Adoption of artificial intelligence-driven predictive maintenance in South Africa's coal mines.

Thabo Mahlangu

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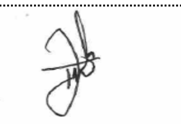
Signature	

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Abstract

The adoption of artificial intelligence (AI) in sectors such as banking and manufacturing is advancing rapidly; however, the mining industry in South Africa, particularly coal mining, exhibits a much slower rate of adoption. This study examined the use of AI for predictive maintenance in South Africa's coal mines, employing the Technological, Organisational, and Environmental (TOE) framework and the Technology Acceptance Model (TAM) to understand the factors influencing technology adoption in the coal mining industry.

The literature review emphasised the benefits of AI in predictive maintenance, particularly in reducing operational costs and enhancing maintenance efficiency. Despite these advantages, most coal mines still rely on traditional maintenance strategies such as preventative, condition-based, and reactive maintenance. The study aimed to examine current maintenance practices, the types of AI predictive technologies adopted, the enablers and barriers to adoption, and overall perceptions towards AI in coal mining. To achieve this, a qualitative approach was used, involving interviews with maintenance engineers, and a reflexive thematic analysis was conducted to identify the emerging themes.

Thematic analysis identified four main themes: technological advancements in maintenance practices, the role of digital innovation in enabling predictive and efficient maintenance, the need for strategic transformation in maintenance to achieve organisational resilience, and the constraints hindering AI adoption. Although some larger mining companies are starting to use digital tools like condition monitoring, most operations remain cautious. Barriers, including high costs, limited access to AI technology, a lack of local support, and low awareness; especially among junior miners; are slowing the shift to AI-driven predictive maintenance.

Despite the challenges, the study found a generally positive attitude amongst maintenance engineers who participated in the research towards AI adoption, suggesting that with sufficient investment in infrastructure, capacity-building, and support systems, the coal mining industry could shift to more efficient, data-driven maintenance models. The TOE and TAM frameworks offered insights into the importance of organisational readiness, leadership support, and perceived ease of use. The study concludes by recommending targeted interventions to address the identified gaps. It proposes future research that extends beyond coal mining to explore AI adoption across South Africa's broader mining sector and the impact of AI-driven maintenance on mines' operational costs in South Africa.

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Chapter 1: Introduction

This chapter introduces the purpose of the research by highlighting the motivation behind it, providing the background on the cost impact on coal mines, and explaining how artificial intelligence can address these challenges. The problem statement outlines the issues faced by coal mines concerning future uncertainties caused by climate change, emerging concerns, and reliance on outdated maintenance practices. The objectives and research questions are discussed, which will facilitate further understanding of the adoption factors of artificial intelligence-driven predictive maintenance in South African coal mines. The delimitations of the study are also outlined, including geographical location, research methods, and the scope of the literature review supporting the adoption of technology.

1.1 Statement of purpose

This research was motivated by the evident advantages of artificial intelligence in various sectors, including manufacturing, banking, and aerospace. The mining industry has been slow to adopt this compelling technology, which is the focus of this study.

1.2 Background of the study

The South African energy sector remains heavily reliant on coal as its primary source of energy for electricity production. From 2023 to Q2 of 2024, coal accounted for 78.5% of SA's electric energy needs (Fitzgerald et al., 2024). The coal supplied to the power utility comes from coal mines concentrated mainly in the Mpumalanga and Limpopo provinces of South Africa. The mining industry utilises mining equipment, which requires a significant capital investment. This mining equipment must be maintained to sustain production profiles. It is noted that the cost of mining equipment maintenance ranges from 20% to 40% of the mine's operational cost (Dayo-Olupona et al., 2022), which constitutes a significant portion of the mine's total operational expenses. As the equipment ages, maintenance costs increase due to an increase in unplanned failures and production losses, resulting in revenue loss for the mine. A balance must be struck between the cost of maintenance and the need for more frequent maintenance.

Artificial intelligence has the potential to enhance operational efficiency, reduce costs and improve equipment reliability and availability.

Artificial intelligence technology is becoming increasingly widely used because it can outperform humans in certain specific areas, such as predicting failures. This achievement has been attributed to the combined influence of the following variables (Ong & Gupta, 2019): faster access to vast amounts of data, rapid advancements in processing power, and gradual improvements in technology for data-driven machine learning.

The maintenance cost-saving potential and efficiency enhancement of adopting this predictive maintenance technology would be significant for any mining operation that adopts this technology. It is noted that poor maintenance can reduce plant productivity by 5% to 20%, resulting in significant financial losses for the company (Evans, 2024).

1.3 Problem statement

The traditional predictive maintenance depends on manually defined set points, human interpretations, and predefined guidelines. This approach utilises condition monitoring instruments to measure equipment parameters according to set points (Mobley, 2002). The traditional maintenance practices applied in the mining sector tend to fail in preventing equipment downtimes (Rojas et al., 2025). The challenges with traditional maintenance approaches that companies are grappling to solve include unplanned downtime by equipment failure, low equipment availability, high spare parts inventory, which results in high inventory costs, safety and environmental risks, increased mean time to repair(MTTR) (Patil, 2022).

On the other hand AI AI-driven predictive maintenance utilises the AI-powered machine learning by continuously extracting real-time data from infused internet of things sensors (Solari, 2024). It can accurately identify early indicators of component failure and learns and adjust to changing equipment conditions. The ability of AI-driven predictive maintenance to automatically identify underlying causes and suggest remedial measures without human input or judgment is by far its most significant advantage.

The study conducted by Deloitte shows that there are great benefits to using predictive maintenance, compared to traditional maintenance approaches. Some of the salient benefits are listed in Table 1 below (Patil, 2022):

Table 1: Benefits of predictive maintenance

Description	Benefits
Reduction in facility downtime	5% to 15%
Increase in labour productivity	55 to 20%
Reduction in inventory levels	10% to 30%
Reduction in equipment costs	3% to 5%

These benefits of AI-driven predictive maintenance have the potential to lower the total maintenance costs and improve the uptime of equipment, thus lowering the operating costs of the business. The cost of mining equipment maintenance ranges from 20% to 40% of the mine's operational cost (Dayo-Olupona et al., 2022). These costs can be significantly reduced with the adoption of AI-driven predictive maintenance.

Preliminary research suggests that adoption of artificial intelligence in the mining industry is snail-paced (Ediriweera & Wiewiora, 2021). At the same time, it is a well-known fact that the coal sector is facing challenges due to uncertainty in funding for major capital projects, primarily driven by climate change factors. This is therefore resulting in the coal mining companies optimising and sustaining the current coal mines, which have a longer life of mine. The coal mines, by nature, are highly capital-intensive and face the challenge of reducing operational costs to remain sustainable during the era of the just energy transition. Artificial intelligence has the potential to improve efficiency and reduce maintenance costs, which contribute a significant portion to the overall operational costs of the mine.

Preliminary research suggests that the coal mines are stuck in old ways of doing things when it comes to technology (Amadi-Echendu et al., 2011). It has been observed that the majority of South African coal mines are still operating under the old maintenance regime, which is labour-intensive and predominantly manual. There appears to be a challenge or gap in adopting predictive maintenance artificial intelligence in South African coal mines, which could help improve efficiency and reduce maintenance costs. It is therefore essential to understand this gap in the adoption of AI and the potential benefits of implementing AI in maintenance within South African coal mines.

1.4 Research objectives

The research under consideration explores the adoption factors of AI-driven predictive maintenance in South African coal mines. The study aims to investigate the following objectives:

1. The current maintenance strategies employed in South African coal mines.
2. The types of AI technologies used for predictive maintenance in the coal mining industry in South Africa.
3. The driving factors that are stimulating the adoption of predictive maintenance AI technologies in South African coal mines.
4. The factors that prevent or enable the adoption of predictive maintenance AI technologies in the South African coal mines.

1.5 Research questions

The research questions that the study seeks to address are the following:

1. What are the current maintenance strategies being employed in South African coal mines? The cost of mining equipment maintenance ranges from 20% to 40% of the mine’s operational cost (Dayo-Olupona et al., 2022). . It is noted that poor maintenance can reduce plant productivity by 5% to 20%, resulting in significant financial losses for the company (Evans, 2024) The maintenance strategies being employed by the mining sector play a vital role in the overall operational cost of the mine. It is therefore essential to examine the current maintenance strategies employed in South African coal mines.

2. What types of predictive maintenance AI technologies are adopted in the coal mining industry in South Africa?
   The study by Gackowiec (2019) and Akinwumi et al. (2025) indicates that preventative maintenance is dominating the maintenance strategies in different industries, and predictive maintenance has shown some signs of improvement in terms of uptake over the years. It is therefore essential to investigate the types of preventative maintenance AI technologies that are being adopted in the coal mining industry in South Africa.

3. What are the driving factors that are stimulating the adoption of predictive maintenance AI technologies in South African coal mines?
   The study conducted by Deloitte shows that there are great benefits to using predictive maintenance, compared to traditional maintenance approaches, some of which include reduction of downtime, increased labour productivity, reduction in inventory levels and reduction in equipment cost (Patil, 2022). It is therefore essential to investigate the driving factors that are stimulating the adoption of predictive maintenance AI technologies in South African coal mines.
4. What are the factors that prevent or enable the adoption of predictive maintenance AI technologies in the South African coal mines?
   Preliminary research suggests that adoption of artificial intelligence in the mining industry is snail-paced (Ediriweera & Wiewiora, 2021). According to Bryan and Zuva (2021) There are three main factors that influence the organisational adoption of technology, which are the technology development, organisational conditions, business and organisational reconfiguration, and Industry environment. Ogrezeanu (2015) explains that the motivation of users to adopt technology is driven by three main factors, which are: the perceived usefulness of the technology, the perceived ease of use of the technology and the attitude towards the use of the technology. It is therefore essential to investigate the factors that prevent or enable the adoption of predictive maintenance AI technologies in the South African coal mines.

1.6 Rationale of the study

The study by Gackowiec (2019) has shown that the most commonly used maintenance strategies, as identified in research articles and conference papers, are predominantly: preventative maintenance, corrective maintenance, predictive maintenance, condition-based maintenance, and proactive maintenance, see Figure 1 below. Artificial intelligence-driven maintenance does not feature on the list and reflects an understudied area.

