and that production had not necessarily increased. They further added that technology had contributed to poorer behaviours by employees who disliked getting “false” alarms. They also said that production had reduced due to technology rules such as weight limitation on trucks and the focus to improve qualities and efficiencies which, according to the drill operator, had resulted in less meters drilled.

6.7.2.6 Organisational factors influencing technology adoption

Organisational factors focused broadly on the leadership and culture within the organisation as perceived and experienced by the employees. On a scale of one to ten, one being the least important and ten being the most important. According to the employees, the importance of technology to the organisations' leaders scored an average of nine point five (9.5) out of ten. The lowest score was seven out of ten and nine of the thirteen employees gave a score of ten. Even though the employees gave high scores on the importance of technology to the organisation’s leaders, six of the employees’ scores were not positive. The six employees mentioned that some leaders were overly reliant on technology and did not spend sufficient time engaging with people in their workplaces.

The section manager expressed how “leaders wanted to tick off the box with a lack of understanding of technology” (Section manager, interview, 2022) and because they wanted to give the impression that it is important for them. One of the truck operators said, “leaders just want to spend money on technology to pretend to care about the safety of the employees and for compliance" (Haul truck operator, interview, 2021) but they did not engage with employees. The waterbowser operator and drilling operations controller mentioned that some leaders overly relied on technology to make decisions without full consideration of what happened and not listening to employees' views and/or experiences.

When asked about how technology had changed the leadership's behaviour and/or attitude, three of the employees said it had positively changed it, nine employees said negatively, and one said that there was no change. The three employees said that technology gave the business competitive advantage, great operational improvements to the mine and leaders were keeping up with the global markets and technology assisted them to make decisions and respond to issues quicker and easier.

The employees who said that the leaders' behaviour and/or attitude changed negatively added that some of the leaders were not engaging and/or listening to operators anymore. They added that some leaders were just "ticking the box" on digital transformation with no consideration of the needs of other stakeholders such as TMM operators and their experiences but instead driving compliance and not real improvements in the mine.

6.7.2.7 Cognitive factors influencing technology adoption

The questions in this theme were focused on how employees perceived technology and how it had changed the way they do their work. When they were asked how technology had influenced their risk perception, eleven of them said that they felt safer and two said that they felt less safe. The two employees mentioned that their risk perception was distorted because of the distractions that technology introduced and the level of complacency of fellow employees which made them unsafe. They further added that some employees had become too reliant on technology and would not take necessary actions to respond to risks in their work places.

The eleven employees discussed the benefits that technology had introduced in their work, and these included the use of cameras to improve operator visibility of blind spots in Heavy Mobile Equipment (HME) such as haul trucks, consequently improving safety of truck operations. Another benefit was transparency in performance measures which improved team morale and removed biased and unfair recognition practices. Data-driven decision-making is another benefit that the employees mentioned wherein different stakeholders are able to use data to make informed decisions, such as dispatching of trucks to manage truck efficiencies by avoiding unnecessary queuing and bunching in loading and tipping areas.

With improved technology, the waterbowser operator mentioned the improved ergonomics at the water filling points where they can fill up a truck by just pressing a button instead of the older manual operated pumps. This reduced the time it took to fill up a truck which in turn has also improved the health operators, reduced fatigue and reduced sick leave absences. Another benefit of technology is reduced fatigue-related incidents due to the use of the fatigue management system to alert operators of fatigue and/or distractions and report these events so that the operators stop for a fatigue assessment. Further to easier access to information and quicker decision-making, the ER officer added the benefit of improved flexibility and productivity brought about by remote working enabled by technology.

The employees were asked what threats they perceived to have been introduced by technology in their work and they said that they were occasionally incorrectly accused of wrongdoing because of the data produced by technology. False fatigue monitoring reports was mentioned as an example and that this also caused unnecessary disruption to production and frustration particularly amongst haul truck operators. They also mentioned that inadequate training on the technology and requirements of advanced computer/IT skills threated job security and career progression for the majority of the current labour force, particularly in autonomous drilling where one operator can operate multiple drills. Another threat was the number of devices installed in TMM operator cabs which caused distraction with the multiple alarms that go off. The VIS was also said to cause excessively harshly braking of haul trucks, inducing injuries on truck operators. This was said to also contribute to operator fatigue and them not always responding to the alarms and sometimes bypassing the VIS system when they approach other TMMs to prevent the harsh braking.

Unreliable electricity supply and network/telecommunication services which resulted in poor communication and slow dispatch system were mentioned as threats to safety and productivity in mining. There is an increased reliance on systems that manage production and safety, such as the fleet management system, autonomous drilling and fatigue management which require good network services to function. The employees also added vulnerability to cyber-attacks as a threat to the organisation and themselves in instances where they had to share their personal information. Installation of advanced technology applications on older infrastructure and equipment was also perceived as a threat for successful technology adoption.

