Gordon Institute of Business Science
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Success and failure factors for the adoption of technology in modern mining

by

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ABSTRACT

Technological advancement and innovation allows mining companies to be more competitive and address some of its most pressing challenges including, depleting resources, productivity levels, cost efficiencies and societal and environmental impact. It is essential for mining firms to understand the contributing factors that would allow them to be successful and remain competitive in its efforts for sustainable production of mineral resources. There are a range of factors that make technology adoption in modern mining fail or succeed and this paper makes use of qualitative data collected through interviews with mining experts to safety representatives to identify the key factors that will enable mining firms to be more successful in their technology journey. Additionally, this paper will provide practical recommendations and a systems-thinking approach to integrate into the mining firms' technology adoption process, which will support their efforts towards technological advancement and mechanisation.

KEYWORDS

Technology adoption, modern mining, barriers and enablers, innovation, success and failure factors.

DECLARATION

I declare that this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorisation and consent to carry out this research.

Signature	Date

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LIST OF ABBREVIATIONS

ADKAR	Awareness, Desire, Knowledge, Ability and Reinforcement
AHS	Autonomous Haulage Solutions
BEV	Battery Electric Vehicle
CAS	Collision Avoidance System
DOI	Diffusion of Innovation
ESG	Environmental, social, and corporate governance
MS	Microsoft
OEM	Original Equipment Manufacturer
RQ	Research Question
TOE	Technology Organisation Environment

CHAPTER 1: INTRODUCTION TO THE RESEARCH PROBLEM

1.1. Introduction

As mines modernise, to enable improved safety, production and sustainability, the implementation of modern technologies becomes more prevalent (Aznar-Sánchez et al., 2019; Gruenhagen & Parker, 2020). The adoption of technology brings along both its successes and challenges in the mining environment. The mining sector deals with challenges of accessing underground mineral resources safely, which requires new technologies to be adopted, including for mining sustainability. Literature suggests that technological innovations may help in reducing costs, environmental impact, may support an increase in production, and importantly improve mineral recovery. Hence understanding success and failure factors to technology adoption is important for the success of technology implementation efforts and for the sustainability of the mining sector. However while the adoption of technologies may contribute to improved safety, production and sustainability, 'failure factors' or those factors impeding successful adoption needs consideration, with 'people factors', amongst others, needing deliberate focus.

Therefore, this study focuses on the success and failure factors in the adoption of technology in modern mining. It seeks to uncover an approach towards the successful adoption of modern technology for modern mining. While the discussion to follow, in the section below, provides a background to the research problem , this study's intent is not only enriching the current theoretical perspectives, but will also highlight practical implications of technology adoption for businesses operating in the mining environment.

1.2. Background to the Research Problem

Modernisation of the mining industry involves transition and transformation towards increased mechanisation and the use of innovative technologies to extend the life of mines, enhance productivity, and improve health and safety standards. The adoptions of technology in the mining industry not only facilitates cost reductions and improves environmental impacts at operational locations, but also increases productivity (Ediriweera & Wiewiora, 2021). The mining industry is riddled with a multitude of challenges, including hazardous work environments, the accessibility of ore deposits,

carbon emissions, and various environmental and social factors (Ediriweera & Wiewiora, 2021).

The continuous advancement in science and technology contributes to increase the knowledge base and heightens problem solving capabilities to address the challenges the mining industry faces (Pietrobelli et al., 2018). The increase in complexities and demands inherent in the mining industry, requires innovation and technological solutions to maintain sustainable mining operations (Stubrin, 2017). The aforementioned, suggests that innovation and technological solutions becomes pivotal to ensure the sustainability of mining practices.

Moreover, the literature also suggests the presence of several barriers to the successful implementation of modernisation and mechanisation of mines, many of which are characterised by ‘soft’ or ‘human’ factors, and it is noted that even the most advanced technologies are susceptible to fail if the human factors influencing implementation are not fully understood and resolved (Stewart, 2015).

The discussion above has highlighted that technology adoption is required for mining sustainability but that the ‘why’ and the ‘how’ to technology adoption remains key, and hence success and failure factors needs deeper understanding.

1.3. Research Problem

The mining industry is rapidly gaining access to technology, but the pace of technology adoption in modern mining raises the concern whether adoption of modern mining technologies is influenced by safety, sustainability, and productivity, amongst others. In addition, how are human factors considered in modern technologies adoption? Further, the introduction of any new technology inevitably brings about challenges and obstacles in the adoption thereof. The above aspects capture the essence of the research problem.

To gain understanding on the above aspects, this study will probe into the success and failure factors of technology adoption in modern mining based on empirical experiences which will add insight to the topic and enrich the existing body of knowledge.

To expand on the research problem, the discussion below provides context in the mining sector, regarding concerns around the adoption of modern mining technologies.

Success factors in this research are those elements that enable people to accept technology, thereby supporting the adoption process. Failure factors are those elements that inhibit the acceptance of technology, thereby hindering the acceptance of technology.

The adoption of technology has been linked job losses which result in both resistance and challenges related to social transformation (Kansake et al., 2019). These challenges while linked directly to employers and employees, encompass a broader range of stakeholders whose influence on the adoption of technology process beyond that of a binary relationship. These stakeholders include local unions, government institutions, business leaders and host communities, all who play significant role in the adoption or resistance to technology (Kansake et al., 2019).

Mining operations are driven by their daily productivity targets and are sensitive towards any factors that might introduce uncertainties impacting production. The introduction of any new technology has inherent risk associated to their effectiveness and efficiency (Ediriweera & Wiewiora, 2021). Consequently, operational teams may not have the risk appetite which makes it difficult for mining firms to be early adopters of new technology (Ediriweera & Wiewiora, 2021). The mining industry has been known to be traditional and conservative to change which create structural barriers to innovate (Bartos, 2007). Furthermore, characterised by being a capital intensive industry, it creates reluctancy by mining firms to introduce new technology due to the need to achieve quick returns on investment for shareholders (Ediriweera & Wiewiora, 2021).

Mining firms need to consider adoption of technology holistically and not only from economic gains perspective but also needs to consider safety, social and environmental factors to meet the requirements of their social license to operate (Fordham et al., 2017). Multiple stakeholders have different interests which creates higher levels of complexity in the adoption of technology and therefore impacts the success in the adoption process (Fordham et al., 2017).

Literature suggests that mining is known to be conservative and capital intensive by its very nature which leads to barriers to innovate (Bartos, 2007). Nevertheless, there is a prospect that technology adoption within mining industry has the potential to address some of the industry's most pressing challenges, including safety concerns,

environmental considerations, and productivity enhancement (Gruenhagen & Parker, 2020).

Importantly too, mining companies, based on their contextual needs to modernise, are progressing in their technology adoption efforts.

Mining firms must transition away from traditional mining methods, failing to utilise new technologies and improve mining methods will cause mining firms to fail in the mining of difficult to access and geologically complex ore bodies cost effectively in South African mining operations (Minerals Council South Africa, 2016). Based on these studies, failing to mine these complex ore bodies will lead to hundreds of thousands of job losses by 2030 (Minerals Council South Africa, 2016).

Hence, large mining companies are reviewing their entire value chain when it comes to technology. For instance, BHP is using 3D laser scan technology to fully automate their shipping loaders which drives better safety, production, cost efficiencies and the creation of new skilled employment opportunities (BHP, 2022). Notably, Roy Hill is planning to convert 96 haul trucks using Autonomous Haulage Systems, a transformative initiative that will establish the largest automated mine in the world, thereby removing mine workers from danger and creating safer working conditions (Roy Hill, 2023). Moreover, Anglo American, a diversified mining company has independently developed the largest hydrogen truck as opposed to partnering with an Original Equipment Manufacturer to develop a solution for them, which will help facilitate the mining firm's ability to achieve its carbon reduction targets by 2030 (Anglo American, 2022).

It is evident that as mines modernise, for their sustainability, the adoption of modern mining technology becomes more real, but how mines navigate this, based on concerns and their contextual needs remains key.

1.4. Theoretical need

In a recent study, Ediriweera & Wiewiora (2021) framework on the adoption of technology reveals both barriers and enablers in the mining industry. This framework was founded on the basis of the Technology Organisation Environment (TOE) framework (Tornatzky et al., 1990), which uses three aspects to illustrate the process of adopting technology, which are, technology, denoting the availability of technology,

organisation encapsulating the firm's scale, structure and scope, and the environment representing the market in which the firm operates in (Tornatzky et al., 1990). The researcher makes use of the TOE framework to highlight the key barriers through the organisational and environmental aspects, and enablers through the technology aspect (Ediriweera & Wiewiora, 2021). Among the environmental barriers highlighted are insufficient stakeholder engagement, geographical dispersion, operational uncertainty, and the cyclical nature of mining. Furthermore, organisational barriers encompass factors such as performance and recognition systems, high risk to unproven technology and limited trust. Conversely, technology enablers encompass factors such as employee empowerment, a culture of continuous learning and cross-disciplinary knowledge sharing. This framework reveals barriers and enablers at an organisational and industry level.

Ali & Rehman (2020) research shows the importance of stakeholders' inclusion in the adoption of technology, by highlighting the complexity of the different stakeholders involved and the impact this has on operational readiness which hinders the adoption process. Ediriweera & Wiewiora (2021) which relates to the acceptance of technology but does not address complex phases of technology integration, deployment and implementation. Building on to Ediriweera & Wiewiora (2021) research, using a system thinking approach, this considers mining as a system with interconnected elements and any change to an element requires an adjustment and modification to yield the required performance (Arnold & Wade, 2015). Research in the field of modern technology adoption in mining is relatively new (Gruenhagen & Parker, 2020), therefore, a study that investigates the successes and failures of technology adoption in modern mining will further contribute to academic knowledge as is the aim of this study.

1.5. Business need

Historically, the mining industry was known to focus on cost reduction to improve their productivity levels (Aznar-Sánchez et al., 2019), and is facing challenges with lower ore grades (Calzada Olvera, 2022) and limited access to scarce resources (Ediriweera & Wiewiora, 2021) that is required daily by mining operations has emerged as concerns. Furthermore, with the recent concerns on climate change, environmental impact and the well-being of society (Bai et al., 2017) requires the mining industry to adopt greener

technology. There has not been a more imperative time for the mining industry to adopt technology and create the step change it requires to address these challenges of increased competition, improved productivity and enhanced sustainability (Aznar-Sánchez et al., 2019). The pace at which mining firms adopt technology is not the only requirement to create a transformative shift, this involves a more complex set of challenges which needs to be considered holistically throughout the firm, such as strategy, operations intricacies and the value proposition extended to customers (W. P. Rogers et al., 2019).

The mining industry is characterised by volatility and fluctuating commodity prices (Gruenhagen & Parker, 2020), coupled with multiple stakeholders with competing priorities; investors attach a risk premium to mining stocks with shareholders requiring larger returns on their investment. In this context, mining firms need to ensure that any technology that is adopted creates value to their shareholders. An in-depth understanding of determinants that makes mining firms successful or fail when adopting technology holds the potential for mining firms to formulate strategies that will deliver value to their stakeholders.

1.6. Purpose statement

The purpose of this study is to understand the success and failure factors in the adoption of technology in modern mining. To understand this, the research will probe into:

- The success and failure factors for the adoption of technology in modern mining.
- Perceptions and insights of technology adoption on people, safety, sustainability, and productivity in mining.
- An approach towards the successful adoption of modern technology for modern mining.

To note, as mining environments differ, this study will consider mines that are modernising in the diamond and platinum sectors to allow rich data gathering for this study. Recommendations and insights stemming from this research may be considered by mines under with similar contextual circumstances and shared experiences.

1.7. Outline of the study

In Chapter one, the study considers the need and purpose for the study. Further, Chapter two undertakes a literature review, encompassing a review of existing academic literature, an analysis of influencing success and failure factors, a review of theorical models and the exploration of systems-thinking. Chapter three provides for the research objective and questions. Detailed insights into the research methodology is expanded in Chapter four. Chapter five discusses the findings of the study based on the research questions. Lastly, Chapter six and seven considers the study holistically and provides the conclusive remarks and actionable recommendations.

1.8. Conclusion

Chapter one has reviewed the research problem, and has provided for an understanding of the research content and purpose. Chapter two will focus on the literature review and insights relevant to the topic that is researched.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

This chapter provides academic context associated to the adoption of technology in mining. Additionally, it details the literature that highlights successes and failures through the technology adoption process. This chapter also provides the theoretical underpinning of frameworks and introduces a system-thinking approach.

2.2. Failure Factors

Failure factors refers to the elements that result in the unsuccessful deployment, integration, and deployment of technology adoption. The rate at which technology is developed and commercialised may take several years and creates a perceived risk that mining firms will not take on unproven technology and prematurely implement these technologies in a production environment (Bartos, 2007). The mining industry is traditional, conservative and well known to be risk adverse which makes the industry resistant to change and slowly implements technology (Fältholm & Norberg, 2017).

Resistance to change is further exacerbated by the cyclical nature of commodity prices (Ediriweera & Wiewiora, 2021) and structural barriers are created due to high capital costs, where mining firms would prioritise productivity over longer term investments with technology (Bartos, 2007). Ali & Rehman (2020) research shows the importance of stakeholders' inclusion in the adoption of technology, by highlighting the complexity of the different stakeholders involved and the impact this has on operational readiness which hinders the adoption process. By not engaging with stakeholders such as unions, government and host communities through the technology adoption process, it is met with resistance due to the lack of awareness, and the lack of engagement which impacts the skills availability. Notably, traditional qualifications do not include aspects of automation and innovation in their curriculums, hence there is a gap between the skills needed for the adoption of technology and the necessary educational framework to develop these skills (Ali & Rehman, 2020).

Mining firms often have a silo structure which result in the exclusion of various stakeholders and leads to limiting employees in the decision making due to hierarchical

structures (Ediriweera & Wiewiora, 2021). The geographical dispersion of mining firms relative to where corporate offices are, creates organisational barriers (Bartos, 2007), and this inhibits technology adoption due to bureaucracy complexities and decision making taking place in group functions (Calantone et al., 2010). Organisational structure of mining firms limit the interconnectedness between corporate offices where decisions regarding technology adoption are formulated, and the mine's operations, where these technologies is to be implemented (Calantone et al., 2010). The lack of integration leads to misaligned priorities, where employees at a mine's operation are measured on key performance indicators (KPIs) related to volumetric tonnes and operational efficiency, rather than factors like innovative problem solving or degree of involvement in the adoption of technology (Ediriweera & Wiewiora, 2021).

Misalignment due to inadequate change management taking place through the technology adoptions process leads to employees focusing on their existing individualist units instead of adopting a holistic view. That is, system-thinking would inform that with any change, adjustments should take place to generate the desired outcomes (Arnold & Wade, 2015). For instance, implementing combined KPIs as opposed to employees only focussing on productivity but looking for ways to incorporate the measure to the full production system (Ediriweera & Wiewiora, 2021). Change management requires to incorporate a larger set of stakeholders which is underrepresented, like the workforce who uses the technology, communities who can be affected by the use of technology since they are within the operating areas and competitors that may obstruct technologies that would be valuable to the industry (Prno & Slocombe, 2012).

The cyclical nature of mining influences the trust dynamic between employees and management, since during down cycles, mining firms go through cost cutting exercises and retrenchments, this leads to employees' attention becomes focussed on their own KPIs and productivity, rather than actively engaging in the technology adoption process (Ediriweera & Wiewiora, 2021). Employees are reluctant to adopt technology since there is a perception that technology may make jobs redundant (Gruenhagen & Parker, 2020), or unproven and immature technologies may affect daily routines and the uncertainties of the technology may hinder their ability to meet their production targets. The skills required is not always available to use the new technology since mining operations are in remote areas (Ali & Rehman, 2020), the lack of operational readiness (Cabral et al.,

2020) and knowledge on new technology makes the adoption of technology far more challenging to yield the desired outcomes (Ghebrihiwet, 2019).

Further, an investment in technology, amongst others, is another important factor. Bryant (2015) highlights that the adoption of technology has faced several challenges, which include:

- Limited investment due to mining firms prioritising cost savings;
- Limited technological advancement by Original Equipment Manufacturers (OEM), worsen by procurement practices from the industry and low expenditure on research and development, effecting technology maturity;
- Commodity prices set by the market;
- Lack of integration of technology into strategic business planning and implementation; and
- Misinformed and lack of understanding by leaders regarding the benefits of technology.