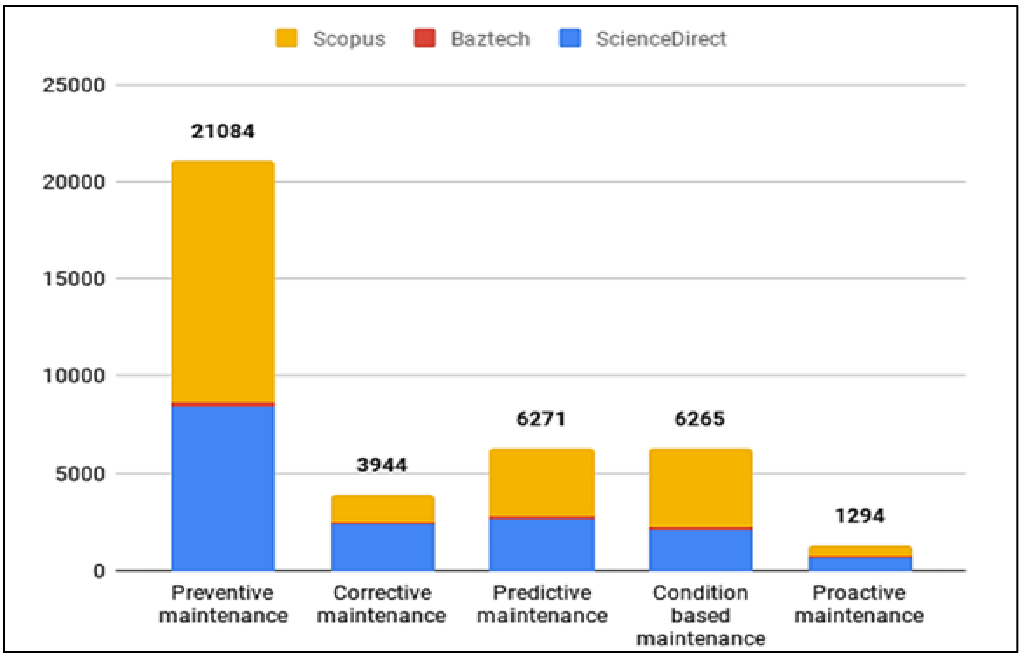

Figure 1Predominant maintenance strategies found in journals (Gackowiec, 2019).

The research study by Akinwumi et al. (2025), comparison of maintenance strategies shown in Table 2 below shows that preventative maintenance strategies are the predominant strategy employed in industry; however, there is an increase in uptake of predictive maintenance strategies during the period of 2019 to 2020.

Table 2: Comparison of maintenance strategies (Akinwumi et al., 2025).

Category	2019 Percentages	2019 Expected Count (Out of 199)	2020 Percentages	2020 Observed Count (Out of 171)
Reactive Maintenance	20%	39.8	15%	25.65
Preventive Maintenance	80%	159.2	70%	119.7
Predictive Maintenance	35%	69.65	40%	68.4
Reliability-Centered Maintenance	25%	49.75	30%	51.3

The preventative maintenance has been identified as the primary maintenance strategy in the study. The AI-driven preventive maintenance is not featured in the analysis, only traditional predictive maintenance features. It has been observed that most of the South African coal mines remain reliant on an old, labour-intensive, and predominantly manual maintenance regime. There appears to be a challenge or gap in the adoption of AI driven predictive maintenance in the industry, which could improve efficiency and reduce maintenance costs. Therefore, understanding this adoption gap and the potential benefits of implementing AI in maintenance within the South African coal mines is crucial.

AI-based predictive maintenance can unlock substantial value by preventing equipment outages and optimising maintenance time. It is estimated that the benefits result in a 5-10% increase in production and greater than 20% savings in maintenance costs (Tycho Möncks et al., 2023). Machine learning and deep learning approaches can monitor and predict equipment failures, and it has been shown in the case study from Ghosh et al. (2022) that predictive maintenance increased equipment lifespan by 30% to 80% and saved millions of dollars.

1.7 Delimitations of the study

The study was limited to South African coal mines in the Mpumalanga and Limpopo areas, where the coal mines are concentrated. The focus was on the maintenance function of the mine. The study was limited to a period of about 6 months. The research method employed was qualitative, consisting of structured interviews. The literature review focused on the frameworks that involve the adoption of technology, specifically the TOE (Technology, Organisation, Environment) framework and the TAM (Technology Acceptance Model). In the terms of the models or frame work employed, the match between the existing workforce skills and new skills required for the AI solution was delimited out for the study and well as the additional costs in time, materials and education were delimited out for the study.

1.8 Assumptions

The study was based on the assumption that the selected theories accurately predict the adoption of new technology and are relevant to this research. The theories (TOE, TAM, etc.) are grounded in empirical research that demonstrates the ability to predict technology adoption and have been proven to be useful tools for similar research studies. The data collection method was suitable for this study and followed proven guidelines for academic research. The interviewed participants provided honest and accurate responses during the interviews. The sampled population was selected from diverse mining companies (both large and small mines) to ensure the diversity of data sources. To increase the accuracy, the interviews were conducted in a neutral environment, free of pressure, and confidentiality was assured. The interviews were conducted in a non-judgmental atmosphere in order to encourage truthful responses.

The next chapters:

Chapter 2, will focus on the literature review and review frameworks relevant to the adoption of new technology studies. Chapter 3 focus on the research methodology and the analysis of the data and how it relates to the chosen framework. Chapter 4 focuses on the research findings and triangulates the findings with the adopted frameworks. Chapter 5 discusses the conclusions, recommendations, and future research.

Chapter 2: Literature Review

In this chapter, the focus is on reviewing frameworks related to the introduction of new technology, with the three widely used frameworks: TAM, TOE, and DOI. The chapter concludes by examining the hypothesis of perceived slow adoption of technology in coal mines.

2.1 Introduction

Several technology frameworks have been developed to examine the adoption and implementation of technology. This study will review the three widely used technology adoption frameworks: TAM, TOE, and DOI.

2.2. Theoretical and Conceptual Framework

2.2.1 Technology Acceptance Model (TAM)

TAM is a model that explains the motivation of users driven by three main factors, which are (Ogrezeanu, 2015); the perceived usefulness of the technology, the perceived ease of use of the technology and the attitude towards the use of the technology.

The TAM also considers external factors such as; training, system characteristics, user participation in the design and the implementation nature, but this model has some limitations because it ignores the social influence on the adoption of technology in the work environment

(Taherdoost, 2017). Another limitation of TAM is that it looks at future behaviours and not actual behaviour, and relies on self-reported data usage (Bryan & Zuva, 2021).

2.2.2 Technology -Organisation- Environment (TOE)

Tornatzky and Fleischer developed the TOE framework to understand the factors that were shaping innovation adoption (Tornatzky & Fleischer, 1990). This framework places more focus on the organisation's context and influences the process by which it adopts and implements a technological innovation (Sean. Xu et al., 2004). Three main factors influence the organisational adoption of technology (Bryan & Zuva, 2021) technology development, organisational conditions, business and organisational reconfiguration, and Industry environment.

There are three attributable contexts in which the TOE is applied to examine the adoption of technology (Sean. Xu et al., 2004), the first attribute looks at the technology context, which examines the internal and external technologies relevant to the organisation. These include the existing technologies in the organisation and technologies available in the market. In terms of organisational context, it includes the company size and scope, the centralisation, formalisation, and complexity of its managerial structure, the quality of human resources and the number of slack resources available internally (Polisetty et al., 2023). In terms of environmental context, it encompasses the space in which the company operates, including its industry, competitors, access to resources, and dealings with the government (Awa et al., 2017).

The TOE has been tested in several studies and has demonstrated its usefulness in identifying both enablers and inhibitors of technology adoption. The shortcoming of TOE is the assumption that the model will apply to large organisations rather than to small and medium enterprises, because large companies have fewer grievances (Bryan & Zuva, 2021).

2.2.3 Diffusion of Innovations Theory (DOI)

The DOI model looks at the diversity of innovations that spread a new idea, and according to Martins et al. (2021), this model is dependent on the following variables: perceived attributes of innovation, type of innovation decision, communication channels, nature of the social system and the extent of the change agent's promotion efforts. The DOI model combines three major components, which are adopter characteristics, characteristics of an innovation and the innovation decision process as its main drivers (Ogrezeanu, 2015); however, its primary limitation is its lower explanatory power and practicality for predicting outcomes when compared to other adoption models (Taherdoost, 2017).

2.2.4 Existing studies of AI in maintenance

There are current studies of artificial intelligence in maintenance. In the renewable energy space, AI-assisted predictive maintenance is utilised specifically for bearing diagnostics in wind turbines using endoscope images during inspection routines, which resulted in a 24.6% improvement in specificity and a 25.3% increase in uptime(Shin et al., 2021). In the aerospace industry, there is a greater focus on AI predictive maintenance for aerospace engines, focusing on its innovation, challenges and technical applications. It emphasises the use of machine learning, edge computing and blockchain technology to enhance operational efficiency and safety (Ramrao et al., 2023). In the coal mining sector, the application of Internet of things (IoT) technology is being developed for a predictive maintenance system for coal mining equipment to enhance safety and efficiency. The proposed system integrates equipment state monitoring stations, a monitoring centre and a remote predictive maintenance system(Dong et al., 2017). The study by Dayo-Olupona et al. (2022) concludes that adopting AI-driven predictive maintenance can significantly reduce costs, enhance equipment availability, and provide a foundation for advanced technologies in the mines.

2.4 Conclusion of the literature review

In conclusion, the frameworks are not one-size-fits-all types; their success depends on the area in which they are employed. This study aims to understand the adoption of technology at the organisational level and the perceptions of technology users. Therefore, the TOE and TAM frameworks appear to be a suitable combination for the study. The existing studies show progress in the application of AI-driven predictive maintenance and the great potential for enhancing efficiency and safety.

2.5 Research hypotheses (or propositions)

It is hypothesised that the adoption of AI-driven predictive maintenance in coal mines is slow, based on research by Ediriweera and Wiewiora (2021), which has an impact on the mine's operating costs, as maintenance plays a significant role in the operational costs portion of the expenditure. It is hypothesised that maintenance costs can be reduced through the efficient use of AI-driven predictive maintenance, based on the study by Patil (2022) where it was shown that there are tangible benefits in utilising predictive maintenance. Bryan and Zuva (2021) and Ogrezeanu (2015) and Bryan and Zuva (2021) have identified the factors that seem to hinder or enable the adoption of AI in the maintenance space of coal mines, and this study aims to investigate these factors.

The next chapter will delve into the research methodology, focusing on research design, data collection and analysis. The quality assurance and ethical considerations for the research will also be addressed.