When the employees were asked to share what their best personal experiences of technology were, they mentioned transparent performance monitoring and optimisation with the shovel operator adding “when I see how many tonnes I have loaded in an hour, I am able to increase loading tempo and I am also motivated by recognition I receive for my work” (Shovel operator, interview, 2021). The waterbowser operator and the drilling operations controller mentioned that they felt assisted by the technology and that created ease of work and comfort/flexibility. The employees also mentioned that learning new things and easier and quicker access to information were some of their best personal experiences of technology in their work. The operators added that they felt safer and gave examples which included working around misfires knowing that there is a technology available to help them locate misfires and CAS which had reduced TMM collisions and related fatalities. The systems specialist shared “feeling proud to have been part of a team that worked on one of the best control room projects” (Systems specialist, interview, 2022) and pioneering digital change in Sishen mine.

The employees shared that their worst personal experiences of technology were the loss of personal privacy with cameras installed in their work areas, such as TMM cabs. The loss of data, incorrect information and production disruption were also mentioned as some of the worst experiences by haul truck operators adding “we lose production with unnecessary fatigue stoppages due to false alarms and risk having fatigue-related accidents from operators that are not reported” (Haul truck operator, interview, 2021). The haul truck operator added discomfort experienced from the VIS harsh braking events which lead to demotivation, loss of sense of control and “discouragement from raising these issues and not getting any response from leaders” (Haul truck operator, interview, 2021). The drill operator mentioned the fear of loss of job security due to automation. The primary dispatchers worst experience was “the amount of manual work we must do when the dispatch systems is down” (Primary dispatcher, interview, 2022) in order to prepare production reports and this affected the accuracy of the reports. The section manager mentioned incorrect technology selection and application as some of their worst experiences which came at a cost and sometimes safety risks too.

6.8 Discussion of Key Findings

The purpose of the research was to investigate the relationship between human factors and technology adoption at Sishen Mine by identifying the benefits and challenges relating to technology adoption. To establish the links between human factors and technology adoption and assessing the extent to which the human factors were incorporated in technology adoption. To also investigate factors that support and/or hinder adoption of technology, identify gaps in the implementation of technology and make recommendations towards the integration of human factors in technology adoption.

6.8.1 Overview of benefits and challenges to technology adoption

The results show that Sishen Mine has installed several technologies in the past decade with some marked benefits to date as is the case in the mining industry globally. The mine employee participants demonstrated a fair understanding of the technology applications in their work. The participants shared their experience of technology adoption in relation to personal expectations and how the technology made them feel about work. The technology OEMs shared their experiences on how their technologies were performing at Sishen and what the challenges and benefits of these technologies are.

In relation to how Khalil (2000) defined technology, the employees shared their understanding of the equipment, knowledge and know-how of technology very well and only some could articulate the know-why well. The technology OEMs shared their technologies equipment, knowledge, know-how and know-why very well, demonstrating the level of adoption at Sishen compared to their technology’s full capability.

The challenges relating to adoption of technology shared by the participants included inadequate engagements and training on the technology in order for the employees to make input. The participants shared that they were expected to know how to use the technologies without a wholistic understanding of them. The technology OEMs expressed that some of the challenges in adoption of technology included inadequate understanding of the technology, lack of buy-in from the mine site leadership and consequent poor enforcement of the requirements for the technology to work.

6.8.2 Human factors and technology adoption at Sishen mine

Majority of the mine employees shared positive personal experiences of the technology in their work and how it had changed how they felt about work. Their experiences included the recognition from supervisors and how they were pioneering change for the future of the mine. These are crucial motivator factors for employee job satisfaction according to the Herzberg's Motivator-Hygiene theory (Kurt, 2021a). These experiences also made them feel like they were continuously learning new skills, kept up to date with information and their work was becoming easier and safer. These experiences correlated well with Don Norman's three levels of emotional design described by Kamil and Abidil (2013).

There were employees who felt not engaged and did not trust the technology. They reflected on how they were not offered an opportunity to share their fears of job losses, not having the required skills for the technology and their poor experiences on technology not addressed by the leaders. These contributed to them feeling "left behind" in the technology transformation journey and consequently demotivated by the technology.

The contrast in the employees' experiences indicated that implementation of technology at Sishen Mine focused mainly on the equipment and know-how part of technology and not so much in the in-depth knowledge and know-why. The adoption of technology is mostly supported by employees who are self-motivated and are eager to learn and participate in change taking place in their work and they identify as Y employees according to McGregor's X and Y theory (Kurt, 2012b). Majority of the employees shared that technology had changed their behaviour and those of their colleagues in a positive manner, especially around safety. Some of them were however discouraged by the number of alarms that go off in their TMM cabs and the screens and cameras that they have to interact with.