The discussion above has highlighted some of the key factors which impede successful adoption of modern technologies. The sub-section below raises success factors in technology adoption.

2.3. Success Factors

Success factors refer to the elements that assist mining firms in achieving their desired outcomes in the context of technology adoption. Literature suggests that technology will be essential for the mining industry to address concerns associated to safety, sustainability, environmental impact to productivity enhancement (Gruenhagen & Parker, 2020). An effective technology strategy for a mining firm is vital in the technology adoption process which needs to be embed throughout the organisation. Studies have shown that organisational structures assist mining firms to cascade and align the adoption of technology, impacting human capital resources, knowledge transfer and communication dynamics (Ghebrihiwet, 2019). Aligning the organisational structure to be congruent with the objectives of technology adoption provide a platform for different departments to foster collaboration, transparent communications and knowledge sharing; this in turn facilitates more effective technology adoption across departments

(Ediriweera & Wiewiora, 2021). The technology strategy should inform the organisational structure of the changes required since group functions and bureaucracy creates hurdles in the adoption of technology (Gruenhagen & Parker, 2020). An example of this is a centralised supply chain function, complex procedures and extended procurement processes in a corporate function constrains proactive technology adoption at a mine's operation (Gruenhagen & Parker, 2020).

Mining operations are located in hazardous and remotes areas (Fordham et al., 2017), with health and safety always being prioritised. The advancement of technology allows mining firms to improve employees working conditions and safety, for instance, the deployment of remote monitoring and control facilities that are located outside the mine's operation or in cities which takes operators away from danger zones (Fu et al., 2018). Such examples on regulations have stimulated the development of fatigue monitoring, collision avoidance systems, and automated mining systems that remove operators from the hazardous environments and allows them to work from remote controlled rooms (Kansake et al., 2019). Technology adoption and its capabilities are well researched, providing the mining industry with the potential to advance mining operations to higher levels of efficiency, improve their environmental footprint and increase productivity (Ghebrihiwet, 2019). The advancement of technology allows the mining industry not only the opportunity to improve its operations but also contribute positively to its environmental impact and increase overall productivity.

The success and failure factors highlighted in 2.2 and 2.3 of the literature review will be confirmed, and potentially enhanced further through this study, through data gathering.

2.4. Theoretical Models

There are several theoretical models available that deals with technology adoption (Oliveira & Martins, 2011), more notably are, the technology acceptance model (Davis, 1989), theory of planned behaviour (Ajzen, 1985), unified theory of acceptance and use of technology (Venkatesh et al., 2003), diffusion of innovation (DOI) (E. Rogers, 1995), and the technology organisation environment (TOE) (Tornatzky et al., 1990). However, within the context of this research, the only applicable theory is the DOI theory (E. Rogers, 1995) and TOE (Tornatzky et al., 1990) since the technology acceptance model

(Davis, 1989), theory of planned behaviour (Ajzen, 1985), unified theory of acceptance and use of technology (Venkatesh et al., 2003) all primarily pertain to the adoption of technology at an individual level rather than to an organisational level (Oliveira & Martins, 2011). Furthermore, the DOI theory is not considered in this study since environmental factors have been excluded in the application of this theory (Oliveira & Martins, 2011).

The TOE framework makes use of three elements that influence the adoption of technology and uses these in the implementation: technological, organisational and environmental (Tornatzky et al., 1990). Technology refers to both internal and external factors in relation to a firm, and encompassing practices, equipment, and technologies that are available (Tornatzky et al., 1990); Organisational describes the firm itself, which includes size, scope and structure; and environment refers to the market that the business operates in, encompassing, regularity influences and the effects of government (Tornatzky et al., 1990).

E. Rogers (1995) theory on DOI explains individual characteristics, internal and external characteristics that influence a firm's innovation process. However, this is similar to the TOE framework which refers to technology and organisation factors, but the distinguishing attribute that the TOE framework introduces is the environment (Oliveira & Martins, 2011). In the context of this study, it makes it more appropriate to use the TOE framework since it incorporates the DOI theory and is underpinned by empirical support (Oliveira & Martins, 2011).

Ediriweera & Wiewiora (2021) uses the TOE framework in a recent study to understand the barriers and enablers of technology adoption in mining. The findings highlight the following: organisational barriers are similar to other industries, such as, lack of relationship building, recognition of performance and the incorporation of unproven technology (Ediriweera & Wiewiora, 2021). Distinctive environmental barriers were identified and are different to other organisations, this includes the cyclical nature of mining, inadequate engagement with stakeholders, geographical dispersion (Ediriweera & Wiewiora, 2021). Organisational enablers within the context of mining was specific to learning culture, engagement with stakeholders and cross discipline knowledge sharing (Ediriweera & Wiewiora, 2021).

The mining environment is different from other industries and should be reviewed from a system lens. A simple mining value chain encompasses exploration, planning, development, mining, processing, transportation and marketing, and the end of life plan (Anglo American, 2023), and any change within this mining value chain, such as, technology adoption impacts the system (Arnold & Wade, 2015). The study on barriers and enablers to technology adoption in mining provide insights to the technology adoption construct which relates to the acceptance of technology, but does not address integration, deployment and implementation of technology in relation to operational readiness, skills availability, information system integration and change management (Ediriweera & Wiewiora, 2021) which requires further study.

2.5. Systems-Thinking Approach

To understand the mining environment, it is important to understand how a mine operates which can be described through their value chain, that is, exploration, plan, develop, mine, process, transport and market, and the end of life plan (Anglo American, 2023). This fundamental value chain describes the process of a mining operation to sell mineral resources to the market. Each step can be considered a system, which is made up of other systems (Arnold & Wade, 2015). For instance, the mining process can be broken down into drilling, blasting, loading and hauling, and hauling can be further broken down into smaller systems. This gives a basic understanding that the entire mining value chain is interrelated, interdependent and interacting elements that form collective entities to the system it operates in (Arnold & Wade, 2015). This makes the successful adoption of technology difficult since a change to an element in the system, will have an effect on the entire system (Arnold & Wade, 2015).

The mining industry uses technology for continuous improvement, to improve profitability and increase production, but technology also provides the mining industry the ability to reduce waste, decrease pollution and improve sustainability practices (Ediriweera & Wiewiora, 2021). Recent literature focusses on organisational, technological and environmental factors in the adoption of technology in mining (Tornatzky et al., 1990), but fails to recognise that the adoption of technology should be reviewed from a systems-thinking lens. The mining value change can be seen as a system, and any change within this system needs to be adapted in order for the system

to work as it is desired too. The Theory of Constraints describes that every system must have a constraint (Goldratt, 1988) and the constraint must be identified so the effectiveness of the system can be maximised, since the constraint affects performance (Rahman, 1998). Consequently, when a mining firm introduces new technology, it can cause a constraint in other areas of the system. For example, a mining operation uses diesel loading vehicles and now adopts battery-electric vehicle (BEV) loaders that will reduce the mining operation's carbon emissions. However, the adoption of this technology is not that straightforward since there is a higher demand on electricity and infrastructure changes are required to accommodate charging bays. In turn, this impacts technical and maintenance resources since they need to be trained to maintain these BEV loaders. Furthermore, this impacts the mining firms supply chain function since the technology is new and the parts attract longer lead times.

The adoption of technology in the mining industry requires an approach of systems-thinking, since a single change of an element may affect the system (Rahman, 1998) and a constraint may move due to this change (Goldratt, 1988).

Current studies may have not used a systems-thinking approach when researching technology adoption in modern mining, and this study into the success and failure factors of technology will enhance existing literature through exploring this approach.

The TOE framework in 2.4 and the systems-thinking approach, in section 2.5, highlights the need for an integrated approach in technology adoption, people, systems and technologies. This becomes important in the recommended approach for technology adoption for this study.

2.6. Organisational Culture

The discussion below highlights some aspects crucial for technology adoption. They expand further on the success factors discussed in section 2.3.

2.6.1. Integration of digital strategy into business processes

Generally accepted definitions of business models encompass the reasoning behind an organisations operational approach, defining how the organisation generates, delivers and secures value (Evans et al., 2017). Ylijoki & Porras (2016) highlights the need for

businesses to review their business models since new technologies by their very nature can be disruptive and organisations should link the adoption of new technologies to their digital strategy. Additionally, Nuur et al. (2020) points out that mining operations have a lock-in effect, since operational procedures becomes entrenched and it makes it complex to implement any new technologies when they are disruptive to existing operational routines. For mining firms to adopt technologies effectively, they require integration of the business strategy by reviewing, adjusting and re-engineering their business processes; achieving this can take place by using systems-thinking approach ensuring that the adoption of technology is looked at within the whole systematic context.

Ackoff & Gharajedaghi (1996), defines a system as a “functioning whole that cannot be divided into independent parts”. Furthermore, Ackoff & Gharajedaghi (1996) adds to this by highlighting that a whole system is made up of different essential parts: One, each of the parts can affect the behaviour of the whole system. Two, each part may not affect the whole system independently since this is dependent on what these parts do. Three, every subset of parts can affect the behaviours of the whole system but none can do so independently of the other parts. This is applicable to that of a mining value chain, each part of the system is reliant on each other to perform to deliver the desired performance; this becomes vital for the adoption of new technologies since the change in one element in the system may affect other parts of the system, hence business processes need to consider through a strategic and systematic lens.

Integrating the digital strategy in to the business processes through systems-thinking allows mining firms to consider the whole system which also includes associated skills, communication, stakeholders, infrastructure, culture policies and procedures. Policies and procedures needs to be reviewed as the adoption of technology takes place, such as roles and responsibilities to ensure there is clarity in what needs to be done and how it needs to be done (Kohli & Melville, 2019). A strategy and its change agents provides the ability to help reshape prevailing beliefs through a shared vision amongst different stakeholders (Westley et al., 2013). Additionally, the importance of legacy frameworks and its change help the integration of new knowledge, experimentation and learning (Westley et al., 2013). Success is an intrinsic element of any organisation which is manifested through the pursuit of performance and creating value from their business strategy.

2.6.2. Change management process

Technology adoption is the process in which organisations implement new technologies into their existing workflows, business processes and systems. To achieve this it requires the acceptance of the technology, change to existing processes and usage of the technology to reap the benefits that these new technologies can provide. New technologies and the change in these processes face challenges of resistance before technology is adopted, and while these technologies need to be used. For example, employees may resist using wearable technologies that track their locations due safety concern or employees may not want to make use of automation on machines because they perceive their roles may become redundant (Gruenhagen & Parker, 2020). Mining firms have traditionally focussed on profits and cost efficiencies, and it becomes very difficult to change from proven work practices that have historically assisted employees to achieve their production targets, hence employees will resist the adoption of technology unless it can impact the bottom line (Fältholm & Norberg, 2017).

The introduction of any new technology requires change in people and processes, Moran & Brightman (2001) define change management as the process of “continually renewing an organisation's direction, structure, and capabilities to serve the ever-changing needs of external and internal customers” (p. 111) and effective change management process requires adaptation to strategy, structures, systems and people (Todnem, 2005).

According to Ediriweera & Wiewiora (2021), it was found that operational employees were hesitant to adopt technology since they did not trust that the technology would deliver the results that are expected; mining companies are risk adverse and will not take on unnecessary risk. Ghazizadeh et al. (2012) stipulates that new technologies need to be socialised, there is a level of trust and reliance in the technology to achieve its intended purpose for it to be adopted effectively. Users of the technology need to be consulted so there is an understanding for the change and if this does not take place the likelihood of acceptance in very low.

Additionally, for the adoption, diffusion and acceptance to take place more effectively, clear change management frameworks should be developed by mining firms, and Warnich et al. (2018) have identified some of the most common failures in the change

management process by organisations. These factors include: Culture and level of readiness for change are not assessed beforehand, Change leaders fail to respect the power of the culture to hamper the change, No strategies are in place to cultivate or grow new culture, Failure to pilot the change, Organisational systems and other initiatives are not aligned to the change, End users are not involved in the process, Lack of a proactive plan for user resistance or rejection, and Processes are not re-engineered and realigned.

2.6.3. Stakeholder engagement and inclusion

Maak & Pless (2006) research shows that organisations today operate in a complex and interconnected business environment and there are several stakeholders that need interaction which include internal focussed stakeholders such as, employees, clients and customers, and business partners, and those that are outside of the organisation such as government, host communities and unions. Stakeholder inclusion encompasses all individuals and groups that influence or are directly influenced by the organisation's goals; sustained interaction with stakeholders is an integral part of the strategy which aims at developing trust and gathering support for the successful adoption of new technologies and other significant changes (Ansu-Mensah et al., 2021).

Awuah et al. (2021) research on different stakeholders in the introduction to initiatives at mining operations highlights some integral factors which include effective decision making becomes more robust when different stakeholders' opinions are considered, this both improves the mining firm's ability to understand concerns from different parties as well as improve current approaches to introduce new initiatives. Furthermore, Awuah et al. (2021) highlights the benefits of host community involvement, mining firms build trust through early engagements which can lead to cost savings since host communities can affect the time required for initiatives to be implemented.

Ediriweera & Wiewiora (2021) research shows that mining firms need to have better and more collaborative relationships with suppliers, communities, research institutions and universities to help provide solutions through new technologies which can improve speed, costs and knowledge. Lack of engagements with suppliers can result in new technologies being developed in isolation from mining firms, which in turn makes

implementation difficult at operational levels since these new technologies do not have access to the different variables on site and therefore making technological solution not fit for purpose (Ediriweera & Wiewiora, 2021). For example, mining firms should establish clear and transparent engagements with suppliers which can provide access to expert knowledge and collaborative solutions that all parties can benefit from (Ediriweera & Wiewiora, 2021).

Employee engagements, who makes use of new technology and play a critical role in the implementation of technology is underrepresented through the adoption of technology (Gruenhagen & Parker, 2020). Decisions are made on change and technology adoption often takes places at executive levels, conversely where execution of these takes places are at operational levels and those employees response making the decisions to implement technology possess limited authority over the implementation process (Ediriweera & Wiewiora, 2021). Employees that are tasked with the implementation of the new technologies often have limited decision making powers and have minimal insights into the initiative evaluation and decision making stages of implementation; this disconnect in involvement throughout the adoption process results in fractured access to information and ultimately impedes the successful adoption of technology (Ediriweera & Wiewiora, 2021).

Stakeholder engagement is crucial and achieving successful adoption of new technologies require comprehensive inclusion and transparency with all stakeholders at all levels.

2.6.4. Skills development and training for digital transformation

Skills development and training programmes specific for technology adoption in the mining operations are required to ensure successful implementation of these new technologies. Continuous improvement, learning and adaptations should be integrated in the process to ensure that these learning are kept up to date with technology. The introduction of new technologies creates skill gaps and, in some instance, existing skills becomes outdated but training can assist to close the gap between the current capabilities that employees have to required capabilities that employees required for change (Pardo del Val & Martinez Fuentes, 2003). Job & McAree (2017) research

highlighted that there was a lack of clear guidelines and training for end users and maintainers when adopting new technology; and this lack of clarity in the training required eventually leads higher costs and lower reliability on the technology.

According to Ali & Rehman (2020) research, showed that employees do have skills sets such as computers literacy and the ability to make use of software from new technology, but this was not seen as adequate to utilise the latest technology. The adoption of technology will increase the demand of skilled employees, and the most effected would be those that lack the skills needed to use new technologies (Ali & Rehman, 2020). Mining operations are geographically dispersed in remote areas around the world and this makes it difficult to source skills and keep attrition levels low due to the high demand and competitive nature of the mining industry (Job & McAree, 2017).

Training of the workforce influences sustainability, not only for longer term professional growth and access to skilled labour, but in the form of social capital for mining regions (Aznar-Sánchez et al., 2019). Stakeholders such government and suppliers provide access to a pool of skilled employees, however, while suppliers can provide training and skilled labour for the adoption of technology (Pietrobelli et al., 2018), it was found that government and universities did not always have a curriculum fit for the purposes of technology adoption in the mining industry (Ali & Rehman, 2020). Knowledge gaps and the diffusion of technology can be addressed through the organisation's ability to foster dynamic capabilities (Teece et al., 2016). Dynamic capabilities help organisations to integrate, build and reconfigure its internal and external competencies to address change; this allows organisations to mobilise resources and learn, absorb and facilitate the development of necessary skills and knowledge required to make most use of new technologies (Teece et al., 2016).