Chapter 3: Research methodology

This chapter outlines the research methodology employed in the study. Firstly, it covers the research in terms of the frameworks discussed in the Chapter 2 literature review section and how they are applied to address the research questions and objectives. It also outlines the research instrument used in the study. This chapter also covers the qualitative research method, which includes data collection and data analysis. A thematic analysis is presented, illustrating how the themes were developed. The chapter concludes with a discussion of quality assurance and ethical considerations for the research study.

3.1 Introduction

The TOE and TAM frameworks are adopted for this study, using a qualitative approach to gain a deeper understanding of the problem. The research questions aim to address the following aspects from the TOE and TAM frameworks:

3.1.1 What are the current maintenance strategies being employed in South African coal mines?

Regarding the TOE framework under the technology element, the current technologies used within the organisation might either restrict or facilitate the adoption of new technologies. Therefore, it is crucial to understand the types of maintenance strategies employed and how they support the integration of AI predictive maintenance.

3.1.2 What types of predictive maintenance AI technologies are adopted in the coal mining industry in South Africa?

Regarding the TOE framework under the technology element, it is important to understand the availability of technology, which assesses the presence and accessibility of technology in the market. This will influence how the technology is adopted within the organisation.

3.1.3 What are the driving factors that are stimulating the adoption of predictive maintenance AI technologies in South African coal mines?

In terms of the TOE framework, it is important to understand the technological, organisational, and environmental contexts of factors that stimulate the adoption of new technology. Organisational size, skills, culture, and resource capability play an important role; similarly, technology availability, the current technology in use, and the attributes of the new technology are crucial in understanding the factors that enable the adoption of new innovations. In terms of the TAM framework, perceived usefulness and perceived ease of use play an important role in stimulating technology adoption. Therefore, it is essential to understand how new technologies are perceived in the coal sector.

3.1.4 What are the factors that prevent or enable the adoption of predictive maintenance AI technologies in the South African coal mines?

In terms of the TAM framework, the perceived usefulness of the technology, the perceived ease of use, and the attitude towards its use play important roles in either preventing or enabling the adoption of new technologies. Therefore, in this study, it is crucial to understand how maintenance engineers—the users of the technology—perceive or understand AI-driven predictive maintenance. Regarding the TOE framework, factors such as technology availability, accessibility, cost, company resources, capabilities, skills, infrastructure availability, market competition, and other elements influence the adoption of technology within organisations. Hence, it is also essential to explore how these factors impact the adoption of AI-driven predictive maintenance.

The application of these frameworks will help answer the questions posed by the objectives of this research study.

3.2 Research design

The frameworks adopted to analyse the adoption of AI-driven predictive maintenance are the Technology, Organisation, Environment (TOE) framework and the Technology Acceptance Model (TAM) framework, both formulated on a qualitative approach to provide a deeper understanding of the factors influencing AI adoption in predictive maintenance within coal mines. According to Liu (2019), the TOE Framework is a popular model for new technology adoption and has proven beneficial for organisations as a helpful tool. The other framework used is the Technology Acceptance Model (TAM), which examines users' motivation or perception of the technology (Bryan & Zuva, 2021). The research strategy employed a qualitative approach, as described by Sharp et al. (2019), which aims to gain a deeper understanding of meanings, patterns, and additional insights.The qualitative approach was chosen to gather maintenance practitioners' experiences, perceptions and patterns of behaviour with regard to the adoption of technology. The numerical data will not fully capture the deep meaning of the perception, experiences and human behaviour. A personal interaction and perceptions of the participants were important to understand personal views with regards to the adoption of technology since according to (Cropley, 2022) every person's view of the world works on the basis of his or her specific interactions with it and constructs insights into these constructions of reality. Therefore, to better understand the adoption of AI-driven predictive maintenance in the South African coal mining industry, a qualitative approach was appropriate. This was achieved by gathering opinions, views, and experiences from engineers involved in maintenance within the coal mining sector. The qualitative method employed a combination of inductive and deductive thematic analysis to strike a balance between flexibility and structure. The TOE and TAM frameworks from the literature review were used as a guide for aligning the research questions and emerging themes in the data, which were evaluated during the research. The aim was to examine and validate the applications of these frameworks in relation to AI adoption in predictive maintenance within the coal mining industry. A descriptive research design was utilised to explore in detail the adoption of AI in predictive maintenance.

The qualitative method involved collecting primary data through interviews with a selected number (sample) of maintenance engineers in coal mines. Since this was a new technology in this environment and secondary data were not available in the South African coal mining sector, it was deemed appropriate to rely on primary data gathered through structured interviews. The data was then used to conduct a comprehensive analysis of the adoption of AI-driven predictive maintenance in the coal mining industry.

3.3 Data collection methods.

The data collection procedure involved drafting a structured questionnaire from the research questions mentioned in section 1.5. Sub-questions were further added under each research question to further simplify the data collection process, see appendix A for the research instrument. The developed interview guide consisted of open-ended questions designed to extract more information from the participants. The lists of coal mines operating in Mpumalanga and Limpopo provinces were sourced from the internet. The researcher reached out to each mine to arrange interviews with the responsible maintenance practitioners following the Wits University ethics guidelines in terms of clearance certificate and obtaining consent from participants. The targeted sampling size for the interviews was a minimum of 15 participants, which is in line with Wits University guidelines for qualitative research interviews.

The data collection method utilised was structured interviews with maintenance engineers involved in the maintenance of plant and equipment at the coal mines. Interviews form part of data gathering in the form of oral questioning with pre-determined questions (Sharp et al., 2019). The structured interview consisted of a predetermined set of questions, which included both closed and open-ended types. These interviews were standardised so that all the respondents were interviewed; see Appendix A for the research question instrument used. A total of 15 participants were interviewed, consisting of engineers involved in maintenance at the coal mines. The engineers interviewed were a combination of large and small mining companies located in the Mpumalanga and Limpopo provinces of South Africa. During the interview process, each participant signed a consent form, indicating their consent to participate in the interview. See Appendix B for the consent form. A participant information sheet was provided to each participant and read aloud for audio recordings; see Appendix D. The interviews were conducted in person, while others were conducted virtually via Microsoft Teams. All interviews were audio recorded to ensure accurate data capture for analysis. The recordings were then transcribed into Microsoft Word format for further analysis in Nvivo software. The data was stored on a password protected computer for safe keeping.

The qualitative research study biases were mitigated as follows:

- Researcher bias: This happens when a researcher's beliefs or preferences influence the data collection, interpretation and analysis. To mitigate this bias, the researcher conducted reflexivity and triangulation when collecting and analysing the data. It was also important to ensure consistency of questioning during the interview sessions. It was also important that the researcher had no prior knowledge or experience with the topic in the context of coal mines.
- Selection Bias: This happens when the chosen sample of the study is not representative of the broader population. This was mitigated by ensuring that there were diverse participants from small and large coal mines. The participants had varying work experiences.
- Participant Bias: This happens when participants alter their responses to conform to perceived norms. During the interview, the researcher built rapport with the participants to gain their trust; the interviews took place at neutral venues preferred by the participants.

3.4 Research Instrument

The research instrument used was structured interviews. A set of predetermined questions which were asked to all the participants in the interviews to answer the research questions that align with the objectives outlined below:

a. Research objective (1): The current maintenance strategies being employed in South African coal mines.
b. Research objective (2): The types of predictive maintenance AI technologies that are adopted in the coal mining industry in South Africa.
c. Research objective (3): The driving factors that are stimulating the adoption of predictive maintenance AI technologies in South African coal mines.
d. Research objective (4): The factors that prevent or enable the adoption of predictive maintenance AI technologies in the South African coal mines.

3.5 Data analysis strategies and interpretation

The data collected from the interviews was collated to determine the factors that influence the adoption of AI-driven predictive maintenance. The inductive reflexive thematic analysis framework developed by Braun and Clarke (2006) was used to analyse the qualitative data; the framework provides a six-phase guide for conducting the thematic analysis. These steps involve familiarisation with the data, initial codes generation, searching for themes, defining themes, and the write-up.

The data used was collected via the interviews from a sample of 15 (fifteen) engineers involved in maintenance at the coal mines in South Africa. The engineers were from different companies, both junior and large mining companies. The interviews were conducted based on a set of research questions outlined in Appendix A. The interview sessions were audio-recorded with the participants' consent. The interviews were hybrid, i.e., some in-person and others online via Microsoft Teams virtual meetings. The length of the interview sessions ranged from about 15 minutes to over 30 minutes. The audio recordings were then transcribed into a Microsoft Word document. The 15 transcripts were then entered into NVivo, version 15 (see Appendix D for a screenshot from the NVivo software). Manual coding was performed in NVivo software to extract the codes from the interview transcripts. The codes in this context refer to labels or interpretive statements that are important to the research question or objectives. The codes were then categorised into subthemes and themes to address the research questions. Table 1 below presents the subthemes aligned with the research question, and Appendix F categorises the subthemes related to the research questions.

Table 3: Initial sub-themes align with research questions

Research Questions Initial Themes	Number of Participants	Participants Codes
(RQ1) Maintenance strategies employed	**15**	**69**
Alignment with technological advances	9	15
Current maintenance strategy employed	14	28
Maintenance strategy performance	8	8
Review of maintenance strategy	12	18
(RQ2) Adopted AI technologies	**14**	**48**
AI technologies employed in maintenance	10	11
Application of AI in maintenance	10	21
Benefits of AI in maintenance	8	16
(RQ3) AI adoption driving factors	**15**	**49**
Enhancing efficiency in maintenance	9	12
Factors driving the adoption of AI in maintenance	7	10
Improve plant or equipment availability	9	11
Potential cost reduction	13	16
(RQ4) AI adoption barriers or enablers	**15**	**52**
Cost of adopting AI in maintenance	10	13
Difficulty in accessing AI in maintenance	9	13
Investment in technology infrastructure	8	9
Role of aftermarket support	13	17

The aim was to carefully examine the data to identify common themes, issues, ideas, and patterns of meaning that emerged from the codes in the interview transcripts. The transcripts were read repeatedly to get familiar with the content, and notes were taken during this process. The initial codes were generated using NVivo software, and approximately 218 codes were manually identified from the transcripts, as shown in Table 1 above. The detailed list of the codes is shown in Appendix F. This process involved reading the transcripts and selecting codes that addressed the research questions.

Sixteen categories, which aligned with the research questions, were generated, and a total of 51 subthemes were identified from the codes in the transcripts (see the Appendix). The 51 subthemes were reviewed and categorised into nine themes, as shown in Table 2 below; details are provided in Appendix G.