The employees and OEM representatives shared that technology is important to the leaders and added that they do use some of the benefits it provides to manage the business. They however shared that in some instances, the leaders did not support adoption of technology but only wanted to “tick the box” on installation. They also indicated that they were used to engaging with leaders more before some of the technologies were implemented. These experiences made some of the participants think that the leaders could support adoption more by still spending time out in the field with them to ensure that the basics were in place, such as adoption of standards and procedures and responding to some of nuisances reported by TMM operators.

6.8.3 Gaps in technology adoption at Sishen Mine

There are gaps identified by Yeates (2021) that are considered important for successful technology adoption. These include limited knowledge of technology by stakeholders, lack of trust in the technology, safety incidents that still occur such as TMM collisions even with CAS installed on TMMs and not all end-users buying-in into some of the technologies. The organisation did not implement a full structure to support implementation and adoption of the technologies by means of supporting KPIs that are aligned with operational and technology strategies. This was shared as inconsistency in safety technology applications as well competing KPIs for production and legal requirements. The operating model was also not adopted for the technology transformation with consideration of specific site requirements and capabilities. The process of implementation focused more on the technology installation and less on the people who are critical to making it work, especially end-users such as TMM operators.

CHAPTER SEVEN: CONCLUSION AND RECOMMENDATIONS

Technology in the global mining industry is growing in order to keep up with industrial revolution as deemed as a solution to addressing the challenges that the industry is faced with. Mining's main focus is production of minerals used in other industries such as manufacturing and the operations are usually located in remote areas with limited infrastructure. Sishen Mine is located in the semi-arid town of Kathu in the Northern Cape. The mine was established about seven decades ago, employs about 10 000 people and exports majority of the iron ore it mines. The mine employs technology to improve the safety of its operations, striving toward zero harm and to enhance productivity towards their goal of hundred percent overall equipment efficiency.

Despite the implementation of technology at Sishen Mine, the mine still experiences safety incidents that could be prevented and as a result has not achieved its goal of zero harm. The purpose of the research was to investigate the impact of human factors on technology adoption at Sishen Mine. The technologies that have been introduced are focused on safety, productivity, cost and efficiencies. The mine employees were interviewed to gain insights from their experiences of technology in their work. The OEMs shared the benefits of their technologies and best practice for adoption and application for realisation of those benefits.

Literature study was done on factors for successful technology adoption and the impact of human factors. The human factors studied included personality, cognitive, motivation, social, attitude and organisational factors. Human behaviour theories were studied to understand how and why people behave the way they do. Human motivation theories focused on factors that motivate people to behave as they do and assist in categorising different type personalities in the workplace.

From the interviews, the participants could articulate the challenges and benefits of technology adoption and there was correlation between them and what the literature study reported in terms of benefits and challenges of technology adoption as well as factors supporting and hindering technology adoption. The participants shared their experiences of the benefits of technology as well as gaps that are hindering full technology adoption at Sishen Mine. The gaps were mostly in the people and organisational space as opposed to the technology capability and equipment. There is a gap in engagement of all stakeholders for everyone to make input, share their fears and expectation of the technology. This is crucial for creating an innovative environment and enhance end-user buy-in.

It is therefore recommended that the gaps that this research identified on the impact of human factors on technology adoption be addressed for the sustainability of the mine. In order for technology to be fully adopted, it is important that the organisation apply a design thinking approach to applying the technology solutions. This will require an in-depth understanding of the problems they are solving, the people who are affected by the problem and those who will participate in ensuring that the solution works. Benchmarking should also be done on the application of the technology and consideration be made to all factors that may be common or different for Sishen before implementation, focusing on human factors such as socio-economic and psycho-social factors.

The TRL model is a good guide to ensuring that there is enough understanding of technologies and all stakeholders are engaged along the process of implementation in order to build trust and enhance buy-in. To further support implementation and adoption, there should be technology adoption champions who will work with end-users, OEMs and site leadership along the process of acquiring technology solutions. The business strategy and operating model should be integrated to support technology adoption. Clear and measurable KPIs should be developed with supporting incentives for technology adoption and be integrated in the business performance measures.