2.6.5. Leadership support

Daft (2011) states that leadership has an influencing relationship among leaders and team members that wants real change to realise their joint goals. Leadership involves inspiring and guiding others to achieve common goals and supports their teams with resources for them to excel in their roles and contribute to organisational success; this encompasses the commitment to the process and creates a healthy environment for

employees to embrace change and integrate new technologies into the organisation. Leaders have to provide directives for the organisation which can be top down (Hinson & Osborne, 2014) and this is effective through their formal power (Robbins & Judge, 2018), when providing strategic direction.

Leaders that provide and encourage a culture of inclusiveness and diversity offers employees the opportunity to learn from each other and act more holistically (Kahn, 2018). A culture that promotes technology, encourages employees to explore new technologies and ideas but also facilitates an environment for where experimentation and learning from failures are encouraged. Luchs (2015) states that leaders and organisations with growth mindsets are able to test ideas and do not fear failure because it's part of the process of change. This becomes pivotal in the adoption process since the implementation of technologies do not always provide the benefits immediately. Suppliers are often the drivers of new technologies (Bartos, 2007) but they create commercial products that different mining firms may use (Ediriweera & Wiewiora, 2021), given that operating environments differ, these technologies do not always realise the optimum benefits immediately and needs more time for employees to familiarise themselves with the new technologies. Often where new technologies do not provide the increased productivities and efficiencies (Gruenhagen & Parker, 2020), employees will revert back to proven methods.

Technology adoption requires a transformational leadership style that have a clear vision of the future and able to inspire employees with that vision; they also are supportive and encourage innovation that fosters a culture that embraces change. Du Brin (2013) highlights eight characteristics that a leader should exhibit for significant changes like that of technology: 1. Raise the employees awareness, 2. Help employees look beyond self-interest, 3. Help people search for self-fulfilment, 4. Help employees understand the need for change, 5. Invest in mangers with a sense of urgency, 6. Commitment, 7. Adopts a broad and long-range perspective, 8. Builds trust, and 9. Concentrates resources where most needed.

2.7. Business value drivers influence on adoption of modern technologies

The discussion below considers the influence of business value drivers for the adoption of modern technologies.

2.7.1. Safety

Mining operations are located in geographically remote and hazards environments (Gruenhagen & Parker, 2020) but technology has the ability to address these safety concerns. Technology systems can operate under harsh working conditions where it is difficult for humans to operate safely (Ali & Rehman, 2020). Technologies have the capacity to remove people from danger and reduce the number of employees in the operation, therefore improving overall health and safety of employees (Ali & Rehman, 2020). Given the inherent risks associated to mining, not only does the mining industry show their commitment to safety through their culture but their strict policies and procedures of how their work activities are safety executed (Lenné et al., 2012). Health and safety is a priority for mining firms but there is also a significant cost associated with safety incidents, not only in terms of medical costs but financial costs due to production losses (Lenné et al., 2012).

Over time suppliers have developed leading safety systems that mining firms have adopted in their operations that have led to improved health and safety of employees (Kansake et al., 2019). For example, Hexagon (2023) has fleet management and mining machinery tracking systems that allows the mining operation to track where mining machinery are located and provides situational awareness. Wabtec (2023) introduced collision avoidance systems that prevent mining vehicle interactions and the system acts on behalf of the operator should there be any risks to mining vehicle interactions. Sandvik (2023) provides closed cabin equipment for underground mining equipment which protect operators in the event of rock falls; their cabins are ergonomically designed that improve the health of the operators. Epiroc (2023) provide automation systems for drill rigs which take operators out of danger in the mining operation into control rooms that are located out of danger.

Safety culture in the mining industry also becomes a barrier to adopting technology, since mining employees are resistant where their current workflow and processes

enable them to achieve a reliable result, unless new technologies can improve safety processes and the operating environment, mining employee will resist these changes (Fältholm & Norberg, 2017). There are also barriers to adoption of technologies such as personal tracking devices, where these are used for safety and health reasons, employees resist the adoption of these technologies because of tracking and privacy issues (Gruenhagen & Parker, 2020). Safe and healthy working conditions are significantly important to stakeholders and the adoption of technology requires a collaborative approach amongst government, employees and other stakeholders.

2.7.2. Production

The mining industry is a capital intensive and cyclical industry with fluctuating commodity prices driven by the market (Dayo-Olupona et al., 2020). The mining industry being cost driven, look for opportunities to either improve their efficiencies or increase their output through production. Gruenhagen & Parker (2020) research showed that the mining industry's cost driven approach towards investment creates barriers to the adoption of technology, since costs are such a major driver in the industry, there is a significant importance put on returns on investment. The implementation of new technologies in the operations is complex since a change in a system can impact the overall mining value change. For example, if the efficiency of drilling and blasting is improved, the operation may need to decide if they will scale down drilling and blasting due to efficiencies or increase it, if the latter option is used, all other systems that follow in the mining value need to have spare capacity so the extra production tonnes can be achieved. The complex nature of mining usually attracts high investment costs and technology needs to be adopted in the early stages of setting up a new mine (Lima & Suslick, 2006).

The mining industry is at a critical point due to the increasingly complex challenges, such as declining ore grades and government regulations. These challenges have created a state of urgency to implement technological innovation in the industry (Calzada Olvera, 2022). New technologies have incremental changes such as large trucks that increase the production tonnes moved or more fuel efficient engines that reduce the amount of diesel consumed (Caterpillar, 2023). Transformational technologies such as Autonomous Haulage Solutions (AHS) for mining trucks improve productivity and

efficiencies in the mining operation (Modular Mining, 2023). Mining operations are risk adverse (Johnson, 2010) and technology adoption has been linked to the perception of job losses by employees (Kansake et al., 2019). Fältholm & Norberg (2017) researched showed that mining employees preferred their current workflows and their proven methods of executing their work because it was reliable and they can trust the outcomes to help them achieve their key performance indicators (KPIs) and is hesitant to try anything new. Bartos (2007) research confirmed that mining employees were more likely to adopt technologies that had an incremental change as opposed to transformation change, this meant that stakeholders were hesitant to adopt new technologies if there was significant change to how they currently work. Mining has traditionally focussed on production and costs, stakeholders will resist the adoption of technology unless there is direct impact to production and costs (Fältholm & Norberg, 2017).

2.7.3. Sustainability

Recent research shows there is an increase in importance of sustainable mining practices, evident from the Paris Agreement on climate change and the Sustainable Development Goals (SDGs) which are both important for “present and future well-being of humanity” (United Nations, 2023). The mining industry is dominated by production by a few large mining firms (Bartos, 2007), which most have taken on Environmental, Social, and Governance (ESG) goals for their respective firms (Mining Technology, 2023). The mining industry inherently has an impact to society and the environment based on their business activities and play a pivotal role in the reduction of carbon emissions, environmental footprint and energy consumption. According to Aznar-Sánchez et al. (2019), the mining industry faces three important challenges: Firstly, mining firms are mining finite resources, and are challenged with depletion. Secondly, the economic efficiency of mining activities. Lastly, environmental and social impact.

The mining industry faces an economic, social and environmental imperative to improve their sustainability practices and is able to achieve this through the adoption of new technologies. Sustainability is made up of three aspects, environment, economic and social factors (Aznar-Sánchez et al., 2018). Sustainability therefore requires mining firms to make a concerted effort to protect natural processes within the ecosystem to ensure they can continue to provide important environmental functions; maximise

revenues based on resources available through economically viable options; ensure consensus amongst stakeholder and distribute benefits equally (Aznar-Sánchez et al., 2019).

From an economic perspective, if the organisation's objective is to generate profit, all stakeholders should benefit from the economic activity, especially affected communities (Fan et al., 2017). For example, autonomous haulage systems improve costs and productivity which can relate to revenue gain but also training and development for new skills is required for its operation. Sustainability from an environmental perspective, is the impact that mining activities has in the areas that it operates in, such as pollution of air, soil and water (Aznar-Sánchez et al., 2019). Mining operations can make use of solar energy to improve energy consumption and improve their extraction of mineral resources that will lower the impact to water. The social factors of sustainability mainly refers to stakeholders impacted, such as local communities or mineworkers (Aznar-Sánchez et al., 2019). Hazardous mining activities impact employee's health and safety, the use of BEVs mobile machinery will eliminate greenhouse gases created from diesel emissions that are inhaled by employees. The implementation of technology provides productivity and revenue improvement but can also enhance the mining firm's environmental footprint and improve the lives of communities in operational areas. For example, local communities may not have the requisite skill sets to operate new technologies introduced by the mining operations, this gives an opportunity for upskilling and providing transferrable skills applicable to other industries, such as computer, software and IT skills (Ali & Rehman, 2020).

2.8. Summary

The literature shows there are factors that hinder the adoption of technology in mining from an acceptance perspective and which can lead to the success or failure through the introduction of technology. The integration and usage steps in the adoption process of technology has remained relatively unexplored and may be viewed through a system's lens to best understand the factors that could contribute to the performance expected from the adoption of technology.

CHAPTER 3: RESEARCH QUESTIONS

3.1. Introduction

The research aims to understand the success and failure factors in the adoption of technology in modern mining. Exisiting literature suggests that technology will assist the mining industry to resolve some of its most difficult challenges (Gruenhagen & Parker, 2020), but there still lies a gap between the levels of technology adoption between the mining industry compared to technologically advanced industries (Bartos, 2007). The research on technology adopting in mining, while still increasing, there are limitations to what has been studied (Gruenhagen & Parker, 2020). Due to the gap that exists in existing literature, the study is aimed to research the contributing factors to success and failure in the adoption of technology in modern mining. The following research questions were developed to better understand these factors:

Research Question One: What are the success factors of technology adoption in modern mining?

The research question aims to understand the factors associated to technology strategy, productivity improvements, safety, and sustainability, and how this influences the adoption of technology within the mining context. Furthermore, this research question will gather any new insights with regards to the adoption process and will provide more context into what outcomes are generated from technology adoption.

Research Question Two: What are the failure factors of technology adoption in modern mining?

This research question is intended to uncover what factors contribute to the failure of adoption of technology within the mining context. This will seek to confirm as the adoption process takes place or post implementation, what are the negativities associated to the technology, are factors such as, change management, new safety risks, fear of job loss and skills availability contributors.

Research Question Three: What is an approach that supports the effective utilisation of technology in modern mining?

This research question aims to determine the interdependencies between the adoption of technology and associate performance that is desired. It will further provide a holistic understanding of changes to an element and how that influences the overall system.

Scope for the study

To note, as mining environments differ, this study will consider mines that are modernising in the diamond and platinum sectors to allow rich data gathering for this study. Recommendations made may be considered by mines with similar contexts and shared experiences.

CHAPTER 4: RESEARCH METHODOLOGY AND DESIGN

4.1. Research Design

A qualitative and exploratory research is used to understand the research questions and help to clarify the underlining problem that occurs (Zikmund, 2000). The aim of this research will be gained through understanding the perspectives of subject matter experts in relation to success and failure factors on technology adoption in modern mining, and to achieve this, an explorative approach is the most appropriate. Exploratory research is used by a researcher who is looking to uncover topics that the researcher is not fully experienced in (Saunders & Lewis, 2018). The research has adopted an interpretivism philosophy which concerns itself by gaining a deeper understanding of organisational complexities and the roles that humans play in as social actors (Saunders & Lewis, 2018). The research used this philosophy to gain insights into the complexities associated to the adoption of technology in modern mining, and by doing such, it enabled the researcher to understand the behaviours and perceptions of the targeted population through in-depth dialogues (Creswell, 2014). As this study looked deeper into the underlying problem being investigated through obtaining of rich insights of subject matter experts, a qualitative, exploratory research methodology thus became relevant for this study.

Saunders & Lewis (2018), suggests there are three research design options, namely, induction, deduction and abduction. An abduction approach is most appropriate in this research, since this approach assisted the researcher to develop propositions and then later meaning based on the actions of adoption of technology as opposed to preconceptions (Yin, 2011). This research made use of a mono-method research design which consists of analysing and interpreting qualitative data in a single study (Saunders & Lewis, 2018). A qualitative research method choice allowed the researcher to gain a deeper understanding of the success and failure factors on technology adoption in modern mining through the engagement with the targeted population (Ediriweera & Wiewiora, 2021). The research made use of cross-sectional study, as opposed to a longitudinal study due to the time constraints under which this study is completed (Saunders & Lewis, 2018). The researcher made use of semi-structured, in-depth

interviews with industry experts to gain more insights into the topic (Saunders & Lewis, 2018).

4.2. Research Methodology

4.3. Population

Saunders & Lewis (2018) describe the population as a set of group members which is not likely to always be available. The population for this study is the mining industry, and as the research does not have access to the whole population due to time limitations of this study, including that it is not feasible to collect data from the whole population, sample data is used. This research is based on sample data, which is the sub-group of the whole population (Saunders & Lewis, 2018). The sample data used in this research is from mining industry experts which have a wealth of knowledge that have enriched the data collected (Ediriweera & Wiewiora, 2021). These mining experts form part of the decision-making process for technology adoption, and this would include those that implement the technology.

4.4. Unit of Analysis

The unit of analysis for this research is based on insights from mining professionals with experience in technology adoption, deployment and integration. The perspectives of professionals from this sample population are best suited to answer the research questions. It is important for the sample population to have the requisite experience and knowledge which are key contributors to this study. As mining environments differ, this study considered information rich participants from mines that are modernising in the diamonds and platinum sectors to ensure rich data gathering for this study. Recommendations made may be considered by mines with similar contexts and experiences. The diamond and platinum mining sectors are considered for this study as these sectors have adopted modern technologies or in the process of modern technology adoption, and thus have rich lessons and insights to share.

4.5. Sampling Method and Size

The sampling method chosen needed to consider limitations such as cost and time constraints to complete the research (Saunders & Lewis, 2018). Since it is not feasible to make use of the population, which is the whole mining industry, a non-probability sampling technique is employed. Non-probability sampling is defined as a technique for selecting a sample population when the researcher does not have access to the whole population (Saunders & Lewis, 2018). The sampling method for participants is used through purposive sampling. Cooper & Schindler (2014) defines purposive sampling as a non-probability sampling process where the researcher uses specific elements and judgement from the target population based on specific criteria. Participants were selected based on their experience in mining and which importantly includes experience in technology adoption and implementation.

4.3. Sample Size

A sample design should consist of between 12 and 30 of participants for semi-structured interviews (Saunders & Lewis, 2018). The sample size provides a guidance of when saturation can be determined, and this will only be determined once the data collection is completed. Creswell (2014) defines the point of saturation is when qualitative data collection is conducted, and no new insights or discoveries can be expected from furthering this process. The sample design for this study included 12 to 24 participants from the mining industry, from diamond and platinum commodities, and data obtained from such participants, as per the table below, will be deemed as adequate for this study.

Table 1 - Unit of analysis

Profession	**Company A - Diamonds**	**Company B - Platinum**
Technology Innovation Manager	2	2
Engineering Foreman / Supervisor	2	2
Operator	2	2
Human Resources	2	2

Safety Representative	2	2
Original Equipment Manufacturer	2	2

4.4. Measurement Tool

The research is based on a qualitative study with the use of semi-structured interviews and open-ended questions. This is used based on Saunders & Lewis (2018), which highlights that to have an effective process for conducting exploratory research, the research should make use of academic literature and interviews, noting that interviews are defined by Cooper & Schindler (2014) being a primary collection technique to allow the researcher to gather primary data.

For this study data collection was conducted using an interview guide. This interview guide (Appendix 2) was constructed and aligned through the literature review to answer the research questions (Saunders & Lewis, 2018). The interview guide is used to ensure there is level of consistency and reliability through the interview process (Cooper & Schindler, 2014). The interview guide is used to focus and understand the different factors that lead to the success and failure factors in technology adoption in modern mining, and includes operational readiness, change management, organization support and utilisation of these technologies.