Table 4: Nine themes generated from subthemes

1.	Theme 1: Limited technological advancement in maintenance practices
2.	Theme 2: Digital transformation in maintenance practices
3.	Theme 3: Optimised maintenance for performance and business alignment
4.	Theme 4: Predictive maintenance for failure prevention
5.	Theme 5: Enhanced safety through maintenance practices
6.	Theme 6: Cost efficiency and workforce implications of technological adoption
7.	Theme 7: Organisational adaptability in response to economic and technological Change
8.	Theme 8: Barriers to AI adoption due to cost and accessibility constraints
9.	Theme 9: Challenges in AI Adoption due to market awareness and support limitations

These themes were further reviewed and categorised into four main themes, as presented in Appendix H. Figure 2 illustrates the themes and main themes that emerged from the thematic analysis process.

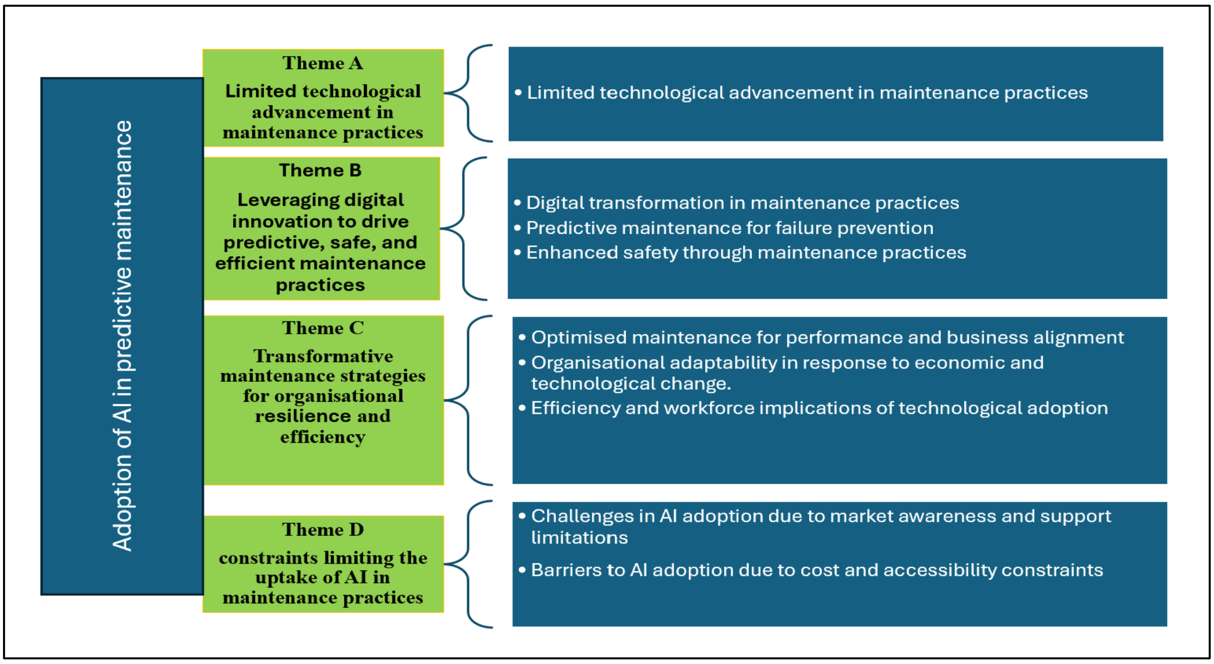

Figure 2: Main themes emerged from the analysis

The following themes were generated from the analysis:

(a) **Theme A**: Limited technological advancement in maintenance practices

The research question (1) required the examination of the current maintenance strategies being employed in South African coal mines. The generated theme highlights that there is a slow pace of adopting technology in the South African coal mines, and the coal mines are still heavily reliant on traditional types of maintenance strategies, such as preventative, condition-based, and reactive maintenance approaches.

(b) **Theme B**: Leverage digital innovation to drive predictive, safe, and efficient maintenance practices.

The research question (2) looked at the types of AI predictive maintenance technologies adopted by the coal mines. The generated theme highlights the importance of adopting digital innovation to improve maintenance practices for safe and reliable plant and equipment.

(c) **Theme C**: Transformative maintenance strategies for organisational resilience and efficiency.

The research question (3) driving factors that stimulate the adoption of predictive maintenance AI technologies in South African coal mines. The generated theme emphasises the importance of adopting the latest maintenance strategies, informed by technological advancements, to minimise operational costs and downtime through both maintenance and breakdowns, as well as lost time for plant and equipment.

(d) **Theme D**: Constraints limiting the uptake of AI in maintenance practices

The research question (4) looked at the factors that prevent or enable the adoption of predictive maintenance AI technologies in South African coal mines. The generated theme reveals the barriers impeding the adoption of AI in maintenance, with the main drivers being high costs, lack of awareness, and access to AI technology for maintenance, which results in slow adoption.

3.6 Limitation

The factors identified limit the generalisation of the findings presented in the report due to the focused nature of the study, which is derived from the coal mines and does not extend to other commodities. The cross-sectional study only captures a snapshot of the relationship between the factors or variables and cannot be used to predict the relationship over a longer period. This study focuses on the adoption of AI technology in predictive maintenance and does not compare its impact on operational costs. The study assumed that the selected population would be representative of the coal mining industry maintenance practitioners.

3.7 Quality assurance

To ensure quality assurance in the qualitative research, the focus was on the trustworthiness of the data and data analysis, which ensured that the data was credible and reliable. The participants for the interviews were selected to represent the populations of both large and small coal mines. The study participants were 15, which was the minimum recommended number for a qualitative study through interviews, ensuring that the saturation point for the study was reached.

3.8 Ethical considerations

The ethics clearance certificate for the research study is included in Appendix J. The research study strictly adheres to the conditions set by the Wits ethics committee, which include obtaining informed consent, maintaining participant anonymity, and ensuring participant confidentiality. This was to ensure that the participants are protected and that a high level of professionalism is maintained in the research being conducted. An ethics clearance certificate was obtained prior to data collection. There was a standard cover letter that advised the participants of the objectives of the research study, and this letter covered the five principles of ethics as mandated by the Wits ethics committee, which are informed consent, voluntary participation, harmlessness, anonymity, confidentiality and right of withdrawal, this letter can be seen in Appendix C. The participants also signed the consent forms; the form is shown in Appendix B.

Chapter 4: Research findings and discussions

This chapter presents the findings from the thematic analysis, providing insights into how the themes shed light on the research questions being investigated. Evidence is provided in the form of quotes from the participants to give context to emerging themes during the analysis. The findings section is then followed by a discussion of the findings in relation to the TOE and TAM frameworks, and the solutions to the research questions are addressed.

4.1 Research findings and discussions

Preliminary literature review has suggested that there is a snail pace adoption of artificial intelligence in the mining industry, while it is a known fact that the coal sector is facing challenges of uncertainty in funding for major capital projects due to climate change factors The artificial intelligence has the potential to improve efficiency and reduce maintenance costs which contributes a significant portion to overall operational costs of the mine. There appears to be a challenge or gap in adopting predictive maintenance artificial intelligence in South African coal mines, which could help improve efficiency and reduce maintenance costs. It is therefore essential to understand the gap in the adoption of AI technology in maintenance and the potential benefits of implementing AI in maintenance within South African coal mines.

It is important to reiterate that the study aims to shed light on the following objectives; the current maintenance strategies being employed in South African coal mines, the types of predictive maintenance AI technologies that are adopted in the coal mining industry in South Africa, the driving factors that are stimulating the adoption of predictive maintenance AI technologies in South African coal mines and the factors that prevent or enable the adoption of predictive maintenance AI technologies in the South African coal mines.

4.2 Research findings

The four themes generated during the data analysis are presented in this section to understand how these themes relate to the research study's Table objectives. Table 5 represents the thematic table that links the research objectives to the generated themes and the findings from the thematic analysis.

Table 5: Thematic representation of the research objectives, themes and findings

Research Objectives	Themes	Findings
The current maintenance strategies employed in South African coal mines.	Theme A: Limited technological advancement in maintenance practices	The generated theme highlights that there is a slow pace of adopting technology in the South African coal mines, and the coal mines are still heavily reliant on traditional types of maintenance strategies, such as preventative, condition-based, and reactive maintenance approaches.
The types of AI technologies used for predictive maintenance in the coal mining industry in South Africa.	Theme B: Leverage digital innovation to drive predictive, safe, and efficient maintenance practices.	The generated theme highlights the importance of adopting digital innovation to improve maintenance practices for safe and reliable plant and equipment.
The driving factors that are stimulating the adoption of predictive maintenance AI technologies in South African coal mines.	Theme C: Transformative maintenance strategies for organisational resilience and efficiency.	The generated theme emphasises the importance of adopting the latest maintenance strategies, informed by technological advancements, to minimise operational costs and downtime through both maintenance and breakdowns, as well as lost time for plant and equipment.
The factors that prevent or enable the adoption of predictive maintenance AI technologies in the South African coal mines.	Theme D: Constraints limiting the uptake of AI in maintenance practices	The generated theme reveals the barriers impeding the adoption of AI in maintenance, with the main drivers being high costs, lack of awareness, and access to AI technology for maintenance, which results in slow adoption.

4.2.1 Theme A: Limited technological advancement in maintenance practices

The theme reflects the traditional maintenance practices still employed at coal mines in South Africa, with minimal adoption of modern technologies in the maintenance space, such as digital tools and artificial intelligence. This highlights a slow pace of adoption of advanced maintenance strategies, and it highlights the lack of innovation in the highly competitive modern business environment faced by the mines regarding economic and environmental concerns. Almost all participants mentioned that they conduct preventative maintenance, condition-based maintenance and reactive maintenance, which are traditional maintenance approaches.

The interview extracts reflect this theme: Participant P1: "*The maintenance strategies that we employ, at the mine, it's got your condition-based maintenance, yeah, and we have also preventative maintenance. Yeah, we also have run-to-failure Strategies that is obviously on your Less costly equipment that you can run to failure. Yeah, and that's mostly about it*".

Some participants identified a need for improvement in adopting new technologies. Participant P1: "*I think that there's room for improvement. I definitely think we are not there yet in terms of technology advances.*"

Some participants see a lot of benefit utilising the current maintenance strategies, P2:*" Yeah, well, I think that's what we've been doing all the years. So, the benefits we've been seeing, but definitely there is a benefit in terms of, we do reach our business targets at the end of the year"*

4.2.2 Theme B: Leverage digital innovation to drive predictive, safe, and efficient maintenance practices.

The theme reflects the use of digital technology, such as condition monitoring and predictive maintenance, employed in some coal mining operations to enhance the effectiveness of maintenance on plant and equipment. This captures the transition from traditional maintenance practices to a more predictive maintenance approach, which enables the mining companies to anticipate equipment failures and optimise the maintenance practices.