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APPENDICES

Appendix A: Ethics Clearance

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

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

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: EMINN/2021/18**
PROJECT TITLE	The relationship between human factors and technology adoption at Sishen Mine
INVESTIGATOR	S Seabela
SCHOOL/DEPARTMENT OF INVESTIGATOR	School of Mining
DATE CONSIDERED	17 August 2021
DECISION OF THE COMMITTEE	Approved unconditionally
RISK LEVEL	LOW RISK
EXPIRY DATE	16 August 2024

ISSUE DATE OF CERTIFICATE 06 September 2021

CHAIRPERSON (Mr H Thomas)

cc: Supervisor: Mrs P Twala

DECLARATION OF INVESTIGATOR

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

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

Signature

Date 14 / 09 / 2021

Appendix B: Participant information sheet

Participant Information Sheet

Good day

My name is Mogaleadi Sandra Seabela and I am a Masters student in Mining Engineering at the University of the Witwatersrand, Johannesburg. As part of my studies, I have to undertake a research project, and I am investigating the impact of human factors on mining technology adoption at Kumba Iron Ore Sishen mine under the supervision of Ms. Pontsho Twala. The aim of this research project is to find out what impact do human factors have on mining technology adoption and how are they incorporated in technology change management processes.

As part of this project, I would like to invite you to take part in an interview. This activity will involve description of your understanding of mining technology and your experience of it in your work and will take between 30 minutes and one hour. With your permission, I would also like to audio record the interview using a digital device. This recording will be stored in the researcher's mobile device and only the researcher will have access to this recording. It will be deleted within three years.

There will be no personal costs to you if you participate in this project. You will not receive any direct benefits from participation but there are no disadvantages or penalties if you choose not to participate or if you withdraw from the study. You may withdraw at any time or not answer any question if you do not want to. The interview will be completely confidential and anonymous as I will not be asking for your name or any identifying information, and the information you give to me will be held securely and not disclosed to anyone else. I will be using a pseudonym (false name) to represent your participation in my final research report. If you experience any distress or discomfort at any point in this process, we will stop the interview or resume another time. If you need some support or counselling services following the interview, the researcher will assist with getting such services as provided by the researcher's employer.

If you have any questions during or afterwards about this research, feel free to contact me on the details listed below. This study will be written up as a research report which will be available online through the university library website. If you wish to receive a summary of this report, I will be happy to send it to you. The data collected from this research project will be stored in the researcher's technology devices and will be kept for up to three years. With your permission the data collected from this research project may be used by other researchers. If you have any concerns or complaints regarding the ethical procedures of this 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:

Mogaleadi Sandra Seabela, 303109@students.wits.ac.za, +27 72 517 0777

Supervisor:

Pontsho Twala, Pontsho.Ledwaba@wits.ac.za, 011 717 7429

Appendix C: Interview questions

Interview questions				
Mine Employees				
Factors impacting technology adoption	**Interview question**	**Yes**	**No**	**Comment**
Management of change	Do you use technology in your work? Safety or production?			
	What is the technology that you use?			
	Do you have any experience prior use of the technology?			
	When and how was it introduced to you?			
Personality factors	On a scale of 1-10 how much do you like trying out new ideas? (1 least and 10 most)			
	How does change/new ways of work make you feel?			
Cognitive factors	How has technology influenced your risk perception?			
	What benefits/threats has technology introduced to your work?			
	What is your worst/best experience of technology?			
Motivation factors	What encourages/discourages you the most about the technology in your work?			
	On a scale of 1-10 how much do you trust the technology and the benefits it brings? (1 least and 10 most)			
Attitude factors	How much do you feel involved in adoption of technology?			
	What is the best way to ensure that technology adoption successful in your work?			
Social factors	How do you think technology changed your behaviour and that of close colleagues?			
	How has technology changed the mine's performance in safety and production?			
Organisational factors	On a scale of 1-10, how important is technology to the organisations' leaders?			
	How has technology changed the leadership's behaviour and/or attitude?			

Interview questions	
Technology OEM/Service Provider	
Interview question	**Response/Comment**
What is the technology product/service?	
What is it used for?	
Is the technology used in other industries?	
What are its key benefits?	
Who are the biggest stakeholders of the technology?	
When was it introduced to Sishen?	
How was the MoC done?	
What is your involvement/role post installation/implementation of the technology?	
Is Sishen realising full benefits of the technology?	
If not, why is that so?	
If yes, how is that measured?	
What factors support the full performance of the technology?	
What factors hinder the full performance of the technology?	

Appendix D: Participant consent form

The relationship between human factors and technology adoption at Sishen Mine

Mogaleadi Sandra Seabela

I, ..., agree to participate in this research project. The research has been explained to me and I understand what my participation will involve. I agree to the following:

(Please circle the relevant options below).

I agree that my participation will remain anonymous.

YES NO

I agree that the researcher may use anonymous quotes in her research report.

YES NO

I agree that the interview may be audio recorded.

YES NO

I agree that the information I provide may be used anonymously after this project has ended, for academic purposes by other researchers, subject to their own ethics clearance being obtained.

YES NO

.... (signature)

.... (name of participant) .... (date)

.... (signature)

Mogaleadi Sandra Seabela (name of researcher) .... (date)