4.5. Data Collection

The research followed a qualitative method using semi-structured interviews with the sample population (Saunders & Lewis, 2018). The researcher is based in Johannesburg, South Africa and where possible interviews would take place in the region; and both face-to-face and virtual options are made available to mining experts based on their availability and preference. The data will be stored on a local hard drive device and backups will be stored on a cloud storage facility. Flexibility between interview mediums was accommodated for: Firstly, South Africa having several global companies in the region which meant that there could be different time zones to considered; and secondly, the availability of participants needs to be considered since there are several mining operations located in South Africa, which means participants could be in different locations, and participants may also have operational pressures.

The interviews are semi-structured and were made available through a virtual meeting with mining industry experts that are involved in the adoption of technology. The following steps were taken pre-interview as guided by the preparation steps from (Saunders & Lewis, 2018). Step one, the initial contact was made with the participant to give an overview of the study and interview. This allowed the researcher to be more familiar with the participants and their background. Step two, the participant was emailed from the researcher's university email address which contains the background and purpose of the study to provide context to the participants. The email also contained consent letters that highlight anonymity and which the participant needed to commit to before an interview will be conducted (Appendix 3). This included confirming the location and how the interview will take place. Step three, the participants are allowed enough time to review the documentation and request any clarification, while the questions are not shared upfront, the salient points are shared with the participant where it is deemed necessary. Further to this, (Saunders & Lewis (2018) highlights the importance of body language and that a professional appearance is maintained, therefore, the interviews will be conducted in a professional manner and business attire was worn.

The semi-structured interviews that were be held with mining experts who have adopted technology, followed a structured process to ensure consistency. These steps are as follows: Step one, each participant was briefed on the background and the purpose of the research. Step two, the participant was informed that each interview will be recorded, and all content was seen as confidential information. The interviews are conducted with audio recordings, which also includes taking notes during the interview. Step three, the recordings and interviews are then transcribed. Step four, the transcriptions were then analysed for results and insights that can be considered for future interviews or clarification. Step five, where there are changes required, the interview process was adjusted based on these insights.

A pilot test with a non-sample population took place to ensure consistency so the technique and required outcomes for interviews are met. Furthermore, the pilot test assisted to make sure questions are understood, the questions were not leading and identified any issues with the interview process prior to the research commencing with the sample population (Saunders & Lewis, 2018). The purpose of the pilot test was to ensure the interview process is robust and that it led to less mistakes through the

answering of the research questions developed for the study (Saunders & Lewis, 2018). The pilot test followed the steps as described in the data collection section, as above, to cover all aspects of the process that needed to follow.

4.6. Analysis Approach

The data followed a thematic analysis approach to identify categories, themes and patterns (Creswell, 2014). A thematic analysis is used when trying to understand perspectives and experiences from a data set (Creswell, 2014). Themes and patterns emerge from the data as codes recurred in the analysis and these themes were then analysed by cross checking it against notes, transcribed material, data sets and literature. The semi-structured interviews were transcribed into word text and uploaded into a qualitative software, ATLAS.ti (Saunders & Lewis, 2018). The use of a Five-Phase cycle was utilised to analyse the data set and support the thematic analysis (Yin, 2011). Phase one, was compiling, where the researcher would organise all data that has been collected (Yin, 2011). Phase two, was disassembling the data or coding the data into smaller pieces and categories (Yin, 2011). Phase three, was reassembling the data and representing them in a tabular form (Yin, 2011). Phase four, was interpreting the data that has been reassembled. Phase five, was concluding where the researcher draws a conclusion from the entire study (Yin, 2011). The Five-Phase Cycle was an iterative process which required the researcher to review and adjust between each phase until a conclusion was determined (Yin, 2011).

4.7. Quality Controls

The research can be contaminated by the researcher's bias (Saunders & Lewis, 2018) due to their background and experience with the adoption of technology in the mining industry. Thus, triangulation is a principle of being able to corroborate and confirm the events, description or facts that has been represented in the study (Yin, 2011). Triangulation was used in this study. The research verified the data by finding at least three ways to corroborate the study. Firstly, the researcher made use of the literature review from multiple sources to validate and provide evidence to themes (Creswell, 2014). Secondly, the interviews with mining experts or third parties with knowledge of adopting technology allowed the researcher to validate the facts that emerge from the

study (Creswell, 2014), this further address concerns around validity and reliability to ensure there is no bias in the researcher's interpretation of the findings. To ensure dependability of the findings, the researcher examined the responses from participants and the insights against the literature. Furthermore, all participants would be briefed on the research and the researcher ensured they have the relevant knowledge on the adoption of technology in modern mining. Research credibility is supported by the purposive sampling (Cooper & Schindler, 2014), which required participants to have the relevant knowledge to contribute to the study. Lastly, the researcher gathered information from different firms as opposed to using only a single firm as a reference. This allowed the researcher to answer the questions and if the research was generalisable and can be applicable to other firms (Saunders & Lewis, 2018). Saunders & Lewis (2018) notes that the data collection should provide consistent findings. The credibility and consistency can be reached once saturation has occurred, meaning there is no further insights that are discovered (Saunders & Lewis, 2018).

4.8. Ethical Considerations

Prior to any interviews with respondents, the researcher was required to obtain ethical clearance from the Research Ethics Committee of the Gordon Institute of Business Science (GIBS). Once the ethical clearance application was approved from the committee, the researcher is allowed to collect data. The objective of the ethical clearance is to ensure that the research was conducted in the appropriate manner and that both parties' rights are preserved throughout the process. Every respondent was asked to participate in an interview and be required to sign a consent form (Appendix 3) which was received as proof of consent before any interview can commence. Interviews was administered in English since it recognised as the business language in South Africa. Anonymity was maintained for all participants and firms in the study, and all respondents was assured of confidentiality and that all data collected during the interview will be kept anonymous.

4.9. Limitations

The research took place over a limited time period and the sample population that was studied may not cover all types of mining commodities. This means that this study

cannot be generalised to the entire population which is the mining industry. The research can be further enriched by looking at all commodity types that are produced in the mining industry. The research is not a qualified interviewer and the method that data is collected can include observer bias (Saunders & Lewis, 2018). Saunders & Lewis (2018) states this is the manner in which an observer interprets the same data and can create different conclusions, thus, creating a bias. Further research can be completed with different participants, such as, mining companies with different commodities, government institutions and stakeholders that develop the technology for the adoption in the mining industry such as suppliers and consultants.

CHAPTER 5: FINDINGS

5.1. Introduction

This chapter presents the findings from the interviews conducted for this study with objective to answer the research questions formulated in Chapter three. The purpose of this study was to identify and understand the success and failure factors for the adoption of technology in modern mining. This study was based on the data that was collected and analysed during semi-structured, Microsoft Teams (MS) interviews where twelve participants were interviewed. The key themes that emerged from the participants who addressed the research questions in Chapter three will be discussed further in this chapter.

5.2. Sample and Data Analysis

Twelve interviews were conducted for this study, which is indicated in Table 2 below and compromised of managers, engineers, Original Equipment Manufacturers (OEM) personnel and safety representatives from different mining firms and companies. The participants were directly involved in the development and execution, and others were involved in decision making and successful implementation of modern mining technologies.

The participants have all had a minimum of eight years of working experience in the mining industry which highlights their relevent experience of the data collected. The data collected showed that the unit of analysis consisted of four managers, four Original Equipment Manufacturers (OEM) personnel, two engineers and two safety representatives which all were involved in the attempt or have implemented technology in mining firms. Table 2 below illustrates the participants years of experience and highlights the commodities they have had experience in. The study focussed on platinum and diamond commodities, however, the participants roles showed that they had experience across several different commodities. All participants were classified as experts in their field and are part of mining groups and companies that operate within a number of different commodities, with only one of the twelve participants in a specific commodity, whereas the remaining eleven are in a mining groups or Original Equipment Manufacturer firms that has experience across different commodities.

The twelve interviews with the participants were conducted over MS Teams due to the global nature of their roles and convienence. The partipants and the firms they work for will be kept anonymous through out the study. The intention of the study was to include operators and foremen from platinum and diamond commodity operations, however, this was not possible due their availabilities. The data collected from the twelve participants have all had experience in platinum and or diamond industries and have had experience with technology adoption in these different commodities. When conducting interviews the interpretation of some questions were asked to be clarified, this was done to help the participant better understand the questions being asked.

Table 2 - List of participants interviewed

Participant	Pseudonym	Role	Diamond	Platinum	Other
P1	Participant 1	Manager	Yes	Yes	Yes
P2	Participant 2	OEM	Yes	Yes	Yes
P3	Participant 3	Safety Representative	Yes	No	Yes
P4	Participant 4	Manager	Yes	Yes	Yes
P5	Participant 5	OEM	Yes	Yes	Yes
P6	Participant 6	Engineer	Yes	Yes	Yes
P7	Participant 7	Manager	Yes	Yes	Yes
P8	Participant 8	Manager	Yes	Yes	Yes
P9	Participant 9	Engineer	Yes	No	Yes
P10	Participant 10	OEM	No	Yes	Yes
P11	Participant 11	Safety Representative	Yes	Yes	Yes
P12	Participant 12	OEM	Yes	Yes	Yes

5.2.1. Details of interview transcripts

The total number of participants interviewed were 12 with a total duration of under 12 hours. The shortest interview was 27 minutes and the longest interview was 74 minutes, answering all the questions specified in the interview guide (Appendix 2). The interviews that took longer was a result of the interviewee providing clarity on the question and the participant providing a detail description in the response to the questions.

Table 3 - Duration summary of interviews

Description	Quantity
Number of interviews	12
Total duration of interviews	690 minutes
Average duration	57 minutes
Shortest duration	27 minutes
Longest duration	74 minutes

5.3. Themes of the Research Study

Through the literature review, the researcher identified emerging themes and these themes developed by the researcher was used to narrow the data provided by participates which was completed prior to the coding process taking place; through a thematic analysis twenty three categories were formulated against the three key themes (Appendix 5). Furthermore, the researcher after analysing the data was able to align the data with the research questions to ensure that the research questions were either confirmed or disproved. The data that is presented in this research is representative of the participant answers, and is discussed further in the Chapter six.

The themes identified for this research include:

- Theme 1: Influencers for adpotion
    - Safety and Health
    - Production
    - Sustainability
    - Cost efficiency

- Theme 2: Success and Failure factors impacting adoption
    - Financial and investment costs
    - Change management
    - Communication
    - Culture
    - Stakeholder engagement and inclusion
    - Environmental and operational factors

- Job loss
- Lack of trust
- Leadership support
- Measurements
- Operational readiness
- Organisational structure
- Skills development and training
- Strategy
- Technology appropriateness and readiness

- Theme 3: Approach to enable adoption
  - Continous Improvement
  - Project Management and implementation
  - Process change
  - Value chain

5.4. Presentation of Findings

The presentation of the findings are aligned to the research questions provided in Chapter three. The study presents the findings by analysing the data and thereafter answers the research questions.

5.5. Findings for Research Question One

What are the success factors of technology adoption in modern mining?

Theme: Influencers for adpotion

- Safety and Health
- Production
- Sustainability
- Cost efficiency

The purpose of this question was to understand the motivation of mining firms to adopt technologies, which entails the value that can be attributed to the technology adoption in modern mining. Insights were achieved from the participants and themes that

emerged were safety improvement, increased production, cost efficienty and sustainability. These are the themes that were highlighted as the influencing factors for mining firms to adopt technology.

[Participant 4] summarises the views shared by most of the participants, which capture the influencing factors for adoption of technology in mining firms across their value chain. Many of the participants also highlight the key influencing factors being: Safety, Productions, Cost Efficiency and Sustainbility.

[Participant 4]: *“It’s safety. It's about the health of our employees. It's about running a more cost effective mine and just maybe one more thing on the cost side. It's not only the the cost associated to the capital cost, but, we do know there are significant benefits associated with the operating cost and being able to reduce the operating cost of the machines.”*

All participants were in agreement that technology adoption is about improving costs, productivity and the safety in mining operations.

5.5.1. Safety and health

All participants agreed that technology has the ability to address the safety and health challenges that mining operations face. The participants further elaborated on technology can provide several benefits to safety and health, namely, reducing safety incidents, removing employees from hazardous environments, and employees that feel safer and are healthy are more productive. Most participants firstly highlighted safety as the main driver for technology and that technology can enable mining firms to achieve zero harm. In most instances, participants alluded to the fact that technology, more specifically, automation can remove employees from dangerous working zones and into a control room some distance away from the mining operations but also such technologies can improve productivy levels. There is also the economic benefits not only from cost efficiencies, but as mineral resources becomes more difficult to access, technology allows mining firms to access these ore bodies where it was too dangerous for humans to work in.

[Participant 9]: *"So bringing in technology takes people away from the working face, improving safety. And also if you not really involving too many people in underground mining you tend to be able to mine in more hazardous conditions using automation and remote mining."*

The table below further provides evidence of safety being a influencing factor for the adopting of technology.

Table 4 - Summary of Safety and Health

Pseudonym	Role	Comments
Participant 8	Manager	*"From a safety perspective, it separates, isolates, removes people from hazards. So it makes things safe for you, for your workforce. It may remove people from the workplace altogether, right? And then the cost savings is typically technology improves efficiencies, right? We can actually get things done quicker. You can actually get things done with less resources. You can allow equipment and the fleet to do what does it and run for longer periods of time. So operational cost savings come in various guises, but it's dominantly safety, safety and costs."*
Participant 6	Engineer	*"We've improved safety and the reason for that is the times where you would introduce technology."*
Participant 10	OEM	*"You know the comfort of operators. You're relying on these guys to give you, your production and stuff, but you need to make sure that the end of the day you are giving them a machine that's comfortable and that is safe to operate and in many instances, that's*

Pseudonym	Role	Comments
		where we also are approaching automation, if you can remove a operator completely from let's say the pit or from underground, that's the next step to try and go on that journey with your customer to try and give them the best solution."

5.5.2. Production

Most participants agreed that improving production tonnes, output and productivity was a main underlying objective of implementing technology. The mechanisation of modern mining has improved mining operation's ability to achieve more output, and with the growth in technological advancements it allows for 24 hour daily operating hours, less human error and better quality equipment, which all related to improving production of the mining operation and its output.

According to [Participant 2]: *"There's been a lot of R&D gone in from the OEMs into equipment and, it's an ongoing thing with us and obviously, so this with other key OEMs that improve products to improve productivity. Obviously, designing new machines, making them better, making them more effective and faster and easier to operate. And really, that means obviously being more productive."*

The table below provides some insights on the impact of technology on the productivity of mining operations. Based on [Participant 9]'s comments, technology assists operators but also reduces the levels of human error in task execution which is vital to improving the quality of work and supporting a safer working environment.

Table 5 - Summary of Production

Pseudonym	Role	Comments
Participant 3	Safety representative	*"If we look at specific technologies that give us productivity gains, the autonomous drilling system is a great example because now suddenly, instead of having an operator in*

Pseudonym	Role	Comments
		there operating in harsh conditions, they are sitting in a control room and operating longer hours because they're fatigue is not as bad as it would be. The autonomous dozing systems that we looked at, we were potentially going to have 1 operator operating 2 dozers from a control room. So from a productivity perspective, we were gaining 3 to 4 hours extra for every shift, which would translate to tonnes moved. So there's definitely been improvements I would say, but automation gives us I think, in the range of twenty five percent to thirty percent improvement. Those are the numbers we had quoted when we put projects in place. And I mean those are quite significant."
Participant 11	Safety representative	*"So you might have a productivity improvement because the unit is more reliable. You know, so advancements in technology bring improved quality control, greater reliability, which has improved availability. So it's less downtime, it's least maintenance, more production."*
Participant 9	Engineer	*"An improvement in productivity because as much as operators are highly skilled. There is that proportion of human error that needs to be considered. So when you take that element away and you put the machine literally in its own control, you tend to find that productivity improves and also quality of the operations itself. Humans tend to move faster*

Pseudonym	Role	Comments
		and faster doesn't always result in high quality yields, so that is certainly something we starting to see in the sense of productivity and efficiency of the autonomous operations"

5.5.3. Sustainability

Most participants highlighted the importance technology plays on sustainability practices which are driven by macro-economic requirements but more emphasis was put on extending the life of mines and being able to access complex mineral bodies. Other participants highlighted specific areas such as reducing environmental footprint and the reduction of carbon emissions.

[Participant 9]: *"So I mean it goes back into the age of the company and, the age of the operations, a lot of the mines are reaching their end of life of mine and new technology innovation initiatives are required in order to actually act, where more unattainable resources are going deeper often has safety risks associated with it as well as cost issues or challenges."*

Table 6 - Summary of Sustainability

Pseudonym	Role	Comments
Participant 1	Manager	*"Instead of an open pit mine, we have an underground mine where there's significantly less disturbance of the land, a much smaller footprint, less tailings, less processing required because we're being much more precise."*
Participant 6	Engineer	*"If you look at things like, you know ESG, if you use electric vehicles, for example, from a health and safety perspective and an environmental perspective, there's a lot of benefits."*

Pseudonym	Role	Comments
Participant 3	Safety representative	*"The monitoring space is definitely improved. So we do have a better sense of what the impacts are on our environments because of nursing facilities like our tailings facilities are water management. All of these aspects we are probably getting better at it because we can simply just monitoring everything a lot better, as compared to maybe 5 years ago in that."*

5.5.4. Cost efficiency

Participants referred to cost efficiencies as an important influencer for the adoption of technology, given that commodity prices are driven by market factors, it is important for mining operations to optimise their costs to remain profitable.

[Participant 5]: *"If you look at it, at a cost curve of mining operations, if you look particularly at copper, it's sort of a table top on the copper market where a lot of the producers are producing almost exactly the same price and I think one of the things that comes with technology is the efficiency side of things."*

Table 7 - Summary of Cost efficiency

Pseudonym	Role	Comments
Participant 5	OEM	*"Increases in efficiency that I think it showed up by technology or improved by technology or a big game changer to an operation. I think the visibility and the ability to mine with better costs, you know sort of higher productivity is a big thing for the industry that we're in."*
Participant 8	Manager	*"The cost savings is typically technology improves efficiencies, right? We can actually*

Pseudonym	Role	Comments
		get things done quicker. You you can actually get things done with less resources."
Participant 10	OEM	*"In terms of technology, it is the way to go. We need to look at doing things, you know, simpler, better, faster and obviously cheaper in many instances. Look at efficiencies, but cheaper is also relative. So look at efficiencies."*

5.6. Findings for Research Question Two

What are the failure factors of technology adoption in modern mining?

Theme 2: Success and Failure factors impacting adoption:

- Financial and investment costs
- Change management
- Communication
- Culture
- Stakeholder engagement and inclusion
- Environmental and operational factors
- Job loss
- Lack of trust
- Leadership support
- Measurements
- Operational readiness
- Organisational structure
- Skills development and training
- Strategy
- Technology appropriateness and readiness

The objective of this question was to understand and identify the failure factors of technology adoption in modern mining. The data from interviews highlighted there are several critical factors and most of these factors also have a positive and negative effect.

For example, it was seen that good commication had a positive effect on technology, whereas poor communication required more engagement and alignment amongst different stakeholder. [Partcitipant 1], highlights this in their comments:

[Participant 1]: *"I spend more of my time on communication, change management of people getting buy in and getting an understanding, getting alignment, then I ever do running the actual technology portion of the projects."*

5.6.1. Financial and Investment costs

Most participants agreed that the financial costs play a crucial role in the adoption process, and its not the initial capital costs, but also the operational costs of introducing new technology.

According to [Participant 4]: *"It's not only the cost associated to almost like the capital cost, but we do know there are significant benefits associated with the operating cost and being able to reduce the operating cost of the machines."*

In most cases participants agreed that the introduction of technology can improve operating costs since newer equipment and machines are more reliable, and this needs to be proven by business cases and investment reviews. Contrary to this, some participants believed that newer technology comes at a higher overall cost but the benefits for safety or improving the environmental impact outweighed these costs which [Participant 8] details.

[Participant 8]: *"One of the issues that we're fighting is that, typically the main metrics for securing capital very much hinge around things like NPV or net present value, internal rate of return, all these types are very straightforward, what is capital, Opex, what is the split right and with new technology particularly safety technology or environmental tech. Technology, you are spending capital to alleviate a significant risk or to avoid a significant future cost."*

5.6.2. Change management

All participants agreed that effective change management is required for the successful adoption of technology, but while there have a number of new technologies adopted in

the mining industry, there is still a deficiency in change management practices in relation to the adoption of technology in the mining industry. [Participant 2] provide evidence of this.

[Participant 2]: *"You need to look at change management in a more serious way, because trust me, if you don't do this, all this new technology that we're trying to implement, if it's not adopted by the mines in the right way, it's not going to be a success."*

Participants confirmed that there are several interconnected systems, functions, process and people that are affected, and when these technologies are not successful, it has been related to the lack of proper change management taking place. Furthermore, some participants highlighted that they do not believe there is change management processes or frameworks that employees can make use of and the lack of change management practices often relate to further resistance from employees when the adoption of technology needs to take place.

According to [Participant 5]: *"These changes to the systems, processes and people are involved with these things. You're going to change your operating principle which needs to be understood throughout the entire operation. You need it. You need a plan to sort of focus on moving away from the current way in which people are working to the new ways of working and that is often difficult to do."*

5.6.3. Communication

All participants highlighted the importance of effective communication, since this both informs stakeholders and provides alignment on new technologies. The participants also shared that communication helps to address concerns that different stakeholders have and an understanding of the associated benefits to new technologies. According to Participant 9, in large mining firms project teams are tasked with the responsibility of rolling out new technology but work in isolation from other functions or the employees that would make use of the technology.

[Participant 9]: *"I feel that often what happens with our organisation is a project team or a project manager will be assigned to rolling out a new technology and a lot of work will*

be done very much in silos and there's not much communication or like conversations around this new technology."

Participant 5 provided an example where effective communication takes place when adopting technology, it met with less resistance, since employees are aware and start to understand the forthcoming changes.

[Participant 5]: *"I think a lot of communication and engagement is really important. I'll refer back to a customer of ours. We've implemented a lot of this kinds of technology into the mining operation and you know they sat down with every single person on that operation that would be affected by it. And that's from the general manager sitting with the staff. It went through every little bit of how those people's job would change and why they were doing it and they needed to step up production considerably in order to stay alive and what would be involved."*

5.6.4. Culture

All participants share the view that culture can enable the adoption of technology but also make it fail. These perceptions stems from the impact of people in the adoption process, that is, people are a key component throughout the adoption process and if they are not supportive of the new technology it will end up failing. According to Participant 1 and 3, if the culture does not exist where employees are in support of technology, if it is difficult for it to be successful.

[Participant 1]: *"People in the areas that you're working in, don't have the culture or don't have the reception towards what you want to do, it's not going to happen."*

[Participant 3]: *"Yes. Unfortunately, or fortunately, it does come down to people. People can really make or break something."*

Most participant's perceptions were that regional factors can affect the ability to adopt technology, that is, where technology has been implemented more, there culture is more receptive of new technologies. To the contrary, [Participant 5] highlighted that even in countries where there is high levels of technology, the culture of the people may still show resistance to new technologies.

[Participant 5]: *"Going back to certain places and cultures, I think you know for argument's sake, the Australians are pretty good at adopting technology. So are the Europeans and the Canadians actually not so much, South Africans, not so much. It's a culture sort of thing. And yeah, in South America, we tend to see a sort of middle of the road and sort of mix on the adoption side."*

5.6.5. Stakeholder engagement and inclusion

All participants highlighted that the lack of stakeholder engagements and inclusion can result as a barrier to technology adoption, and this extends beyond that of internal stakeholders but includes external stakeholder. The importance of executives, communities, employees, unions and government institutes all have an influence on the success of introducing new technologies into mining operations, and the lack of alignment can be detrimental to the adoption process. According to [Participant 10], stakeholder engagements can also influence the time required to implement new technological solutions.

[Participant 10]: *" You need to have regular stakeholder engagements and the correct forums for it, and that's how you can then ensure that the project is successful in the quickest amount of time."*

Most participants agreed that there is a lack of engagement with users of the technology, and there is no means for them to provide feedback in some instances before the technology is fully implemented. This disconnect was noted as a significant contributor to the failures in the adoption process of technology.

[Participant 9]: *"So you can have the best systems out there, but if your operators aren't using it, it's basically just a white elephant. So involving them very early in the process is critical, some that means also involving unions and supplier personnel stakeholders because what we don't want to happen, is for technology to be brought on the site not having an understanding of the acceptance and we just end up getting quite a bit of resistance to using this technology. So operators' involvement, getting their feedback from the technology is also extremely useful from an OEM perspective, where OEMs have gotten quite good feedback from operators and have further developed their products based on the use at the frontline level."*

5.6.6. Environmental and operational factors

Most participants agreed that operational factors influenced the adoption of technology but also to what degree technology can be adopted. Factors such as regional culture, skills, mining methods, workflows, procedures and the cost of labour are all different by country and by mining operation which all impact a mining firm's ability to adopt technology successfully. [Participant 1], emphasises the importance of different regions and that planning for technology implementation needs to consider a mining operation's unique requirements.

[Participant 1]: *"Sometimes we've taken those solutions that fit in one jurisdiction in the world and have tried to rapidly replicate them elsewhere where either the culture isn't ready for that implementation or the level of skill set isn't there, or there's community related issues… So some jurisdictions in the world, it is incredibly expensive to pay an operator to be in one of those haul trucks day in, day out, it's a major cost for the asset and contributes quite a bit to the bottom line of cost per ton of mining… Every skill set associated with those jurisdictions is at a different skill point, and it's understanding what fits for one might not be a good fit for others, and that one culture might not accept a solution from somewhere else. It might have something of its own need in terms of tailoring to ensure that there's a positive outcome."*

5.6.7. Job loss

Participants shared there is a perception from employees that technology will result in job losses, therefore, end users resist the adoption of technology in fear that their jobs may become redundant. A key influencer in the mining industry is cost efficiencies by using less to produce more output, which is linked to employees, that is, if technology can create better efficiencies there is a case to reduce the number of employees.

[Participant 9]: *"One of the major risks is I think, the fear from our workforce. South Africa is an extremely labour intensive operation or country and bringing in more technology is almost seen as a risk of job losses. So you tend to be quite anti-new technology coming in because as we make that journey towards automation which is purely for the sake of improving safety and also quality of output, we are challenged with the fact that mining does provide one of the most jobs, job creation for a lot of the South African population."*

Some participants agreed that the introduction of technology may affect the number of jobs but also that new technologies creates more skills and potential for career growth.

[Participant 6]: *“The risk is I see that it has created a mistrust between leadership and employees because when technology comes, the employees see as they're going to cut our jobs, which is not necessarily true, you create secondary jobs, you upgrade, you upskill people.”*

5.6.8. Lack of trust

Participants shared that there is a lack of trust in the technology to perform to the expected levels, which is turn leads to resistance since there a perception and low level of confidence that potential benefits can be achieve through the deployment of new technologies. This lack of trust stems from several different stakeholders including executives, managers and operators which leads to barriers to innovate and introduce new technologies. The focus on production is the mining industry remains a key business driver and when there is a lack of trust in the technology, employees will resist the adoption or if the technology does not work, revert to previous methods of working. Mining firms have a conservative approach to the adoption of technology since this may impact their ability to achieve production targets.

[Participant 1]: *“The technology systems aren't working well and more times than not, you default back to what you were doing before and you just try and do it better.”*

According to [Participant 4], the low risk appetite towards production can be seen in how specifications of machines are developed, that is, there is different levels of technology built into the machines to ensure production can be maintained, where machines can work in manual mode, should the autonomous modes not work appropriately.

[Participant 4]: *“It’s almost like we always try and maintain the fallback position in case the technology won't work and having a manual mode to fall back onto. Now quite often we start off the system in that manual mode, and then we never get it out of the manual mode, because whenever we try the next level, it fails. People very quickly say switch it off, to operate manually.”*

5.6.9. Leadership support

Some participants highlighted the need for leadership support in two ways. Firstly, communicating the benefits and the transition the mining firm is taking in regards to technology. Secondly, it was raised by some participants that leadership support is required to learn and develop in the first instance where the technology was not successful immediately and provide the necessary support through resources and adequate time to ensure the technology has an opportunity to perform to its intended purpose. In most cases, where technology is not working, leaders and managers allow employees to revert to previous work methods to ensure production targets are met.

[Participant 6]: "*Having a leadership team that truly believes in technology and technology adoption is very important when you are trialling or when you're at the beginning phases of technology, sometimes you don't get an advance, you don't get the amount of productivity that you would want and it's up to the leadership team to be able to absorb that painful process at the beginning of the implementation of the technology. And if the management team does not have that tolerance to say, look, this is going be painful at the beginning, but in the future it will benefit us. It's hard to now embed or sustain the technology because at the first sight, when things go wrong, we should switch it off. Let's revert back to non-technology ways."*

5.6.10. Measurements

Most participants agreed that there is traditional KPIs that are in place and can measure the effects of new technology. For example, if the production rates increase over a period of time it can be established that the new technology that has been deployed plays a factor in this change.

[Participant 1]: *"I'd say yes and no. KPI's would be the same as essentially what we had in place before any sort of technology adoption… More micro KPIs that might look at what's the start of shift versus the end of shift or have we moved to a 24 hour cycle because there is no shift change."*

However, this is limiting since it does not take into consideration the efficiency gains that can take place prior to technology being implemented. Some participants agreed there

are specific KPIs that can measure the introduction of technology, contrary to this some participants did not believe there is effective measures to understand the full impact of technology. Technology brings about a more connected mining operation since machines have onboard computers to capture data, this in turn can be used to understand the measures associated to the technology but participants alluded to the fact that mining operations do not always make use of this data and in instances where they do, quality of the data is an issue.

[Participant 3]: *"It's a lack of quality data, so we have tons of data, you know from a safety perspective, I can tell you, [Safety Reporting System] is definitely a system that has data, but we are still relying on people to put their data together… What we've realized is a lot of the data quality is probably a bit suspicious. So trends and all of that kind of analysis we do is fairly good, but we still rely on people to do that. So there's that element which is a quality of data piece."*

5.6.11. Operational readiness

Participants emphasised that mining operations failed to provide the right operational environment that is conducive for the adoption of new technology, such as resources, infrastructure, tools and changes in procedures and processes.

[Participant 5]: *"Just about every bit of technology today runs around on some sort of Wi-Fi and the Internet and the mining environment underground not so much the surface it can be a big stumbling block to some of the technologies that are available you know they're the kind of network that you have to have on an operation in order for this type of technology to work. It needs to have a fantastic uptime so you know if you're looking at 99% plus uptime that takes a lot of people to make sure and go and check that that all of those access points and everything in the operation are actually operational and working."*

Participants agreed that in most instances, mining operations have not done the correct upfront work to make sure they are ready to accept and operate the technology effectively and some of these risks only appear through the implementation phases. Some participants allude to the fact that not all employees understand the technology well enough and do not prepare the mining operation to operationalise the technology

appropriately. According to Participant 2, mining operations shift the risk to OEMs to ensure that technology is working but in doing so there is limit support given to OEMs to ensure their success.

[Participant 2]: "*I want this workshop. I'd like this. I want that. I want that and sometimes they gave it to you. Sometimes they wouldn't give it to you. I mean, there are people that would only give us the workshop once every five weeks to take a machine. This is the sort of things. the culture that was there, then I'd say, how can you expect a machine to run with a high mechanical availability if you only give us workshop facilities once every five weeks?"*

5.6.12. Organisational structure

Poor engagements across the different functions have led to poor levels of technology adoption in the mining industry. The mining industry is categorised to have a hierarchical structure that is not well integrated throughout their organisation. Participants have agreed that organisational structure and the lack of integration causes barriers in the adoption process. Based on [Participant 5]'s perspective, it's believed there is a disconnect between different functions. For example, this could be head offices' leading the decision-making process for what types of technologies to be implemented and expecting the mining operations where these technologies are used to be accepted.

[Participant 5]: *"The head office and operations level. There's often a disconnect in the mining industry, in what the head office wants as part of their strategy and what actually gets implemented on the operation. And I do think that a lot of the change management that has to go on with that is sorely lacking in the mining industry… The operations team will get something pushed upon them and they're not going take it on board because they don't like the change."*

Furthermore, different departments are compartmentalised since they are monitored on their specific KPIs which creates the separation between different departments. According to [Participant 6], there is misalignment between corporate offices and the mining operations in terms of the benefit the technological solution brings about.

[Participant 6]: *"If you use electric vehicles, for example, from a health and safety perspective and an environmental perspective, there's a lot of benefits, but you get to*

the ground, the implementation is completely misaligned because the average employee or the average supervisor or mine overseer or mining manager is not necessarily looking at ESG. He's looking at the daily target. What does it take for me to get the daily target and if technology is almost a hindrance, they just let go of it."

5.6.13. Skills development and training

All participants agreed there is a need for skills development and training as new technologies are introduced by mining firms. The lack of skilled employees and effective upskilling of employees were seen to be a significant reason for the failure of implementing technology in mining. New technologies require a different level of skillset with more technical skills, such as computer literacy and the ability to use and understand the associated hardware and software. [Participant 1] provided an example of how skills and job profile are changing with the introduction of technology.

[Participant 1]: *"The example I often give is that it's easy to have hand somebody a laptop and they'll be able to turn it on, but their ability to actually use that laptop and all the functions that it has to its highest ability, that's where we start getting into the people and change management. How do you teach them to use the systems?"*

Furthermore, the introduction of new technologies also means that there's been a recent investment in development and training to upskill resources to make use of technology which make these resources in high demand across the market.

[Participant 12]: *"I think an important portion of technology adoption is having skills that can be able to work with it and maintain it. And if you don't put in the effort to have those guys trained up, you are going to struggle. But we are sitting in a situation where the world is almost open to people who has gotten experience in technology and they get almost, the moment that they've gone through a training period and they're comfortable with it, they are being pulled by other people or even it can either be abroad."*

Different from other participants, Participant 1 and 4 both confirmed that that resources used to assist with the implementation of technology do not always have the requisite skills since they would either understand information management systems or mining but rarely both. This creates a gap between the knowledge needed to effectively implement new technologies into the mining operation.

[Participant 1]: *“A lot of these technology projects they've looked at as deferring to IM type people or IT people and those are people that are great at the infrastructure and design and those things, they're not great at, is the actual mining side of the job and understanding what are the tasks and processes that are going on in an active mine because their IT people, they're not mining people that haven’t spent time, boots on the ground as mining engineers or geologists or operators.”*

5.6.14. Strategy

Participants agreed there is a need for a technology strategy since this informs this business the types of technology that will be adopted during a set period, but this also provides support from a resource and financial perspective. The strategy helps the mining firms plan, execute and resource the technology that is rolled out. From the participants’ perspective, the lack of strategic intent for technology adoption leads to failures, such as, insufficient resources, unsupportive organisational structure, inadequate budget allocation to finance new technology, and a lack of alignment with different areas of the business to work towards a common goal.

[Participant 3]: *“There is a huge focus and a very pointed focus on technology and technology adoption, and you'll see that within our structures as well each business, there is an innovation or a technology manager specifically looking at how we incorporate technology in our business.”*

Most participants agreed there is a strategy that informs the adoption of technology but some participants pointed out that the availability of resources, budgets and lack of support is an indicator that the strategy is not always supported or cascaded with the requisite alignment across stakeholders.

[Participant 8]: *“I then go to a different business unit, which is our [PLATINUM] business unit whose default position is saying we're not really interested. We are squeezed with capital. This is going to be really tough. I think we should leave it for a while until the capital position improves, right? I'm having two business units which are displaying a different reaction level of support to the same technology to essentially the same project.”*

5.6.15. Technology appropriateness and readiness

All participants agreed that the technology needs to address a problem that the mining firm is facing but also be appropriate in its application. Most participants agreed that technology needs to be commercially ready and mature for it to be considered in their operations since the mining firms are risk adverse, especially towards changes that impact their production targets.

[Participant 11]: *"Yeah, absolutely the maturity of the tech because then you know, there's a track record and it's being used elsewhere. Often there's a reference you know, especially when you benchmark, you'd like to see where it's being used, where it's being deployed successfully."*

Contradictory to what [Participant 11] mentioned, there are instances where technology is mandated, such as from government, and the technology is not fully ready or commercialised by OEMs. In these instances, mining operations fast track the development with OEMs to make these solutions available.

[Participant 11]: *"All mining equipment in South Africa will have CAS level 9. So it will slow down and stop the equipment when another truck, another equipment is detected. So we've had to fast track our test work. I think in that space [Company] has been pioneering a bit in identifying key supplies both in the market, you know both locally and globally that have the technology to do that. But there were issues where it wasn't fully developed or, you know, all the scenarios that you would cater for in terms of the collision scenarios."*

Some participants believed that mining firms introduced technology to be seen as technologically advanced by the market and there was no purpose to introducing the technology since it did not resolve a problem the mining operation is facing.

[Participant 1]: *"I think we sometimes chase shiny objects and we do things just for the sake of doing it, not to not to install those systems for output goals, but rather just installing to see those systems there. So we can say that we have these systems in place."*

5.7. Findings for Research Question Three

What is an approach that supports the effective utilisation of technology in modern mining?

Theme 3: Approach to enable adoption

- Continuous Improvement
- Project Management and implementation
- Process change
- Value chain

The intentions associated with this research question were to understand the most appropriate approaches to adopt technologies in modern mining. This also considers the system thinking approach, where changes are made, what would be the most appropriate way to investigate these effects and ensure that the overall system's performance is maximised and not just the sub-element of this system. [Participant 1] highlights the importance of looking at technology adoption more holistically since technologies are becoming more complex but while the mining operations are conscious of this, it seems to still be a gap in the adoption process.

[Participant 1]: *"Instead of looking at these as complex systems that are going into an already established ecosystem, it's looked very much at plug and play, all we've got to do is mine, just bring it in. This is what we've been doing for many, many years within the mining industry, but the complexity of the systems that we're looking to install, not only in terms of running themselves but all the different teams and departments that need to be involved to help install, maintain and execute on these systems is infinitely higher than anything that we've seen in the mining industry before."*

5.7.1. Continuous Improvement

Some participants believed technology takes place at a staggered and incremental level, due to the risk adverse nature and sensitivities associated to significant changes in a mining operation. Technologies is not implemented all at once since it can mitigate the risk of failure but also it allows the mining firm to learn and continuously improve in the

use of new technologies. According to [Participant 7], technology also has been evolving over time with incremental improvements that further enhance existing technologies.

[Participant 7]: *"I think it's incremental. I've been with [Company] for four years now, so if I use that as the time period. In outcomes, in terms of productivity or sustainability of operations in terms of that capable and stable side of things, it's incremental. As the technology advances and those advances over time, have been incremental. I say that the opportunity for autonomous or semi semi-autonomous drilling has been around for a long time, but it's ability or its implementation has been slow... We learn as we go and incrementally improve."*

The table below further provide evidence continuous improvement being an appropriate factor in the adoption of technology.

Table 8 - Summary of Continuous Improvement

Pseudonym	Role	Comments
Participant 1	Manager	*"If we never have that kind of 360 review to look at, the good, the bad, the ugly, which we don't at the moment, we can't have honest conversations about where we take this, how we potentially improve or how we prevent the same issue from happening at its next deployment at the mine, down the road within the portfolio."*
Participant 3	Safety Representative	*"Don't put this thing on 100 trucks. Put on 10 trucks for me for now. See what what you're change management looks like. See what the impacts are in your business and your unintended consequences."*
Participant 5	OEM	*"If you give everybody everything at once, there's just a big wave that hits them and it's a problem. So I think you know sort of the stepping up or ramping up."*

5.7.2. Project Management and implementation

All participants agreed that the adoption of technology in mining requires proper planning to ensure that the implementation of the technology initiatives are successful. The approach of using project management is to mitigate any risks throughout the implementation process since the introduction of technology requires change and this change may introduce risks associated to critical business drivers including production and safety.

According to [Participant 7], planning becomes essential in the implementation of technology because it relies on resources, employees and infrastructure to be in place for it to work successfully.

[Participant 7]: *"Then when technology comes along that we could implement, but we don't have the structure or the systems for it, then we're less likely to pick it up because its seen as an additional complexity or additional cost to the implementation of certain technology. And so it's a hindrance because our current infrastructure or system is already completed and utilized with its existing requirements that it can't expand to take on new technology or an updated technology*."

Some participants highlighted challenges associated to the mismatch of skills in project teams and that project roll outs have limited engagements with different business areas that will be affected. It was also seen that project roll outs were seen as transactional in nature and the implications of the changes did not have the requisite level of integration into the business. The table below illustrates evidence of this from participants.

Table 9 - Summary of Project management and Implementation

Pseudonym	Role	Comments
Partcipant 8	Manager	*"Financial support and schedule support. It's quite key if you're trying to implement new technology or if you want to test new technology. A critical thing is to take it off the critical path for your project or for your production. So that you can test it properly and*

Pseudonym	Role	Comments
		transition the into the system properly, because quite often you're making change to a broad system."
Participant 9	Engineer	*"I feel that often what happens with our organization is a project team or a project manager will be assigned to rolling out a new technology and a lot of work will be done very much in silos and there's not much communication or like conversation around this new technology."*
Particpant 10	OEM	*'"You need a proper plan. You need proper measurements cause it doesn't help you, you sell this whole thing to the customer without actually selling them the benefits. So for me a key thing is KPIs to say if we start this project by the end, this is what should be met. These are the targets that we have and then working together with your customer to achieve them."*

5.7.3. Process change

Most participants highlighted that there is investigations into existing processes and the subsequent adjustment to these processes to accommodate the new technologies introduced to the mining operation. According to [Participant 6], mining firms have detailed change process documentation that helps the facilitation of these changes and communication.

[Participant 6]: *"So the process the organisation has adopted is the ADKAR model. It would start with a high level strategy and then trickle down to operations and operations would then start well before it even gets to the end user."*

Some participants alluded to the fact that the process changes were limited and lacked the level of integration, in some instances the change in process was not embedded,

allowing employees to revert to previous methods of work execution processes. Furthermore, some participants highlighted there is no standard framework, therefore there can be gaps in the implementation phase which have downstream effects to the process changes that are required. The table below provides evidence of this.

Table 10 - Summary of Process Change

Pseudonym	Role	Comments
Participant 1	Manager	*"We need to have an additional tranche of information there or checklist that would be about, how can it be operationalised? How do we make this something that's actually going to work in an operation? How do we install it? How do we maintain it? How does this interact with the various systems that are already in place at that location, and how do we ensure that it's going to be a success because it's easy to get something installed the first time, having that maintained and stand up overtime and being readily available, that's where the challenges really come into it."*
Participant 4	Manager	*"Short answer is probably no, there isn't. A recognised approach that I can basically go and pull out of a library or say this is the approach for the following. So no, I think we've got huge gaps around that, typically trying to address change management per project per technology that we are introducing and not necessarily making use of a standard approach that's been defined generically for all technologies that you actually have to know implement."*

Pseudonym	Role	Comments
Participant 6	Engineer	*"I think we always find that theres a lack of integration in the midst of it… There's a lot of network infrastructure backbone that needs to be built way ahead of the communication system coming live. And we found that some of this very key parts, do not come through right.*

5.7.4. Value chain

A few participants acknowledged there are systems and specific departments that are available to understand the impact of technology changes to the mining value change.

[Participant 9]: *"Absolutely. We get quite involved in having business improvement look at the pre and post effects of technology. So looking at KPIs we wanted to where we identify the issues and the as is rate."*

According to [Participant 5], the mining industry is challenged at assessing the effects of technology deployment in the mining value chain and associates this barrier to organisational structures that limits collaboration across different functions.

[Participant 5]: *"In general, I'm going to say we're not good at that. There are some companies that are very, very good at it and looking at the value chain and seeing what their productivity gains are and what effect that would have either upstream or downstream. It is not often really brought out. I think we still incredibly silo based as an industry."*

The table below provide further evidence of this from participants.

Table 11 - Summary of Value Stream

Pseudonym	Role	Comments
Participant 3	Safety Representative	*I don't think we do that well. I just, even within, you know, our team, we've kind of gone, OK? But you know we've put CAS in place, but can*

Pseudonym	Role	Comments
		we really check the effectiveness of the system and is there a means to monitor or quantify the effectiveness of what we've put in place and we don't have an answer."
Participant 11	Safety Representative	*"I can't say it's always done and consistently done, but definitely that is part of the the evaluation and that talks to integration that talks to up and downstream, sideways in terms of the support and the things that are required and need to be in place to make it work."*
Participant 12	OEM	*Not often enough. I do think that the conversation comes up and you know it is said, you know what? There's the downstream benefits that is also coming along but I don't think very often as being viewed… As for our company, a special group of people are there that basically can run certain analysis and operational programs almost to simulate operations."*

5.8. Conclusion

This chapter looked to investigate the understanding from mining employees as the implementers of technology with regards to safety, production, cost efficiency and sustainability, identify the success and failure factors associated to the adoption of technology in modern mining and reveal an appropriate approach to the adoption and implementation of technology; as well as to understand an approach that may allow for technology adoption in mining.

The participants agreed that safety, production, cost efficiency and sustainability were the main influencing factors to the adoption of technology, additionally success and

failure factors were identified. Understanding obtained through this study suggests that several factors have a positive effect if executed correctly or may yield a negative outcomes when they are absent or inadequately addressed. Additionally, the research was able to confirm there is a limitation to mining firm's ability to systematically understand the effects of technology across the mining value.

CHAPTER 6: DISCUSSION OF FINDINGS

6.1. Introduction

This research discusses the findings from Chapter five in reference to the research questions in Chapter three and compares it to the key findings in the literature in Chapter two. The research aims to gain insights and understand the success and failure factors of technology adoption in modern mining. The sequence for Chapter five will be applied within the context of this Chapter six, as the objective of this chapter is to confirm or reject the findings against that of the findings in the literature review in Chapter two. This chapter will also provide similarities and the differences in the findings to that of the literature which will be considered by each research question.

6.2. Discussion of results for Research Question One

What are the success factors of technology adoption in modern mining?

The research question aims to understand the factors associated to production enhancement, safety improvement, sustainability and cost efficiencies, and how this influences the adoption of technology within the mining context.

6.2.1. Safety and Health

The findings shows that mechanisation and technology improves safety by either reducing the number of employees working in hazardous and dangerous areas, removing employees from danger and providing employees with technology and machinery that protects them in such dangerous environments. Furthermore, technology helps improve the health of employees by reducing exposure to dust and carbon emissions. The adoption of technology within mining firms support the provision for safer and healthier working conditions, reduce safety incidents and help mining firms in their pursuit to achieve zero harm.

According to Gruenhagen & Parker (2020), technology has the ability to address safety concerns in dangerous and hazardous environments where mining employees are exposed to daily. Furthermore, technology has the ability to remove and reduce the number of employees exposed to dangerous conditions but also has the capacity to

work under harsher conditions where employees would not be able to (Ali & Rehman, 2020). Safety and health is a priority for mining firms but it also has a significant cost should these factors not be managed well, that is, safety not only has a financial cost associated to medical expenses to those that are injured but also losses in production and therefore revenue losses (Lenné et al., 2012).

Technology can assist mining firms to reduce safety incidents and improve overall work place conditions for employees and therefore it is necessary for mining industry to adopt technology, which is supported by both the literature and the data collected from participants.

6.2.2. Production

The mining industry rely on production as it is the basis of their revenue generation, improved production output can be realised through the introduction of technology. The advancement of technology has impacted the reliability, size and effectiveness of equipment which help improve production levels. Technologies has the capacity to improve the efficiency and effectiveness of mining operations, as such, it also improves the mining employee's ability to work faster, longer and provide better quality work.

Fältholm & Norberg (2017) highlights that mining firms main business drivers have traditionally been on production and cost, and mining firms will resist the adoption of technology unless there is a direct impact to production and costs. The mining industry is facing more complex challenges, including hard to access mineral resources, lower ore grades and government regulations, and this has created a burning platform for mining firms to innovate and implement new technologies to tackle these issues (Calzada Olvera, 2022).