Several participants noted the use of condition monitoring technology to monitor the health status of equipment. Participant P8: "*We also have implemented what we called the telematics monitor, which basically monitors the health of our equipment*".

Some original equipment manufacturers (OEM) have introduced condition monitoring on the equipment, as participant P10 alluded: "*They do have onboard monitoring sensors that continuously communicate their health and all of that for the equipment, and then I used to receive also emails*"

Most participants alluded to the aftermarket support by technology provider as very important to sustainability of the technology offerings, Participant P1*:" If you implementation a new system which has never existed before. You know aftermarket support, it's very important if you don't have that, then it's going to fail*".

4.2.3 Theme C: Transformative maintenance strategies for organisational resilience and efficiency.

The theme highlights the adoption of maintenance strategies that align with the business needs of mining companies, technological advancements, and economic and environmental pressures. The theme emphasises the need for mining companies to strategically transform their maintenance strategies through innovation, adaptability, and optimisation to reduce operational costs.

Out of the fifteen sample of participants interviewed, only one participant had started the process of adopting an AI predictive maintenance system, according to participant P12: "*We are busy with the project. Like I said, at the moment, in our primary equipment, we will deploy a set number of sensors that will take samples at millisecond intervals that get sent to the cloud and that data gets analysed by an AI algorithm that will predict failures that are going to happen and then also with that predict corrective actions you can take to prevent that equipment from failing*".

In the challenging environment the coal mines operate in, there is a greater need to build resilience and efficiency. Participant P12: "*In the current economic climate that we are in with the economic pressures that we're seeing, I think mostly it is about cost. So, you want to reduce your labour cost, your overheads.*"

Leadership plays a central role in putting up the transformative strategies as mentioned by participant P10:" *And also one thing that drives mines to adopt is, I think it's also the culture of the organisation. For example, if it's got a structured approach to technology adoption, you know when a technology arrives there's a process to review it, there's a process to stress test it in all of that*".

The cost reduction is seen as a significant benefit in the larger mines Participant P13: "*But one of the benefits is you know, it can be a cost saving initiative where we might be probably over* *maintaining certain items and based on actually prediction from AI, then we can reduce cost and the frequency of those activities*".

4.2.4 Theme D: Constraints limiting the uptake of AI in maintenance practices

The theme highlights the barriers or challenges that hinder the adoption of AI predictive maintenance in South African coal mines. The constraints include high implementation costs, limited access to advanced AI technologies for predictive maintenance, a lack of market awareness among the mining companies, insufficient local support, and the shortage of skilled AI professionals in South Africa. These factors are by far the most significant contributors to the slow adoption of AI in maintenance or digital transformation in general, which prevents, especially junior miners and some mining houses, from leveraging the high potential of AI to enhance maintenance efficiency and reliability of plant and equipment.

Almost all participants expressed concern about the high cost of the technology, which is perceived as a significant barrier. Participants P12, who are in the process of implementing AI predictive at their mine, attested to this fact P12" *It is still extremely expensive. I mean some equipment you need to put like 300 to 400 sensors to cover all the all the equipment that needs to be monitored and you're looking at around between 10000 to 15,000 rands per sensor, but I think as it progresses and improve, that should come down".*

Most participants attested to the lack of accessibility of AI predictive technology for maintenance. Participant P3:*" I think at the current moment with the resistance to adopt the AI is still a challenge to access the AI technology. So that's the only challenging part".*

Most participants believed that the local capability to produce AI systems for maintenance is very limited, participant P12:*" So I think in a country like South African, it is difficult. I mean, we do not really have access to this kind of technology at the moment that is developed in South African. I think in the rest of the world. It could possibly be more accessible in more developed countries, more mature economies where there is big tech sector".*

Most participants showed lack of awareness about companies that provides AI products for maintenance, participant P1:*" I think in South African, maybe I don't know about a lot of places that do it, but it seems to me like in South African especially, it is still quite difficult because I am not aware of a lot of companies that currently do this specifically for like coal mines in terms of maintenance".*

4.2.5 Conclusion: Summary of the research findings

The themes supported by the data extracted from participant interviews indicate a slow pace of adoption of AI technologies in maintenance at the coal mines, primarily driven by the high initial cost of adoption, awareness, and market access to the technology. However, participants expressed hope for improvement, suggesting that, over time, the cost will decrease as more local technology providers enter the AI in maintenance space.

4.3 Discussion on findings with respect to objectives and literature

This section discusses the key findings for the study concerning the following objectives; the current maintenance strategies employed in South African coal mines, the types of predictive maintenance AI technologies that are adopted in the coal mining industry in South Africa, the driving factors that are stimulating the adoption of predictive maintenance AI technologies in South African coal mines, the factors that prevent or enable the adoption of predictive maintenance AI technologies in the South African coal mines.

The key findings from the data in Theme A suggest that the coal mines are predominantly applying traditional maintenance approaches or strategies, which are preventative maintenance, condition-based maintenance and reactive maintenance. There is minimal adoption of modern maintenance practices in most coal mines, indicating a need for improvement. The TOE framework (Bryan & Zuva, 2021) technology development notes that the types of existing technologies currently being utilised in organisations might enable or constrain the adoption of new technologies. In terms of this assertion, the data suggest that the current maintenance strategies being employed at the coal mines still yield benefits as the mines are still able to achieve the set KPIs (key performance indicators) within the organisation. TAM framework (Taherdoost, 2017) with respect to attitude towards using technology, whether positive or negative feelings towards using the technology, the data suggests that most participants anticipate positive improvement in terms of adopting the new AI predictive maintenance, as long as the costing and access issues are resolved.

The key findings from the data on Theme (B) are that several coal mining companies are leveraging digital innovation, such as condition monitoring technologies for maintenance, and the importance of aftermarket support for the new technology. In terms of the TOE framework (Bryan & Zuva, 2021) with regards to technology the availability of technology plays an important role in the adoption of new technologies, the data for the research study supports this assertion due to the increasing adoption of condition monitoring technologies in the coal mines and these technologies are well supported by the original equipment manufacturers (OEM) and that makes access easier for the coal mines. In terms of the TAM framework (Taherdoost, 2017), with regard to the perceived ease of use, where a person believes that using a particular technology will be easier, this assertion is supported by the data from the research that most mining companies are leveraging the use of digital technologies supported by the OEM of the equipment.

The key findings from Theme (C) are that it emphasises the need for mining companies to strategically transform their maintenance strategies through innovation, adaptability, and optimisation to reduce costs. The TOE framework (Bryan & Zuva, 2021) suggests that the managerial structure, which informs leadership and decision-making processes in organisations, is crucial in driving technological change, and it also relates to the organisation's capabilities, especially financial resources. The data suggest that the management and leadership of coal mining companies are slow to adapt to new technologies, as they do not allocate resources where they can achieve maximum benefits using the technology. This is evident in the observation that only a small proportion of mining companies are adopting new technologies to enhance maintenance practices. The data also suggests that there is a greater focus on reducing costs due to challenging economic conditions.

The key findings from Theme (D) are that some barriers or challenges hinder the adoption of AI predictive maintenance in South African coal mines. These constraints include the high cost of AI technology, limited access to AI technology for predictive maintenance, a lack of awareness about AI technology for predictive maintenance, and insufficient local support for the technology.

The TOE framework (Bryan & Zuva, 2021), in terms of technology development, suggests that the availability of technology, in terms of the presence and accessibility of new technologies in the market, is crucial for enabling technology adoption. The research data shows a lack of presence and accessibility for AI predictive maintenance in South African coal mines. Consequently, mining companies are turning to overseas service providers to deliver the service, which makes the cost of adoption relatively high for local mining companies. In terms of the TAM framework (Taherdoost, 2017), the attitude towards the use of the technology is positive for those who understand the AI predictive maintenance system. The data indicate a lack of awareness about AI predictive maintenance among some mining companies, particularly among participants from junior miners.

The study has shown that by incorporating TOE and TAM frameworks in the research study, a holistic and more integrated approach was established when formulating the research questions and analysing the thematic analysis results and findings. The TOE is limited to organisational level while TAM is limited to user level and by combining the two frameworks it was evident that both organisational and user environments were catered for in a balanced approach in understanding the adoption of AI-driven technology in SA coal mines. This has provided a foundation for future studies to adopt a more integrated approach to technology adoption.

Chapter 5: Conclusions, recommendations and future research

5.1 Conclusions

In conclusion, the research study, based on the four themes generated from the data, reveals that coal mining companies in South Africa are still reliant on traditional maintenance strategies, with a limited but growing interest in adopting AI-driven predictive maintenance technologies. Some miners, especially the large mining houses, are leveraging digital innovations such as condition monitoring. The broader adoption of AI predictive maintenance is hindered by high costs, limited access, inadequate local support, and insufficient awareness. The TOE and TAM frameworks help to explain these subtleties by highlighting the importance of technology availability, organisational readiness, leadership commitment and user perceptions about the new technology. Despite these constraints, the overall attitude of the participants is positive towards adopting AI in maintenance, which suggests that with the right investment in infrastructure, awareness, and local support, coal mining companies can progressively transition to more efficient and data-driven maintenance strategies that enhance efficiency and reduce operational costs.

5.2 Recommendations

The findings from the study have shown that barriers impeding the adoption of AI in maintenance are high costs and access to AI technologies in South African coal mines. For the adoption of AI for predictive maintenance, it is recommended that AI service providers partner with the original equipment manufacturers to increase economies of scale and lower the costs associated with adopting new AI technologies in maintenance. This strategic action will align well with the OEMs of the equipment because they already have specific hardware that can be utilised to achieve this objective and reduce their costs of doing research and development in this area.

The lack of awareness about new AI technologies in maintenance is a significant concern, as maintenance engineers must stay current with the latest advancements in maintenance technology. It is therefore essential that technology providers are visible and participate in forums such as mining engineering associations and at stakeholder engagement meetings.

There is a greater need for local technology providers to enter the space of AI predictive maintenance technology development, facilitating access and greater inclusion for local mining companies, especially junior mines, who are financially constrained.

5.3 Future research

The study has shown that there is a slow pace of adopting technology in the South African coal mines; these coal mines are still heavily reliant on traditional types of maintenance strategies, such as preventative, condition-based, and reactive maintenance strategies. The study has shown that these strategies do not enhance efficiency and cost reduction. It is therefore unclear whether other mining houses that mine other commodities have adopted AI predictive maintenance. Since this research study on the adoption of AI technology in maintenance focused on coal mining companies in South Africa, it limits the generalisation of the findings presented in this report from this qualitative study. It is unclear whether the findings or the challenges faced by these coal mines extend to other commodities in the sector, such as gold, platinum, and other mineral mining companies. It is recommended that future research be conducted to encompass the broader mining sector and to investigate the adoption of AI-driven predictive maintenance across the entire South African mining industry.

The findings from the study have revealed that adopting the latest maintenance strategies informed by technological advancements has the potential to reduce costs and downtime. Therefore, it is recommended that future studies be conducted on the impact of operational costs resulting from the adoption of AI-driven artificial intelligence in the South African mining sector. The research study should take the form of a case study where AI-driven predictive maintenance has been adopted, and the cost-benefit analysis of the technology can be studied in detail in the mining sector of South Africa. From the findings it was revealed that insufficient local support, and the shortage of skilled AI professionals in South Africa is one of the challenges that hinders the adoption of AI driven predictive maintenance, it is therefore important to study the match of existing workforce skills and new skills required for these technological advances and how the education system should be enhanced to produce the necessary skills.

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7 Appendix A: Research Instrument: Interview Questions

Research Topic: The adoption of AI-driven predictive maintenance in South African coal mines.

The research instrument adopted for this study is a structured interviews with predetermined standard questions. The aim of the survey is to share light on the following objectives of the research:

1. The current maintenance strategies being employed in South African coal mines.
2. The types of predictive maintenance AI technologies that are adopted in the coal mining industry in South African.
3. The driving factors that are stimulating the adoption of predictive maintenance AI technologies in South African coal mines.
4. The factors that prevent and enable the adoption of predictive maintenance AI technologies in the South African coal mines.

The interview questions will be structured in the following manner.

1. **Demographic**
   1.1. Company name (Optional)
   1.2. Size of the company
   1.3.Sector/commodity
   1.4.Location
   1.5.Position of interviewee in the company
   1.6.Highest Qualifications
   1.7. Years of experience in maintenance environment

2. **Research objective (1): The current maintenance strategies being employed in South African coal mines.**

   2.1. What maintenance strategies do you employ at your mine?
   2.2. How does your maintenance strategies align with the current technological advances in the maintenance space?
   2.3.Do you think the current maintenance strategies being employed yield benefits?
   2.4.What informs the review of your maintenance strategy?

3. **Research question (2): The types of predictive maintenance AI technologies that are adopted in the coal mining industry in South African.**

3.1 What do you think about the application of AI in maintenance at the coal mine?
3.2 What AI-driven maintenance technologies do you employ at your mine?
3.3 What benefits do you think the AI-driven maintenance can bring to your mine?

4. **Research question (3): The driving factors that are stimulating the adoption of predictive maintenance AI technologies in South African coal mines.**

4.1 The preliminary literature review suggests that AI-driven predictive maintenance has the potential to reduce maintenance costs. What do you think about that?
4.2 The preliminary literature review suggests that AI-driven predictive maintenance enhances efficiency in maintenance. What is your view about that?
4.3 The preliminary literature review suggests that AI-driven predictive maintenance improves plant or equipment availability and reliability. What is your view about that?
4.4 What other factors do you think are driving mines to adopt AI-driven predictive maintenance?

5. **Research question (4): The factors that prevent or enable the adoption of predictive maintenance AI technologies in the South African coal mines.**

5.1 The preliminary literature review has suggested that the cost of adopting AI-driven predictive maintenance is relatively high. What is your view about that?
5.2 The preliminary literature review suggests that access to AI technology for predictive maintenance is challenging. What do you think about that?
5.3 The preliminary literature review has suggested that business that invests in technology infrastructure find the adoption of AI-driven predictive maintenance less challenging. What is your view about that?

5.4 The preliminary literature review suggests that the aftermarket support provided by the technology provider plays a crucial role in the success of adopting AI in maintenance. What is your view about that?

8 Appendix B: Consent Form

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

Consent Form For The Interview

Title of project

Adoption of artificial intelligence driven predictive maintenance in South Africa's coal mines.

Name of researcher :

Thabo Walter Mahlangu

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

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

Participant

…………………………………… (signature)
…………………………………… (name of participant)
…………………………………… (date)

9 Appendix C: Participant information sheet

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

Participant Information Sheet (PIS)

Dear Sir / Madam

My name is Thabo Mahlangu I am a Master's student in Business Administration at the University of the Witwatersrand, Johannesburg. My supervisor is Dr F Mlambo. I am conducting a research study about the adoption of artificial intelligence in maintenance in the coal mines. The study title is "adoption of artificial intelligence driven predictive maintenance in South Africa's coal mines".

I am inviting you to take part in an interview activity about the adoption of artificial intelligence in maintenance at the mine. If you decide to take part, your participation in this research study will last about 15min. The interview activity will take place online or in person at a convenient place.

With your permission, I would like to audio record the interview activity. This data will be stored in the archives of the university of the Witwatersrand in Johannesburg for one year and/or deleted after one year. Only the researcher will have access to the data.

During the research activity, I will need to ask for some personal information about you, including demographic information such as position, experience, qualifications, employment.

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

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

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

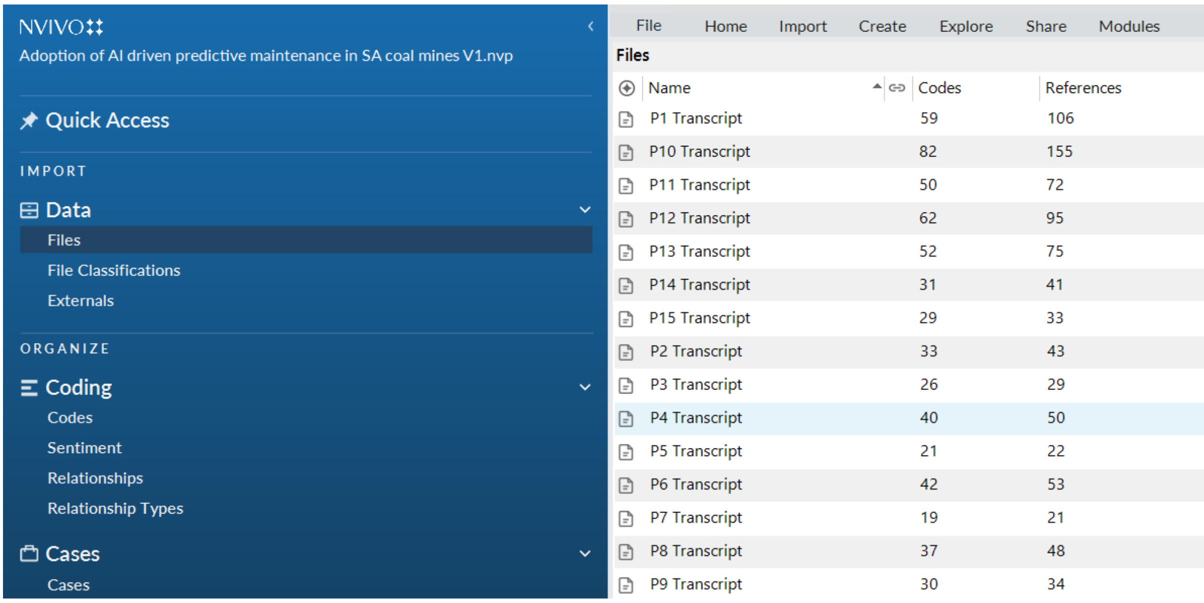
This research study will be written up as a research report. The report will be available on the university library website. If you would like to receive a summary of this report, I will be happy to send it to you.

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

Yours sincerely,

Researcher:
Thabo Mahlangu, 0215904h@students.wits.ac.za.
Supervisor:
Dr Farai Mlambo , Farai.Mlambo@wits.ac.za

10 Appendix D: Transcripts loaded in NVivo (define the columns)



11 Appendix E: List of subthemes and codes generated from the transcripts

No.	**Research Questions Initial Themes and Codes**	**Number of Participants**	**Participants Codes**
1	**(RQ1) Maintenance strategies employed**	**15**	**69**
2	Alignment with technological advances	9	15
3	Alignment with technological advances (theme)	9	14
4	Adopted digital tools for maintenance(sub-theme)	5	9
5	condition monitoring	1	1
6	condition monitoring (2)	1	1
7	digital planning scheduling tools like SAP	1	1
8	drones to inspect areas that one wouldn't necessarily have access	1	1
9	tracking of spares or tracking of component installation in terms of hours or time.	1	1
10	utilise technology such as sensors temperature to detect abnormalities, which then fits into our current maintenance strategy	1	1
11	we are busy with a project for an online condition based monitoring system, OK.And that system will use AI to predict failures	1	1
12	We do condition monitoring, we do laser monitoring and balancing of our screens and the crushers.	1	1
13	We recently about two years ago we even adopted the autonomous operation of drones	1	1
14	Improvement opportunity(sub-theme)	3	3
15	I think there's that gap is growing bigger and bigger	1	1
16	room for improvement	1	1
17	there is room for improvement	1	1
18	Manual work no adoption of technology(sub-theme)	2	2
19	we don't do a lot of technology	1	1
20	We don't have any technology.	1	1
21	Current maintenance strategy employed	14	28
22	Analytics based maintenance approach(sub-theme)	3	3
23	condition monitoring	1	1
24	condition monitoring (2)	0	0
25	predictive	1	1
26	predictive maintenance.	1	1
27	Traditional maintenance approach (sub-theme)	14	25
28	condition based maintenance	1	1