Both literature and participants have agreed that the improvement of production is an influencing factor to adopt technology in the mining industry.

6.2.3. Sustainability

Environment factors have created further hurdles needed to be addressed by the mining industry. Factors such as life of mine, carbon emissions and environmental impact of mining practices must be addressed in order to have social licenses to operate and

maintain sustainable mining production. Sustainability practices was not consistently acknowledged as an influencing factor of technology adoption in mining firms, rather it was related to production, safety or improving life of mines. Sustainability of mining goes beyond these factors; therefore this factor is contradicted between literature and the data collected from participants.

The mining industry faces several challenges associated to sustainability, namely, finite resources and its depletion, environmental and social impact (Aznar-Sánchez et al., 2019). Government also create regulations that necessitate the change in the mining industry through policies on safety, pollution and energy consumption and require the adoption of technology to address these stricter requirements to have a positive impact to society (Fu et al., 2018).

The differences seen between the literature and what was observed from participants was not consistent and, in some instances contradictory. Literature suggests that sustainability practices are associated to environment and social impact factors, where participant did not always associate both, but rather presented the case for technology in relation to production, safety and longevity of mining operations.

6.2.4. Cost efficiency

Technology has the capacity to lower operating cost as fewer people are required in operations due to utilisation of machines and more comfortable machines means that employees are likely to be more productive and work for longer hours. Technologies such as automation allows for multiple machines to be used by a single employee which can reduce cost. Additionally, autonomous machines reduce the number of breaks and shift changes, and mining operations can operate 24 hours a day. Barriers to the adoption of technology are high capital costs, the need for skills and development and infrastructure requirements that are incurred in the early stages of implementation.

Mining firms are sensitive to costs due the capital intensity of the industry and commodity prices since this is determined by the market with little to no influence of prices, hence the high focus on input costs (Dayo-Olupona et al., 2020). According to Ediriweera & Wiewiora (2021), the implementation of technology has the ability to reduce costs and also improve productivity. Job & McAree (2017) points out that the lack of clear

procedures and adequate training can lead to higher operation costs and lower reliability due to poor maintenance practices.

The literature and participants agree that cost efficiencies are an influencing factor for the adoption of technology. Additionally, the lack of training and upskill mining employees will lead to higher maintenance and operating costs.

6.3. Discussion of results for Research Question Two

What are the failure factors of technology adoption in modern mining?

The purpose of this research question was to investigate and understand the contributing factors that lead to the failure of technology adoption in the mining industry. These factors considered are those that prevent technology from being adopted as well as the factors that inhibit mining firms from being effective in the implementation.

6.3.1. Financial and Investment costs

The mining industry is a capital intensive industry driven by cost efficiency due to fluctuating commodity prices that are determined by the market. The adoption of technology requires upfront investment that include capital, infrastructure and skills development and training. The investment in technology needs to have a business case that evaluates its ability to provide returns, either financial costs including reducing operating costs or improving production.

Ediriweera & Wiewiora (2021) points out that the cyclical nature of commodity prices creates resistance against the adoption of technology, and barriers where mining firms would prioritise productivity over longer term investments in technology (Bartos, 2007). Mining firms have a cost driven approach, since is it is a major driver in the industry, subsequently this creates resistance to any change and there is a significant importance put on the return on investment (Gruenhagen & Parker, 2020).

Consensus between participants and literature show the importance on costs and the sensitivity to investments in the mining industry. Any financial and investment cost associated to technology is scrutinised through investment reviews and internal

governance forums to ensure there is a strong case for the adoption technology and it will lead to productivity gains and the reduction of operating costs.

6.3.2. Change management

The adoption of technology requires effective change management, since this involves people to work differently, procedures and policies to change, and communication, without this in place technology is likely to fail. The mining is industry is risk adverse and is resistant change due to already established workflows. Poor change management can increase the risks associated to safety and production losses.

The mining industry has barriers to innovate since they are risk adverse and resistant to change (Bartos, 2007). Change management requires change in direction, structure and capabilities in order to adopt new technologies (Moran & Brightman, 2001), and effective change management to adopt new technologies requires the change to strategy, processes and people.

Participants and the literature agreed that the adoption of technology require changes, to employees' capabilities, structure and process to be successful. The lack of change management through the introduction of technologies introduce risk to safety and production in the mining operations.

6.3.3. Communication

Communication amongst the different stakeholders in the mining firm is of importance since it facilitates the understanding of why the change is necessary and the associated benefits of the technology. The disconnect in communications amongst those responsible for the implementation and use of the technology are often different employees and without communication there will be a lack of buy in and support to use the technology.

Communication helps disseminate information and knowledge transfer in an organisation which assists to create support and alignment for the provision of technology adoption (Ghebrihiwet, 2019). Alignment across departments and functions plays an important role to foster collaboration and transparent communication in respect to the objectives and benefits of technology (Ediriweera & Wiewiora, 2021).

To ensure alignment and buy in from employees, transparent and collaborative communications on new technologies will reduce employee resistance, this is both supported by the literature and participants.

6.3.4. Culture

Leaders play a critical role in the shaping the organisational structure and this influences the organisation behavioural traits of its employees, with the importance put on production, cost efficiencies and safety improvements, employees will resistance changes that would impact these factors. The silos and individualistic KPIs in the mining operations also act as a barrier to technology since employees are resistant to any changes that will affect their own KPIs, and having a culture driven by KPIs reduce employee's willingness to take on risk that may lead to failure.

Leaders who build diverse and an inclusive culture allows for collaboration across different functions and gives opportunities for employees to learn and develop from each other (Kahn, 2018). According to Luchs (2015), leaders and organisations that promote a growth mindset are able to learn, develop and test ideas as opposed to fearing failure but rather see it as part of the change process.

Literature and the data from participant confirm that culture can either be supportive of technology adoption or inhibit it. To remove these barriers, creating a culture of growth, development and learning allows employees the freedom to test ideas as opposed being fearful of being reprimanded due to not achieving their KPIs.

6.3.5. Stakeholder engagement and inclusion

Stakeholder engagement is a critical step in the introduction of technology as it facilitates alignment, collaboration and feedback from internal and external stakeholders. Employees who make use of the technology are not always aware of the changes or involved in the decisions making process which can create failures in the adoption process, specifically, end-user feedback could be the difference between technology being successful in the first instances since this can determine if the technological solution is useable.

Awuah et al. (2021) research shows that the introduction of initiatives in mining operations require input from different stakeholders since factors like decisions making becomes more robust when different stakeholders' opinions are considered, this improves the mining firm's ability to understand concerns and improve the approach to introducing new technologies.

Alignment between participants and literature shows the importance of more inclusive stakeholder engagements, collaboration and feedback, which improves the overall decision making process and the implementation of new technologies.

6.3.6. Environmental and operational factors

Differences between operations affect the degree of which technology can be adopted, this is further seen within different regions and countries, which include culture, procedures and mining methods. The implementation of a 'one size fits all' approach can be met with resistance since operations may differ from each other.

Tornatzky et al. (1990) refers to environmental factors which includes the market the mining firm operates in but also geographical locations, operational uncertainty and cyclical nature of mining. Locations of operations impact the mining method, procedures, governmental regulations and the availability of skills.

The literature and participants agree that environmental and operational factors influences the level of technology adopted since this may affect the operational costs and requirements needed to maintain the mining firms license to operate in different regions.

6.3.7. Job loss

Technology has the capacity to improve productivity and cost efficiency that may impact the employment of mining staff. Machines improve productivity levels and automation reduces the number of employees required to perform these tasks. Technology also demands new skills required to fulfil the requirements of new job profiles but the introduction of technology may lead to the creation of secondary job opportunities.

Kansake et al. (2019) study highlights that technology adoption has been linked the reduction of employees and job losses which increase the resistance towards technologies by employees. Contrary to this, technology is required to transform from historical and traditional mining methods to extract deep-level and complex ore bodies, failure to do this in South Africa may lead to 200,000 job losses by 2023 (Minerals Council South Africa, 2016).

The literature and participants agree that in the first instance, the introduction of technology may lead to job losses but also that employees are upskilled and new roles and employment opportunities are created. Furthermore, technology allows mining firms to have longer life of mines and allows mining operations to sustain employment of resources for longer periods of time.

6.3.8. Lack of trust

Stakeholder resistance within the mining industry towards new technologies stems from the lack of trust regarding their reliability and effectiveness. This reluctance creates barriers and hinders the dissemination of technology in the workplace.

During the introduction of new technologies it requires a process of socialisation, which trust, confidence and benefits in the technology can be established to ensure the effective adoption for its intended purpose (Ghazizadeh et al., 2012). Stakeholder engagement, inclusive of individuals and groups that are impacted by changes, requires interaction as it is fundamental aspect of the strategy to develop trust and support for the successful implementation of technology (Ansu-Mensah et al., 2021).

Lack of trust can lead to resistance from employees in the adoption of technology and can act as a barrier to other stakeholders. Stakeholder engagement, feedback, training and transparent communication on the benefits for the change is critical to gather trust and buy in from the different stakeholders, which is supported by literature and the participants.

6.3.9. Leadership support

Support from executives and leaders in the mining firm is fundamental in the adoption process, as it allows for support and creating awareness across the firm. It’s necessary

for leaders to create an inclusive environment, that provide support through resources, influence and socialisation.

Daft (2011) points out that leadership provides an influential relationship amongst leaders and team members, working collaboratively to achieve change in the drive to accomplish shared goals. Leaders must provide the organisation with directives, which may follow a top-down approach (Hinson & Osborne, 2014), and this is impactful in hierarchical structured firms like in the mining industry through formal power (Robbins & Judge, 2018), specifically in the context of strategic guidance.

Literature and participants agree that leadership is important in technology adoption since it creates strategic guidance, awareness, resource support and creates a culture that is accepting of change and technological advancements; without this in place technology deployment will fail.

6.3.10. Measurements

The implementation of technology requires measurements, with key indicators, to understand the degree of performance, without this the technology is questionable. Sharing the benefits of technology and creating awareness of its success assists with trust and buy-in from stakeholders that have an impact on the adoption process. Having more inclusive and realistic measurements assists with collaborative efforts in the implementation phase, since support is a contributing factor to its success.

According to Bryant (2015) leaders that do not have a working understanding of the benefits of modern technology and innovations further hinder the adoption process. Misaligned priorities and the lack of integration on the measurement of KPIs decreases the abilities of mining firms to collaborate since functions are focussed on their own KPIs, a more holistic and inclusive set of measures can assist with this (Ediriweera & Wiewiora, 2021).

Participants and literature support that the measurement of technology been implemented helps to evaluate progress and helps to provide transparency in challenges and opportunities for continuous improvement; this also helps with decisions being data driven and the effective allocation of resources.

6.3.11. Operational readiness

The mining operation needs to be best place to accept new technology in order for it be successful, and may include training and development of employees, infrastructure and systems that support the changes in workflows. Underestimating the resources and support required to ensure the successful adoption of technology is a common occurrence in the mining industry leading to failure in its deployment.

Research shows the significance of involving different stakeholders, which also increases the levels of complexity when they are involved in the adoption process, this complexity impacts the operational readiness of a mining operation and can impede the process (Ali & Rehman, 2020). The availability of skilled resources needed to utilise new technology is note always readily available in remote areas where mining operations are located. Poor operations readiness (Cabral et al., 2020) and knowledge on new technology makes the adoption of technology far more challenging to yield the desired outcomes (Ghebrihiwet, 2019).

Participants agree that operational readiness can hinder the adoption of new technologies, such as the availability of skills, the required infrastructure and resources, this is also supported by literature.

6.3.12. Organisation structure

An effective organisation structure outlines the roles, responsibilities and relationships within the mining firm, and supports the decision making and implementation process of technology adoption. It is crucial for mining firms to have a supportive and inclusive organisational structure since it determines how effective and efficient technology is integrated within the organisation and impacts factors such as communication, accountability and resource allocation.

The TOE framework shows organisational factors which are required to support the adoption of technology, and includes how the organisation is structured, scope and scale (Tornatzky et al., 1990). According to Ediriweera & Wiewiora (2021), mining firms have

silo structures that excludes a diverse group of stakeholders, and limits employee's involvement in decision making often as a result of their hierarchical structures.

Participants and literature converge on the topic of organisational structures, that it needs to be more inclusive and provide collaboration across the different functions to enable better integration of new technologies into the mining firm.

6.3.13. Skills development and training

A well-educated and trained workforce is essential to effectively utilise and ensure the success of new technologies. Upskilling, learning and development all employees to utilise technology to its full potential; they become more agile in its application, troubleshooting and it reduces the resistance to new technologies.

New technologies often results in skill gaps and can render existing skills obsolete but training and development helps bridge the gap between current skills and required skill necessary for the adoption of technology (Pardo del Val & Martinez Fuentes, 2003). Research has shown there is gap between guidelines and training of the end users and maintenance employees during the implementation of technology, this can lead to poorer performance, higher costs and lower reliability of technology (Job & McAree, 2017).

Skills development and training of employees helps improve performance and reduces the resistance to technology which was supported by participants and the literature.

6.3.14. Strategy

A strategy that is well defined provides a clear guideline for the adoption and integration of technology in the mining firm, aligning to the business goals, objectives and the provision of resource allocation to ensure its optimally utilised. A strategy also creates cohesion, helps reduce risks, optimises decision-making and provides better communication, and consistency on the technology adopted by the business which are essential for its success.

A mining firm's strategy facilitates co-ordination through its various departments, and to create a transformative shift, holistic factors such as operational intricacies, value

proposition and the pace for technology adoption needs to be considered for it to be implemented throughout the organisation appropriately (W. P. Rogers et al., 2019).

Misalignment on technologies to be adopted, the availability of resources and unique operational requirements needs a holistic approach underpinned by a well-defined strategy. Both literature and the participants suggest a technology strategy supports the successful adoption of technology in an organisation.

6.3.15. Technology appropriateness and improvement

Mining firms need to ensure that technology selected for adoption is appropriate and enables the firm to meet specific needs and objectives. Mature technology solutions reduce the risk of mining operations failing, but the requirements of mature technology varies based on the need to address key business drivers such as safety, production and improved cost efficiencies.

According to (Bryant, 2015), technology readiness hinders technology adoption, since reduced purchasing from OEMs and lowered research and development spending impacts the speed and availability of technology. Furthermore, leaders that do not have a working understanding of the benefits of technology becomes a barrier, since these leaders are fundamental to the socialisation of the new technologies that are aimed to be deployed by the mining firm.

The appropriateness and readiness of technology can lead to the failure of technology since employees rely on executives and managers to communicate the benefits and reasons to adopt technology. Literature and participants agreed that appropriateness and readiness can impeded the adoption process, however, the literature does not suggest that low maturity technologies are implemented in modern mines which is contradictory to the data collected from participants.

6.4. Discussion of results for Research Question Three

What is an approach that supports the effective utilisation of technology in modern mining?

The purposed of this question was aimed to understand the interdependencies between the adoption of technology and associate performance that is desired. This investigation

would allow the research to further understand if a system approach would be a suitable solution in the adoption of technology.

6.4.1. Continuous improvement

Mining firms that embrace continuous improvement enables firms to enhance efficiency, quality and technological changes over time. It helps create a culture of learning and adaption given the exponential growth, development and change of technology. Incremental improvements and a staggered approach to technology adoption in the mining industry helps to reduce risk to production losses and safety incidents, therefore reducing resistance to technology that has more transformational effects.

Research shows that mining firms are more willing to adopt technologies that have incremental change than transformational changes, which means stakeholders are less likely to resist incremental changes since there is less risk involved in the adoption of these technologies as opposed to significant changes (Bartos, 2007).

Literature shows that there is alignment on incrementally introducing technology into mining operations and it also supported by the views of participants but this was not confirmed for overall continuous improvement in the process and workflows, with the exception that continuous learning can assist with improving overall performance.

6.4.2. Project management

Project management provides a co-ordination function that allows mining firms to plan, execute and monitor the adoption technologies to achieve the desire outcomes, within scope, time and budget. The function of project management helps communicate, manage risks and allocates resources appropriately within the mining firm.

Poor planning for technology adoption impacts the availability of funds and resources for a mining operation, subsequently leads to poor execution (Bryant, 2015). Mining firms are sensitive to costs, without the allocation of resources and capital for the investment in technology, this creates barriers for mining to introduce new technologies (Gruenhagen & Parker, 2020).

Proper planning and execution of technology is essential for mining firms since it helps to secure capital, resources and provides communication and collaboration across the different stakeholders. These factors are supported by literature and the participants.

6.4.3. Process change

The introduction of new technologies impact existing processes, procedures and policies that mining firms have, and need to be adjusted to accommodate the changes that come with new technologies. Often employees resist change due to the lack of trust in the technologies and revert to previous processes when the technology does not perform to expectations.

Mining operations have a lock-in effect, since operational processes and procedures are entrenched in employees working routines and it becomes complex for new technology to be implemented since it is disruptive to existing operational routines (Nuur et al., 2020). It becomes difficult for employees to accept new technologies since current work practices are reliable and have helped achieved KPIs in the past (Fältholm & Norberg, 2017).

Participants and literature support that successful technology implementation requires changes in procedures and processes since employees will default to previous work practices when technology does not provide immediate performance results.

6.4.4. Value chain

Understanding the changes from procedures and process to value driven is crucial since it aligns the mining firms' goals beyond that of the technology being adopted. This allows stakeholders to understand the overall impact of the technological change that will require more commitment and collaboration in the adoption process, and better support the integration of technology into the organisation's business processes.

A simple mining value chain is exploration, plan, develop, mine, process, transport and market, and the end of life plan (Anglo American, 2023), and illustrates how each system element is interrelated, interdependent and interacting (Arnold & Wade, 2015). The adoption of technology has a ripple effect throughout the value chain and it makes it

difficult to understand for all stakeholders, since a change to an element in the system, will have an effect on the entire system (Arnold & Wade, 2015).

The production and revenue generation in mining firms are based on a mining value chain, while mining firms and OEMs are able to understand the impact of technological changes to the value chain, mining firms do not always do so. This leads to missed opportunities and the introduction of risks into the mining value chain since the change in one element of this system is not understood well, in terms of its impact to other elements of the system.

6.5. Summary

In conclusion, the research uncovered the influencing factors for technology adoption, success and failure factors impacting adoption and an approach to enable adoption of technology. In Chapter seven, the conclusion and recommendations will be provided to develop strategies to mitigate these success and failure factors in the process of technology adoption in mining firms.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1. Introduction

The purpose of this research was to investigate and identify the success and failure factors associated to technology adoption in modern mining. This chapter provides a summary of the findings from Chapter five and six which were based on the research questions detailed in Chapter three. The purpose is to provide the mining industry with an understanding of the factors that needs to be considered as it pertains to their technology adoption process and journey towards more technologically advanced mining operations. This chapter will identify the limitations of the research that needs to be considered for further research in addition to the existing body of knowledge around the adoption of technology in mining industry. The chapter provides conclusive remarks and recommendations for the mining industry and stakeholders for future research.

7.2. Consolidations of findings

7.2.1. Influencers for adpotion

Research Question One: What are the success factors of technology adoption in modern mining?

Chapter two identified the key influencing factors that are considered by mining firms when adopting technology, this includes safety, production, sustainability and cost efficiency. (Ediriweera & Wiewiora, 2021) states that the adoption of technology not only facilitates cost reductions and improves environmental impacts at an operation, but also increases productivity. The mining industry is known to focus on cost reductions to improve their production and revenue generation (Aznar-Sánchez et al., 2019), but faces challenges such lower ore grades and difficult to access ore bodies (Calzada Olvera, 2022). Additionally, sustainability concerns encompassing climate change, environmental impact and the well-being of society (Bai et al., 2017) requires the mining industry to adopt greener practices that have less impact on the environment. There has not been a more imperative time for the mining industry to adopt technology and create the step change it requires to address these challenges of increased competition, improved productivity and enhanced sustainability (Aznar-Sánchez et al., 2019).

The research has shown that technology has the capacity to improve safety performance, enhance productivity and decrease environmental impact at mining operations. Cost efficiency is a key influence in the adoption of technology for mining firms, but it has been noted through the research there are instances where mining firms are willing to absorb higher costs to improve safety and pursue zero harm in their operations.

7.2.2. Success and failure factors impacting adoption

Research Question Two: What are the failure factors of technology adoption in modern mining?

This research question was intended to investigate the failure factors associated with the adoption of technology in modern mining, but these factors that have been identified can interpreted by mining firms to assist in the technology adoption process.

The mining industry is sensitive to any costs that they incur since they are price takers and are exposed to market conditions determining the price of the commodities that they sell to the market (Gruenhagen & Parker, 2020), coupled with stakeholders that have competing priorities, mining firms needs technology to add value to their firms and shareholders since investors attach a risk premium to mining stocks, expecting larger returns on their investment. Change management facilitates the dissemination of information and acceptance of technology, and the use of change management frameworks can assist mining to firms to avoid the following failures: Culture and level of readiness for change are not assessed beforehand, Change leaders fail to respect the power of the culture and hampers the change, Little to no strategies are in place to cultivate or grow new culture, Failure to pilot the change, Organisational systems and other initiative are not aligned to the change, End users are not involved in the process, Lack of a proactive plan for user resistance or rejection, and Processes are not re-engineered and realigned (Warnich et al., 2018).

Organisational structures assist mining firms to cascade and align the adoption of technology, which effect the access to human capital resources, knowledge transfer and communication amongst stakeholders (Ghebrihiwet, 2019). Poor integration leads to misaligned priorities, where employees at a mine's operation are measured on KPIs

related to volumetric tonnes and operational efficiency, rather than factors like innovative problem solving or degree of involvement in the adoption of technology (Ediriweera & Wiewiora, 2021). Different stakeholders have different interests which creates higher levels of complexity in the adoption of technology and the lack of stakeholder management and inclusion will impact the success in the adoption process (Fordham et al., 2017). The skills required is not always available to use the new technology since mining operations are in remote areas, and traditional qualifications do not include aspects of automation and innovation in their curriculums, which creates gaps between the skills needed for the adoption of technology and the necessary educational framework to develop these skills (Ali & Rehman, 2020).

Technology appropriateness and maturity plays an important role in the adoption of technology and the risk appetite for the mining operation may be the determining factor since mining firms are likely to not take on unproven technology and prematurely implement these technologies in a production environment (Bartos, 2007). There are several barriers to the successful implementation of modernisation and mechanisation of mines, many of which are characterised by ‘soft’ or ‘human’ factors, and it is noted that even the most advanced technologies are susceptible to fail if the human factors influencing implementation are not fully understood and resolved (Stewart, 2015).

7.2.3. Approach to enable adoption

Research Question Three: What is an approach that supports the effective utilisation of technology in modern mining?

The mining industry uses technology for continuous improvement, to improve profitability and increase production, but technology also provides the mining industry the ability to reduce waste, decrease pollution and improve sustainability practices (Ediriweera & Wiewiora, 2021). Effective planning and project management should be integrated into the mining firm’s strategy to ensure co-ordination of the right technologies, allocation of human and financial resources are provided for the technology adoption process to be successful (Bryant, 2015).

Mining operations have entrenched processes and procedures making it complex to implement any new technologies when they are disruptive to existing operational

routines (Nuur et al., 2020). As technology adoption takes place, it becomes essential for policies and procedures to be revisited, such as roles and responsibilities to ensure there is a clear guideline on what tasks should be performance and how it should be executed (Kohli & Melville, 2019).

The value chain describes the process of a mining operation to sell mineral resources to the market. Each step can be considered a system, which is made up of other systems (Arnold & Wade, 2015). The entire mining value chain is interrelated, interdependent and interacting elements that form collective entities to the system it operates in (Arnold & Wade, 2015). This makes the successful adoption of technology difficult since a change to an element in the system, will have an effect on the entire system (Arnold & Wade, 2015).

7.3. Key recommendations

Based on the above mentioned, the key recommendations for mining firms includes:

- Mining firms differ in context, mining methods, commodities and projected life which all effect the degree to which technologies needs to be implemented. Each mining operation will have their own unique requirements and the technology strategy needs to provide the purpose of how technology will unlock value to that firm based on these requirements. Frameworks may assist mining firms in their modernisation journey but an ‘one size fits all’ approach will not work given different unique circumstances of that firm.
- Change management and operational readiness should be prioritised by mining firms given the complexity of the business and different stakeholders involved. Technology adoption needs to be purpose driven with focus usability and human factors should be underscored since this can influence the success of any implementation of new technology.
- Stakeholder engagement and inclusion helps build alignment, ensures accountability and buy in from the various stakeholders to achieve a successful outcome in the introduction of new technologies. Engaging and understanding the needs from different stakeholders enhances decision making process, and gives a level of ownership to those effected by the decisions towards identified technologies.

Establishing a cadence with stakeholders allows for better communication and the ability to address any concerns which mitigates the risks of resistance to the technology; stakeholder engagement and inclusion can support a better transition and effective integration of new technologies in mining firms.

- A systems-thinking approach may assist mining firms to better understand the implications of new technologies, which can aid in risk mitigation and improving the overall performance of the mining value chain as opposed to only a sub-system. This systems-thinking may assist mining operations to have better results and realise the full benefits associated to technology adoption.

7.4. Limitations of this research

The following sections identifies the limitations of this research, which should be taken into account for the understanding of technology adoption in the mining industry:

- The study was limited to the number of mining employees included in the study, and the distribution to further employees across the different departments within the mining firm could be considered, including operators, foremen and maintenance personnel.
- The data collected focussed on two commodities, namely, diamonds and platinum which have been identified as commodities that are in a transition towards higher levels of technology. Different commodities including coal, iron ore and copper could be further investigated.
- The interviewer has no prior experience on interviews to data analysis and this may impact the interpretation and analysis of the data collected.
- This study did not investigate end user feedback and capabilities when utilising new technologies which should be further investigated.

7.5. Future study

This research contributes to the current body of knowledge that exists on the adoption of technology in the mining industry. Mining is a complex industry that needs to satisfy several stakeholders, both internally and externally while still needing to cater for safety, social license to operate and governmental regulations. This research identified success

and failure factors of technology adoption in modern mining, however, further research is needed, including:

- Quantitative research to confirm research findings.
- Investigate the impact of sustainability practices and the performance of mining operations.
- A review of end-user factors that affect the implementation of technology.
- Effects of leadership support and capabilities required for technology adoption.

7.6. Conclusion

The study aimed to investigate the success and failure factors for the adoption of technology in modern mining. The research concluded that safety, production, sustainability and cost efficiency influences mining firms to adopt technology, and these are strategic objectives needed to be met to achieve organisational goals and provide value to their stakeholders. The research also uncovered that technology acceptance are derive from technical and human factors, including technology maturity, change management, organisational culture and leadership support. Other factors that influence technology adoption include systems-thinking, operational readiness and leadership support that would further support mining firms ability to adopt technology successfully.

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Appendix 1: Project Plan

Phase	Activity	Duration	Completion date
Proposal	Draft 1	14 days	24-May-23
Proposal	Final Draft	4 days	28-May-23
Proposal	Submission	1 day	31-May-23
Elective	Disruptive Technologies and the Fourth Industrial Revolution	3 days	8-Jun-23
Core	Strategic Implementation Syndicate Assignment Submission	1 day	11-Jun-23
Ethical Clearance	Draft	14 days	30-Jun-23
Ethical Clearance	Submission	1 day	3-Jul-23
Leadership	Individual Assignment 1 Submission	7 days	10-Jul-23
Elective	Strategic Finance and Value Creation	3 days	16-Jul-23
Ethical Clearance	Approval	14 days	17-Jul-23
Leadership	Individual Assignment 2 Submission	7 days	24-Jul-23
Questionnaire	Draft	14 days	24-Jul-23
Elective	Geopolitics and Grand Strategy	4 days	26-Jul-23
Questionnaire	Pilot	7 days	4-Aug-23
Questionnaire	Send Survey	3 days	10-Aug-23
Elective	Investment Finance	3 days	17-Aug-23
Global Module	Virtual attendance	3 days	28-Aug-23
Elective	Global Business Strategy: Global Economics & International Business Risk	3 days	3-Sep-23

Phase	Activity	Duration	Completion date
Research report	Chapter 1 to 4	21 days	18-Sep-23
Questionnaire	Data Collection	42 days	22-Sep-23
Data	Analysis	14 days	3-Oct-23
Research report	Chapter 5	7 days	10-Oct-23
Research report	Chapter 6	7 days	17-Oct-23
Research report	Chapter 7	7 days	24-Oct-23
Final Report	Submission	1 day	1-Nov-23

Appendix 2: Proposed Interview Guide

Section A: Demographics

Description	To be completed
Your designation:	
Years of experience in mining:	
Commodity type:	
What technology have you been involved in for adoption thereof?	

Section B: Interview Schedule

Research Question	Interview questions
Research Question One: Success Factors	What are the main benefits for your organisation to adopt technology?
	Is there a link between the company strategy, planning and technology implementation in your organisation?
	To what extent has your organisation been able to yield benefits in implementing technology, in respect to safety, sustainbility and production?
	What would you consider as success factors to support modern technology adoption?
	Is your organisation able to measure the success from the adoption of technology?
Research Question Two: Barriers or failures	To what extent does technology readiness influence the acceptance of technology in your organisation?
	Is there a process of change management in your organisation for the adoption of technology?
	How does employees influence or in support of the adoption of technology?

Research Question	Interview questions
	What would you consider as the barriers that impede the adoption of modern technologies?
	To what extent does orgnisational behaviour influence the adoption of technology in your organisation?
Research Question Three: Enabling factors and approach	What is the process that your organisation follows when adopting technology?
	What would you consider as a key factors towards an enabling approach to support the adoption of modern technolgies?
	What would be an applicable approach for modern technologies adoption?
	To what extent does your organisation investigate effects of implementing technology in the mining value chain?
	What are the risks that have emerged as technology is implemented in your organisation?

Appendix 3: Consent letter

Dear *Sir/Madam*

I am currently a student at the University of Pretoria's Gordon Institute of Business Science and completing my research in partial fulfilment of an MBA.

I am conducting research on the success and failure factors of technology adption in modern mining. Your consent is herewith needed for participation in this sudy. Our interview is expected to last about an hour and will help us understand how can the mining industry adopt modern mining technologies effectively. **Your participation is voluntary, and you can withdraw at any time without penalty.** All data will be reported without identifiers. If you have any concerns, please contact my supervisor or me. Our details are provided below.

Researcher name
Email 27103570@mygibs.co.za
Phone

Research Supervison name
Email
Phone

Signature of participant _____

Date _____

Signature of researcher _____

Date _____

Appendix 4: Consistency Matrix

Research questions	**Sections in literature review**	**Data collection tools**	**Analysis technique**
What are the success factors of technology adoption in modern mining?	Success factors	Interview questions	Content analysis to uncover types of contributing factors.
What are the failure factors of technology adoption in modern mining?	Failure factors	Interview questions	Content analysis to uncover types of contributing factors.
What is an approach that supports the effective utilisation of technology in modern mining?	Theoretical model; Systems thinking	Interview questions	Content analysis on open ended questions, to determine elements in and out of the system that are impacted.

Appendix 5: Categories and Themes

Categories	Theme
Safety and Health	Influencers for adoption
Production	Influencers for adoption
Sustainability	Influencers for adoption
Cost efficiency	Influencers for adoption
Financial and investment costs	Success and failure factors impacting adoption
Change management	Success and failure factors impacting adoption
Communication	Success and failure factors impacting adoption
Culture	Success and failure factors impacting adoption
Stakeholder engagement and inclusion	Success and failure factors impacting adoption
Environmental and operational factors	Success and failure factors impacting adoption
Job loss	Success and failure factors impacting adoption
Lack of trust	Success and failure factors impacting adoption
Leadership support	Success and failure factors impacting adoption
Measurements	Success and failure factors impacting adoption
Operational readiness	Success and failure factors impacting adoption
Organisational structure	Success and failure factors impacting adoption

Skills development and training	Success and failure factors impacting adoption
Strategy	Success and failure factors impacting adoption
Technology appropriateness and readiness	Success and failure factors impacting adoption
Continuous Improvement	Approach to enable adoption
Project management and implementation	Approach to enable adoption
Process change	Approach to enable adoption
Value chain	Approach to enable adoption