29	condition based maintenance.	1	1
30	corrective	1	1
31	corrective maintenance	1	1
32	currently we not following any the new tech advancement.	1	1
33	OEM recommendation in terms of replacements	1	1
34	OEM recommended maintenance	1	1
35	OEM requirements	1	1
36	preventative	1	1
37	preventative (2)	1	1
38	preventative maintenance	1	1
39	preventative maintenance (10)	1	1
40	preventative maintenance (2)	1	1
41	preventative maintenance (3)	1	1
42	preventative maintenance (4)	1	1
43	preventative maintenance (5)	1	1
44	preventative maintenance (6)	1	1
45	preventative maintenance (7)	1	1
46	preventative maintenance (8)	1	1
47	preventative maintenance (9)	1	1
48	preventative maintenance.	1	1
49	reactive maintenance	1	1
50	reactive maintenance (2)	1	1
51	Related inspection	1	1
52	usage based maintenance	1	1
53	Maintenance strategy performance	8	8
54	Achieves set KPIs(sub-theme)	5	5
55	definitely there is a benefit in terms of we do reach our business targets at the end of the year	1	1
56	I would say mostly so I would say 90% of what we do, does benefits	1	1
57	it does yield benefit to me because we are you know, achieve our KPIs	1	1
58	They do because you still are able to prevent any form of failures	1	1
59	we do get the benefit,	1	1
60	Room for Improvement(sub-theme)	3	3
61	I believe there's room for improvement to some areas	1	1
62	room for improvement	1	1
63	there's room for improvement	1	1
64	Review of maintenance strategy	12	18
65	Business re-alignment(sub-theme)	1	2
66	Business requirements	1	1
67	significant downsizing that needs	1	1
68	Equipment Failures(sub-theme)	9	9

69	catastrophic fail in one of the assets	1	1
70	critical damage or failures on piece of kit	1	1
71	failure	1	1
72	informed by failure mode	1	1
73	larger breakdowns	1	1
74	machine breaks down	1	1
75	reoccurring downtimes	1	1
76	repeated failures	1	1
77	repetitive, catastrophic or significant downtime	1	1
78	OEM requirements(sub-theme)	2	2
79	input from an OEM	1	1
80	introduction of new technology	1	1
81	Reducing performance(sub-theme)	2	2
82	decreasing availability or reliability	1	1
83	we run our meantime, before failures and then we monitor a number closely	1	1
84	Safety requirements(sub-theme)	3	3
85	change in legislation	1	1
86	it's also triggered by accidents	1	1
87	safety incident	1	1
88	**(RQ2) Adopted AI technologies**	**14**	**48**
89	AI technologies employed in maintenance	10	11
90	Adopted condition monitoring systems(sub-theme)	4	4
91	implemented what we called telematics monitor	1	1
92	just condition monitoring	1	1
93	onboard monitoring sensors that continuously communicate their health and all of that for the equipment	1	1
94	we are busy with the project. Like I said, at the moment, the way our primary equipment, we will deploy a set number of sensors that will take samples at millisecond intervals	1	1
95	AI not adopted(sub-theme)	6	6
96	I'm not aware of any AI	1	1
97	We currently do not have any of my applications on our systems	1	1
98	we don't employ any technology	1	1
99	We don't have any AI maintenance strategies or technologies that we've employed at the mine	1	1
100	we don't really have a lot of them in application	1	1
101	we're not really, we're not there yet.	1	1
102	Application of AI in maintenance	10	21

103	Ability to predict failures (sub-theme)	3	3
104	ability to predict imminent failures	1	1
105	I think it will be a benefit in terms of, it will predict what can fail and so that we can implement the solution beforehand	1	1
106	it could assist in better predictive predict condition of equipment	1	1
107	Affect current jobs(sub-theme)	3	4
108	cutting the number of people then the headcount in the field of maintenance	1	1
109	the technology and available skills for using this technology	1	1
110	there's a natural resistance to change, to accept technological advancement,	1	1
111	You still need the human, the intervention	1	1
112	Game changer(sub-theme)	1	1
113	In maintenance for the mining industry, let alone for coal industry, it's really a game changer	1	1
114	Optimise resource scheduling(sub-theme)	3	3
115	can schedule correctly and also have the right resources available	1	1
116	I think it's brilliant actually.For me, if we start to use AI where I see it, you could. You could even develop digital twins and with digital twins you can able to model and run scenarios without actually damaging your primary Equipment.	1	1
117	it will create great improvement the availability and reliability of equipment	1	1
118	Slow adoption locally(sub-theme)	2	3
119	In terms of the application of AI in SA We are not there.	1	1
120	it's seen as an IT project	1	1
121	The fact that not everyone is adopted it or maybe it's not widely adopted such there is a high cost to it.	1	1
122	Benefits of AI in maintenance	8	16
123	Better control of maintenance resources and reliability of systems(sub-theme)	5	9
124	better information fed to you in terms of the condition of your assets	1	1
125	corrective actions will be planned in advance	1	1
126	fewer breakdowns	1	1
127	help the maintenance team supervision to regain control of resources	1	1
128	identify potential failures	1	1
129	maintenance strategy would be less reactive and more preventative	1	1

130	predictability of maintenance	1	1
131	The benefit would be that AI has got less reliance on someone's experience, someone's knowledge, or even someone's presence, you know, and absenteeism	1	1
132	You will see the exact condition of your equipment	1	1
133	Cost reduction(sub-theme)	3	3
134	cost reduction	1	1
135	cost saving initiative	1	1
136	save cost	1	1
137	Increase equipment performance(sub-theme)	2	2
138	Increase your reliability	1	1
139	increased equipment uptime	1	1
140	Safety(sub-theme)	1	1
141	definitely will be safety	1	1
142	**(RQ3) AI adoption driving factors**	**15**	**49**
143	Enhancing efficiency in maintenance	9	12
144	Efficient maintenance practices(sub-theme)	4	4
145	It will be more efficient	1	1
146	It will improve the efficiency	1	1
147	So the conducted maintenance will be more efficient.	1	1
148	So your efficiency in terms of just that and you're picking up issues	1	1
149	Increase uptime(sub-theme)	2	2
150	It also sounds correct to me so what we've seen with this project of ours, so through AI driven predictive maintenance, you are able to like I said establish the through condition of your equipment at the time.	1	1
151	It will definitely a great deal improve the availability and reliability of equipment	1	1
152	maintenance resource optimization(sub-theme)	4	4
153	I think by having AI that will be able to tell you exactly what is the condition of your plant.	1	1
154	I think it does the efficiency because it should be able to tell you exactly where to.To focus on.	1	1
155	plan for all resources to be available just in time	1	1
156	spend more time in the correct places than spending a little time in all of the places	1	1
157	Factors driving adoption of AI in maintenance	7	10

158	Adapting to changing technology(sub-theme)	3	4
159	fear of being left behind	1	1
160	I believe that with a changing technology	1	1
161	mining houses that feel like they also need to adopt with the times to stay relevant	1	1
162	we are seeing AI pop up all over the place and in different environments	1	1
163	Economic pressures(sub-theme)	2	2
164	economic pressures that we're seeing	1	1
165	the productivity	1	1
166	Management and leadership(sub-theme)	3	4
167	I think there's a definite push from the top with some mines.	1	1
168	On the mines is safety	1	1
169	the culture of the organisation.	1	1
170	willing management and operations team	1	1
171	Improve plant or equipment availability	9	11
172	Better Breakdown prediction(sub-theme)	2	2
173	detected at its earliest stage of failure that it will save on your maintenance cos	1	1
174	I think from the feedback we received from our sister complex was that there was a great improvement with regards to predicting failures.	1	1
175	Better decision making(sub-theme)	3	4
176	Absolutely, this is. This is the game changer	1	1
177	better information to make decision making easier and bette	1	1
178	can predict better predict breakdowns before they happen	1	1
179	I think where AI is going to assist We're not saying it's going to replace human capital totally, but we're saying it will give us better information for better decisions	1	1
180	Equipment performance improvement(sub-theme)	4	4
181	I strongly believe that they that will.	1	1
182	it improves your equipment availability and your reliability as well	1	1
183	it will definitely improve the reliability and the availability of plant equipment.	1	1
184	Our project however, because it's still a pilot project. We have seen benefits,	1	1
185	Timeous completion of work(sub-theme)	1	1
186	better chance of executing and completing the work within a specified time frame	1	1
187	Potential cost reduction	13	16

188	Cost reduction(sub-theme)	7	8
189	AI will reduce the cost.	1	1
190	cost reduction surely surely it will	1	1
191	Especially when it comes to predictive maintenance	1	1
192	it could reduce the potential maintenance cos	1	1
193	It does the potential of reducing the maintenance cost	1	1
194	It will definitely reduce the cost of maintenance	1	1
195	my view is yes it	1	1
196	reduce cost in terms of breakdowns	1	1
197	Depend on accuracy of the system(sub-theme)	2	2
198	Great cost implications, not as great as having a breakdwown on it	1	1
199	obviously I mean the key factor is the accuracy of the AI predictive maintenance	1	1
200	Extend component with prediction(sub-theme)	3	3
201	extend component life based on the indication from predictive maintenance	1	1
202	I agree with the statement because if you are able to predict the failure of the equipment	1	1
203	reducing cost of doing unnecessary replacements	1	1
204	Labour reduction(sub-theme)`	3	3
205	because of the ability to have control on when you deploy personnel	1	1
206	It could potentially reduce your labour cost because you know you don't need maintenance personnel to go and do physical inspections every single day	1	1
207	People will reduced drastically and reduce the maintenance cost drastically.	1	1
208	**(RQ4) AI adoption barriers or enablers**	**15**	**52**
209	Cost of adopting AI in maintenance	10	13
210	Cost is too high(sub-theme)	6	7
211	cost of these technologies are good and the implementation cost is high	1	1
212	equipment you need to put like 300 to 400 sensors to cover all the all the equipment that needs to be monitored and you're looking at around between 10000 to 15,000 per Sensor	1	1
213	I think it is high	1	1

214	I think it's true on my side as I, as I said earlier on we, my previous organisation,	1	1
215	it is quite high	1	1
216	it is still extremely expensive	1	1
217	my view is that it is the truth	1	1
218	Small mining companies cannot afford(sub-theme)	2	2
219	I think it will be a bit difficult for some of the junior miners that they would want to adopt.	1	1
220	make it difficult for smaller mining houses.	1	1
221	Technology providers are price makers (sub-theme)	4	4
222	I believe it true but I don't think the technology, excuse me itself is expensive. I just think that people selling the product expensive.	1	1
223	It used to be in the beginning	1	1
224	the costs are high, but overtime it will I think it will equalise	1	1
225	the technology has been new and I those in the forefront perhaps are trying to milk this thing	1	1
226	Difficulty in accessing AI in maintenance	9	13
227	Difficult to access AI in SA(sub-theme)	6	6
228	AI is still a challenge to access the IA technology	1	1
229	I believe that with a changing technology	1	1
230	I don't think it's readily available right now as we would want	1	1
231	I think in a country like South Africa, it is difficult	1	1
232	it seems to me like in South Africa especially it is still quite difficult	1	1
233	it's difficult there.Are very few Research and development companies doing this for the mining house	1	1
234	Few player in AI space(sub-theme)	3	3
235	definitely challenging because only few currently have developed	1	1
236	mainly you know available internationally	1	1
237	That is why we're also using an overseas company for our project.	1	1
238	Not fully marketed locally(sub-theme)	4	4
239	It’s not yet Fully developed	1	1
240	it's not as widely known	1	1
241	still not a lot that have been developed locally	1	1

242	t could possibly be more accessible in more developed countries	1	1
243	Investment in technology infrastructure	8	9
244	Company stands a better chance(sub-theme)	5	5
245	I think what's critical, what the adoption is when you are clear on what you want your AI to deliver	1	1
246	if there's a company that that invests in a lot of technology, people are exposed to technological advances	1	1
247	improving in infrastructure it, it becomes much easier	1	1
248	need to implement AI driven technology for maintenance with regard to the hardware	1	1
249	once the company's attitude is having a good technology infrastructure and AI is just the perhaps one building block from that.	1	1
250	Not widely known(sub-theme)	4	4
251	But I don't know because I never used it	1	1
252	I don't think I've got much info	1	1
253	it's not as widely known	1	1
254	resistance from people from the workforce	1	1
255	Role of aftermarket support	13	17
256	Aftermarket support is important(sub-theme)	8	10
257	aftermarket is paramount	1	1
258	aftermarket support will be extremely critical	1	1
259	I mean after sales support plays an important role	1	1
260	I think it is very important	1	1
261	So I think first when adopt you will find challenges and then you will need the aftermarket support.	1	1
262	so you do need that assistance from the provider to continuously develop and update and Change With the advances in the technology,	1	1
263	the developer or the provider is important that they are right side by side by us or even ahead of us.	1	1
264	the project that we've got, we do have that support at the moment and it does help if you've got questions or if there's issues with the system.	1	1
265	The technology you know becomes sustainable.	1	1
266	You know aftermarket support, it's very important if you don't have	1	1

267	Need competition amongst technology providers(sub-theme)	3	3
268	a lot of aftermarket service providers, it makes the technology more accessible and also cheaper because now there's competition in prices	1	1
269	I mean the more possible the more possibilities for buying the product for introducing technology.	1	1
270	The solution provider wants to make money.So the easier it is, the less reliance you have on them and the less money they make. So for you to be reliant on them	1	1
271	Skills shortage risk(sub-theme)	3	3
272	Still a challenge with.Service providers because in South Africa.You you still don't have that.	1	1
273	Typically system is installed and people have been teething problems and it ends up being returned and nobody using it because of the lack of supply.	1	1
274	we are way behind in terms of understanding how the system works	1	1

12 Appendix F: Categorisation of Subthemes

Research question (1): The current maintenance strategies being employed in South African coal mines.	Research question (2): The types of predictive maintenance AI technologies that are adopted in the coal mining industry in South African.	Research question (3): The driving factors that are stimulating the adoption of predictive maintenance AI technologies in South African coal mines.	Research question (4): The factors that prevent or enable the adoption of predictive maintenance AI technologies in the South African coal mines.
(RQ1) Maintenance strategies employed	**(RQ2) Adopted AI technologies**	**(RQ3) AI adoption driving factors**	**(RQ4) AI adoption barriers or enablers**
1. Current maintenance strategies(theme) • Traditional maintenance approach (sub-theme) • Analytics based maintenance approach(sub-theme) Current maintenance strategies(theme)	2.2.1 Application of AI in maintenance(theme) • Ability to predict failures (sub-theme) • Optimise resource scheduling(sub-theme) • Affect current jobs(sub-theme) • Game changer(sub-theme)	3.1.1 Potential cost reduction(theme) • Cost reduction(sub-theme) • Labour reduction(sub-theme) ` • Extend component with prediction(sub-theme) • Depends on accuracy of the system(sub-theme)	4.1.1 Cost of adopting AI in maintenance(theme) • Cost is too high(sub-theme) • Technology providers are price makers (sub-theme) • Small mining companies cannot afford(sub-theme) 4.1.2 Difficulty in accessing AI in maintenance(theme)

• Traditional maintenance approach (sub-theme) • Analytics based maintenance approach(sub-theme) 1.1.2 Alignment with technological advances (theme) • Adopted digital tools for maintenance(sub-theme) • Improvement opportunity(sub-theme) • Manual work no adoption of technology(sub-theme) 1.2.3 Review of maintenance strategy (theme) • Equipment Failures(sub-theme) • Reducing performance(sub-theme)	• Slow adoption locally(sub-theme) 2.2.2 AI technologies employed in maintenance(theme) • AI not adopted(sub-theme) • Adopted condition monitoring systems(sub-theme) 2.2.3 Benefits of AI in maintenance(theme) • Better control of maintenance resources and reliability of systems(sub-theme) • Increase equipment performance(sub-theme) • Cost reduction(sub-theme) • Safety benefits(sub-theme)	3.1.2 Enhancing efficiency in maintenance(theme) • maintenance resource optimization(sub-theme) • increase uptime(sub-theme) • efficient maintenance practices(sub-theme) 3.1.3 Improve plant or equipment availability(theme) • Better decision making(sub-theme) • Timeous completion of work(sub-theme) • Better Breakdown prediction(sub-theme) • equipment performance improvement(sub-theme) 3.1.4 Factors driving adoption of AI in maintenance(theme)	• Difficult to access AI in South African (sub-theme) • Few players in AI space(sub-theme) • Not fully marketed locally(sub-theme) 4.1.3 Investment in technology infrastructure(theme) • Not widely known(sub-theme) • Resourced Company stands a better chance(sub-theme) 4.1.4 Role of aftermarket support(theme) • Aftermarket support is important(sub-theme) • Skills shortage risk(sub-theme)

• Business re-alignment(sub-theme) • Safety requirements(sub-theme) • OEM requirements(sub-theme) 1.2.4 Maintenance strategy performance(theme) • Achieves set KPIs(sub-theme) • Room for Improvement(sub-theme)		• Economic pressures(sub-theme) • Adapting to changing technology(sub-theme) • Management and leadership(sub-theme)	• Need competition amongst technology providers(sub-theme)

13 Appendix G: Categorisation of the subthemes into main themes

Theme 1: Limited technological advancement in maintenance practices	**Theme 2: Digital transformation in maintenance practices**		**Theme 3: Optimised Maintenance for Performance and Business Alignment**	**Theme 4: Predictive Maintenance for Failure Prevention**	**Theme 5: Enhanced Safety through Maintenance Practices**	**Theme 6: Cost Efficiency and Workforce Implications of Technological Adoption**	**Theme 7: Organisational Adaptability in Response to Economic and Technological Change**	**Theme 8: Barriers to AI Adoption Due to Cost and Accessibility Constraints**	**Theme 9: Challenges in AI Adoption Due to Market Awareness and Support Limitations**
• Traditional maintenance approach (sub-theme) • Manual work no adoption	• Analytics based maintenance approach(sub-theme) • Adopted digital tools for	•	• Improvement opportunity(sub-theme) • Reducing performance(sub-theme)	• Equipment Failures(sub-theme) • Ability to predict failures	• Safety requirements(sub-theme) • Safety benefits(sub-theme) •	• Cost reduction(sub-theme) • Cost reduction(sub-theme)	• Economic pressures (sub-theme) • Adapting to changing technolog	• Cost is too high(sub-theme) • Slow adoption locally	• Aftermarket support is important(sub-theme) • Skills shortage

of technology (sub-theme) • OEM requirements(sub-theme) • AI not adopted(sub-theme) •	maintenance(sub-theme) • Adopted condition monitoring systems(sub-theme) •		• Business re-alignment(sub-theme) • Achieves set KPIs(sub-theme) • Room for Improvement(sub-theme) • Optimise resource scheduling (sub-theme) • Game changer(sub-theme)	(sub-theme) • Depends on accuracy of the system(sub-theme) • Better Breakdown prediction(sub-theme) •		• Labour reduction(sub-theme) ` • Affect current jobs(sub-theme) • Need competition amongst technology providers(sub-theme) •	y(sub-theme) • Management and leadership(sub-theme) •	(sub-theme) • Technology providers are price makers (sub-theme) • Small mining companies cannot afford(sub-theme) • Difficult to	risk(sub-theme) • Few players in AI space(sub-theme) • Not fully marketed locally(sub-theme) • Not widely known(sub-theme) •

			• Game changer(sub-theme) • Better control of maintenance resources and reliability of systems(sub-theme) • Increase equipment performance(sub-theme) • Extend component with					access AI in South African (sub-theme) •	

			prediction(sub-theme) • maintenance resource optimization(sub-theme) • increase uptime(sub-theme) • efficient maintenance practices(sub-theme) • Better decision making(sub-theme) • Resourced Company						

			stands a better chance(sub -theme) • Timeous completion of work(sub-theme) • equipment performance improvement(sub-theme)						

14 Appendix H: Categorisation of the generated main themes

Theme A: Limited technological advancement in maintenance practices	**Theme B:** Leveraging Digital Innovation to Drive Predictive, Safe, and Efficient Maintenance Practices	**Theme C:** Transformative Maintenance Strategies for Organisational Resilience and Efficiency	**Theme D:** Constraints Limiting the Uptake of AI in Maintenance Practices
• Limited technological advancement in maintenance practices	• Digital transformation in maintenance practices • Predictive Maintenance for Failure Prevention • Enhanced Safety through Maintenance Practices	• Optimised Maintenance for Performance and Business Alignment • Efficiency and Workforce Implications of Technological Adoption • Organisational Adaptability in Response to Economic and Technological Change	• Barriers to AI Adoption Due to Cost and Accessibility Constraints • Challenges in AI Adoption Due to Market Awareness and Support Limitations

15 Appendix J: Ethics Clearance Certificate

Graduate School of Business Administration
University of the Witwatersrand, Johannesburg

Wits Business School

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

Ethics Clearance Certificate

Ethics protocol number: WBS/BA0215904h/701

This certificate is only valid with a legitimate ethics protocol number and signed by the Researcher (below).

This certificate is only valid if accompanied by formal permission from the relevant stakeholder(s).

Project title	Adoption of artificial intelligence driven predictive maintenance in South Africa's coal mines
Investigator / Researcher	Mr Thabo Mahlangu
Nature of Project	MBA (Research Article)
Decision of the Committee	Approved, provided stakeholders and participants are guaranteed anonymity and confidentiality.
Issue Date of Certificate	24/10/2024
Expiry date	Date of submission of the project / research report
Chairperson	Dr Ayanda Magida ☎ +27 11 717 3953 ✉ ayanda.magida@wits.ac.za

Declaration by Researcher

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

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

Signature

28/10/2024
Date: