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# EMBRACING TECHNOLOGY TO REJUVENATE SOUTH AFRICAN MINING: A COMPARATIVE CASE STUDY ANALYSIS OF A SOUTH AFRICAN AND AN AUSTRALIAN MINING FIRM

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**Dissertation submitted for the degree of Master of Commerce by Research**

## ABSTRACT

It is well recognised that the mining industry is the historic bedrock of the South African economy. However, since 2000 the industry has shown signs of decline that include, *inter alia*, a slowdown in growth along with productivity issues. Since South Africa (SA) lags behind its global competitors in terms of technological innovation and implementation; many leaders in the mining industry are of the view that the increased use of technology will arrest this decline and restore the mining industry to a stronger position in the South African economy. What is, however, not fully understood is the extent to which technological change is contextually path dependent. This meaning that technological change in an industry is restricted by past events which enhance its resistance to change. This results in a lack of knowledge regarding how best to manage technological change. This would include understanding the most suitable implementation methods for certain contexts.

The intention of this dissertation is to explain why firms in the South African mining industry lag behind their global competitors in terms of technological adoption. It aims to understand how differing contextual factors influence mining firms' behavior, that, in turn, has an industry-level effect. It aims to understand how firms should manage this technology properly to optimise its interaction with its environment. Additionally, it aims to understand which theoretical approach, in relation to technological change, mining firms should follow to properly navigate their technological trajectories in light of contextual imperatives.

The unit of analysis in this methodology is at the firm level. It takes specific contextual factors into account to determine which method of implementation is more appropriate for new technological advancements. This was executed by conducting two methodology phases. Phase 1 of the methodology which consisted of a holistic comparative case study analysis of a South African and an Australian mining firm. This study phase analysed archival documents that tracked changes in the responses of these mining firms over time. This was conducted using information from their financial statements and company reports, with the aim of investigating how these matched the government and environmental contexts seen in policy and country related documents. Phase 2 of the methodology comprised a qualitative analysis that used individual interviews in an attempt to develop useful insights that contextualise and support the findings of Phase 1. Various theoretical predictions have been derived in the form of propositions. The theory thus inductively developed has been used to answer some *how* and

*why* questions about the strategic responses of firms to contextual imperatives. The study therefore produced a holistic analysis illustrating how each firm engaged with its respective contexts and how this may have resulted in path dependant relationships regarding technological innovation.

The research emphasises that the South African mining industry's lag in technological adoption compared to global competitors could be attributed to an imbalanced innovation focus and a restrictive business context. It suggests that firms should address their technological and contextual needs separately to effectively manage innovation. The findings also stress that incremental improvements alone, are unlikely to enable a catch-up up with global leaders. Instead, radical interventions are necessary to shift the current trajectory toward one that prioritises productivity to achieve social objectives, enabling a plausible catch up.

Keywords for this study include: Automation, drivers of innovation, contextual factors, technological trajectories, innovation ecosystem, incremental innovation, radical innovation, foreign direct investment, absorptive capacity, productivity, sustainability, economic growth

## DECLARATION

I declare that this research project is my own work. It is to be submitted in fulfilment of the requirements for the degree of Master of Commerce at the University of the Witwatersrand. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorisation and consent to carry out this research.

T.Vink

**TARRYN VINK**

Signed on this the 12 day of September 2023

## ACKNOWLEDGMENTS

I would like to express my deepest gratitude to the interview respondents; to all the industry experts who contributed to this research as participants, thank you very much. To my supervisor, Professor Chris Callaghan for his wisdom, guidance and patience in all that my work. I am grateful to my family for their constant support and encouragement.

# TABLE OF CONTENTS


ABSTRACT II

DECLARATION IV

ACKNOWLEDGMENTS V

TABLE OF CONTENTS VI

LIST OF TABLES X

LIST OF FIGURES XI

CHAPTER 1: RESEARCH PROBLEM AND RESEARCH QUESTIONS 1

1. INTRODUCTION 1
1.1 BACKGROUND OF THE STUDY 1
1.2 RESEARCH PROBLEM 2
1.3 RESEARCH QUESTION 4
1.4 STUDY AIMS 6
1.5 RESEARCH OBJECTIVES 7
1.6 CHAPTER SEQUENCE 8
1.6.1 CHAPTER ONE: STUDY BACKGROUND, RESEARCH PROBLEM AND RESEARCH QUESTIONS 8
1.6.2 CHAPTER TWO: LITERATURE REVIEW 8
1.6.3 CHAPTER THREE: RESEARCH METHODOLOGY 9
1.6.4 CHAPTER FOUR: METHODOLOGY PHASE 1- CASE STUDY FINDINGS 9
1.6.5 CHAPTER FIVE: METHODOLOGY PHASE 2 – INTERVIEW-BASED QUALITATIVE ANALYSIS FINDINGS 9
1.6.6 CHAPTER SIX: DISCUSSION AND CONCLUSION 10
1.7 CONCLUSION 10

CHAPTER 2: LITERATURE REVIEW 11

2.1 INTRODUCTION 11
2.2 THEORETICAL OVERVIEW 11
2.2.1 THE NELSON AND WINTER EVOLUTIONARY THEORY OF ECONOMIC CHANGE 11
2.2.2 NEO-SCHUMPETERIAN LONG WAVE THEORY 14
2.2.3 THE IMPORTANCE OF CONSIDERING CONTEXTUAL FACTORS 15
2.2.4 THEORETICAL GAP 16
2.3 HISTORY OF THE GLOBAL MINING INDUSTRY 17
2.4 THE GLOBAL MINING INDUSTRY TODAY 17
2.5 HISTORY OF THE SOUTH AFRICAN MINING INDUSTRY 18
2.6 THE SOUTH AFRICAN MINING INDUSTRY TODAY 19
2.6.1 IMPORTANCE OF THE INDUSTRY 19
2.6.2 THE MULTIPLIER EFFECT OF THE MINING INDUSTRY 20
2.7 DECLINE IN THE SOUTH AFRICAN MINING INDUSTRY 21
2.8 COUNTRY SPECIFIC CONTEXTUAL FACTORS 22
2.8.1 LIMITED BASIC EDUCATION 22
2.8.2 HIGH UNEMPLOYMENT RATES 23

2.8.3 LAGGING INFRASTRUCTURE DEVELOPMENT 23
2.8.4 ELECTRICITY SUPPLY ISSUES 24
2.8.5 REGULATORY UNCERTAINTY 25
2.8.6 DEEP MINES CREATING DIFFICULT MINING GEOLOGY 26
2.8.7 COST COMPETITIVENESS 26
**2.9 COMPANY PERFORMANCE 27**
**2.10 LABOUR PRODUCTIVITY 28**
**2.11 THE FOURTH INDUSTRIAL REVOLUTION 29**
**2.12 WHY INNOVATION MATTERS 32**
2.12.1 TYPES OF INNOVATION 34
**2.13 INVESTMENT IN TECHNOLOGICAL R&D 34**
**2.14 INVESTMENT IN HUMAN CAPITAL 36**
**2.15 ABSORPTIVE CAPACITY 37**
**2.16 FOREIGN DIRECT INVESTMENT IN MINING 38**
2.16.1 TECHNOLOGY SPILLOVERS IN MINING 39
**2.17 CONTRIBUTION OF THE STUDY 39**
**2.18 CONCLUSION 44**

**CHAPTER 3: RESEARCH METHODOLOGY 45**

**3.1 INTRODUCTION 45**
**3.2 RESEARCH CONTEXT 45**
**3.4 RESEARCH PARADIGM 46**
**3.4.1 CRITICAL REALISM 46**
3.4.2 ONTOLOGICAL ASPECT OF CRITICAL REALISM 47
3.4.2.1 ONTOLOGICAL ASPECT OF CRITICAL REALISM: STUDY PHASE 1 48
3.4.2.2 ONTOLOGICAL ASPECT OF CRITICAL REALISM: STUDY PHASE 2 48
3.4.3 EPISTEMOLOGICAL ASPECT OF CRITICAL REALISM 48
3.4.3.1 EPISTEMOLOGICAL ASPECT OF CRITICAL REALISM: STUDY PHASE 1 49
3.4.3.2 EPISTIMOLOGICAL ASPECT OF CRITICAL REALISM: STUDY PHASE 2 49
3.4.4 AXIOLOGICAL ASPECT OF CRITICAL REALISM 49
3.4.4.1 AXIOLOGICAL ASPECT OF CRITICAL REALISM: STUDY PHASE 1 49
3.4.4.2 AXIOLOGICAL ASPECT OF CRITICAL REALISM: STUDY PHASE 2 49
**3.5 RESEARCH APPROACH FOR PHASE 1&2: INDUCTIVE 50**
**3.6 METHODOLOGICAL CHOICE FOR PHASE 1&2: QUALITATIVE 50**
**3.7 RESEARCH DESIGN 51**
3.7.1 A MULTI-METHOD APPROACH 51
3.7.1.1 PHASE 1 RESEARCH STRATEGY: CASE STUDY RESEARCH 51
3.7.1.2 PHASE 2 RESEARCH STRATEGY: INTERVIEW-BASED QUALITATIVE ANALYSIS 52
**3.8 SAMPLING 53**
3.8.1 PHASE 1: SAMPLING SIZE ESTIMATION 53
3.8.1.1 PHASE 1: SAMPLING TECHNIQUE 53
3.8.2 PHASE 2: SAMPLING SIZE ESTIMATION 54
3.8.2.1 PHASE 2: SAMPLING TECHNIQUE 54
**3.10 DATA COLLECTION METHODS 55**
3.10.1 PHASE 1: DATA COLLECTION 55
3.10.1.1 ARCHIVAL DOCUMENT REVIEW: COUNTRY CONTEXTUAL DOCUMENTS 56
3.10.1.2 ARCHIVAL DOCUMENT REVIEW: COMPANY DOCUMENTS 56
3.10.2 PHASE 2: DATA COLLECTION 57
3.10.2.1 INDIVIDUAL INTERVIEWS 57
3.10.2.1.1 THEORETICAL SATURATION 58
**3.11 DATA QUALITY CONTROL 60**

**3.12.1 PHASE 1: DATA ANALYSIS METHODS 62**
3.12.1.1 WITHIN-CASE ANALYSIS LAYOUT 63
3.12.1.2 CROSS-CASE ANALYSIS LAYOUT 64
**3.13 PHASE 2: DATA ANALYSIS METHODS 65**
**3.14 ETHICAL CONSIDERATIONS 67**
**3.15 CONCLUSION 67**

**CHAPTER 4: CASE STUDY FINDINGS 68**

**4.1 INTRODUCTION 68**
4.1.2 INTRODUCTION TO EACH CASE 68

**4.2 FIRM A – ANGLO AMERICAN WITHIN-CASE ANALYSIS 69**

3.12.2 FOCUS AREA ONE: CONTEXT 69
4.2.2 FOCUS AREA TWO: HOW INNOVATION FITS INTO THE IDENTITY OF THE FIRM 80
4.2.3 FOCUS AREA THREE: FIRM ACTIVITY IN THE INNOVATION SYSTEM 80
4.2.4 FOCUS AREA FOUR: TYPE OF INNOVATION AND TECHNOLOGICAL ACTIVITY PURSUED BY THE FIRM 81
4.2.4.1 THE IMPORTANCE OF P101 82
4.2.4.2 THE IMPORTANCE OF FUTURESMART MINING? 84
4.2.4.3 THE *WHY* BEHIND THE FIRM'S INNOVATION 90
4.2.5 FOCUS AREA FIVE: FIRM INVOLVEMENT IN DEVELOPING NETWORKS AND COLLABORATION 92

**4.3 FIRM B – RIO TINTO WITHIN-CASE ANALYSIS 97**

4.3.1 FOCUS AREA ONE: CONTEXT 97
4.3.2 FOCUS AREA TWO: HOW INNOVATION FITS INTO THE IDENTITY OF THE FIRM 100
4.3.3 FOCUS AREA THREE: FIRM ACTIVITY IN THE INNOVATION SYSTEM 101
4.3.4 FOCUS AREA FOUR: TYPE OF INNOVATION AND TECHNOLOGICAL ACTIVITY PURSUED BY THE FIRM 102
4.3.4.1 WHAT IS AUTOMATION, SMART MINING, AND AI? 102
4.3.4.2 THE WHY BEHIND THE FIRM'S INNOVATION 108
4.3.5 FOCUS AREA FIVE: FIRM INVOLVEMENT IN DEVELOPING NETWORKS AND COLLABORATION 109

**4.4 FIRM A AND B – CROSS-CASE ANALYSIS 114**

4.4.1 LEVEL OF FIRM COMMITMENT TO DEVELOPING TECHNOLOGICAL CAPACITY 114
4.4.2 MAIN FIRM DRIVER FOR INNOVATIVE CHANGE 120
4.4.3 NATURE OF TECHNOLOGICAL INVESTMENTS MADE BY FIRM 122
4.4.4 INFLUENCE OF COUNTRY CONTEXTUAL FACTORS ON FIRM PATH DEPENDENT TECHNOLOGICAL TRAJECTORY 126
4.4.5 FIRM CULTURE REGARDING TECHNOLOGICAL DEVELOPMENT 132
**4.5 CONCLUSION 136**

**CHAPTER 5: INTERVIEW-BASED QUALITATIVE ANALYSIS FINDINGS 138**

**5.1 INTRODUCTION 138**
**5.2 THE DATA STRUCTURE 138**
**5.3 THE GROUNDED MODEL 139**
**5.4 INVESTMENT 181**
**5.5 REJUVENATION 185**
5.5.1 REJUVENATION THROUGH EXPLORATION 185
5.5.2 REJUVENATION THROUGH EDUCATION 186

5.5.3 REJUVENATION THROUGH INCREASED USE OF INNOVATIVE TECHNOLOGY 188
5.5.4 REJUVENATION THROUGH ACCESSING DEEP-LEVEL GOLD RESOURCES 192
**5.6 A LINK BETWEEN SUSTAINABILITY AND PRODUCTIVITY 196**
**5.7 THE CO-EXISTENCE BETWEEN HUMAN AND MACHINE 199**
**5.8 THE INFLUENCE OF CONTEXT ON TECHNOLOGICAL TRAJECTORY 201**
**5.9 A LINK BETWEEN THE SOCIAL NARRATIVE AND NEED FOR PRODUCTIVITY 204**
**5.10 CONCLUSION 205**

**CHAPTER 6: DISCUSSION AND CONCLUSION 206**

**6.1 INTRODUCTION 206**
**6.2 SYNTHESIS OF THE RESULTS AND COMPARISON WITH EXISTING LITERATURE 206**
6.2.1 GLOBAL CATCH UP REQUIRES A CERTAIN TYPE OF INNOVATION ACTIVITY 206
6.2.2 SOCIAL UPLIFTMENT SHOULD BE THE OBJECTIVE OF THE INDUSTRY, BUT PRODUCTIVITY THE VEHICLE TO ACHIEVE THIS 211
6.2.3 ANALYSIS OF TRAJECTORY AS OPPOSED TO CONTEXT TO DETERMINE STRATEGY 214
6.2.4 INVESTMENT UNDERPINS THE ABILITY TO REJUVENATE 217
**6.3 THEORETICAL AND PRACTICAL IMPLICATIONS 221**
**6.4 LIMITATIONS OF THE STUDY 222**
**6.5 AVENUES FOR FUTURE RESEARCH 223**

**REFERENCE LIST 224**

**APPENDIX 266**

**APPENDIX 1: CONTRIBUTIONS FROM EXISTING LITERATURE 266**
**APPENDIX 2: SEMI-STRUCTURED INTERVIEW GUIDE (SOUTH AFRICAN INTERVIEWEES) 274**
**APPENDIX 3: SEMI-STRUCTURED INTERVIEW GUIDE (AUSTRALIAN INTERVIEWEES) 278**
**APPENDIX 4: PARTICIPANT INFORMATION SHEET 283**
**APPENDIX 5: CONSENT FORM 285**
**APPENDIX 6: ETHICS APPROVAL 287**
**APPENDIX 7: SUMMARY OF TURNITIN REPORT 288**
**APPENDIX 8: PROOF OF LANGUAGE EDITING 289**

## LIST OF TABLES

Table 1: Interview participant information ..... 57
Table 2: Within-case analysis criteria ..... 63
Table 3: Similarity criteria used in selecting each case ..... 69
Table 4: SA - Political & Legal Context ..... 70
Table 5: SA - Economic Context ..... 72
Table 6: SA - Social Context ..... 74
Table 7: SA - Technological Context ..... 77
Table 8: SA Environmental Context ..... 78
Table 9: Tracking of firm innovation activity over an eleven-year period ..... 81
Table 10: P101 Functions ..... 82
Table 11: FutureSmart Mining Functions ..... 84
Table 12: Drivers and Nature of Innovation ..... 87
Table 13: AA's existing collaboration partners in 2022 ..... 92
Table 14: AA's 2022 SMME development ..... 95
Table 15: AA's efforts to enhance digital literacy in the current and future workforce ..... 96
Table 16: Australia's PESTLE Context ..... 97
Table 17: Tracking firm innovation activity over an eleven-year period ..... 101
Table 18: Automation Functions ..... 103
Table 19: Smart Mining Functions ..... 105
Table 20: Drivers and nature of Innovation ..... 106
Table 21: RT's existing collaboration partners in 2022 ..... 109
Table 22: RT's 2022 SMME development ..... 111
Table 23: RT's efforts to enhance digital literacy in the current and future workforce ..... 112
Table 24: Similarities and differences of innovation system activity ..... 118
Table 25: Similarities and differences of the firms' *why* behind its innovation drive ..... 121
Table 26: Similarities and differences regarding the nature of the innovation pursued ..... 124
Table 27: South African context influencing AA: Heat map diagram ..... 128
Table 28: Australian context influencing RT - Heat map diagram ..... 129
Table 29: Possible interaction between contextual environment and firm strategic direction ..... 129
Table 30: Similarities and differences regarding firm innovation culture ..... 133
Table 31: Dimensions, Themes, Categories, and Quotes ..... 145
Table 32: Concluding points for the type of innovation activity needed ..... 207
Table 33: Concluding points for the link between achieving social objectives and promoting productivity increases ..... 212
Table 34: Concluding points for the use of trajectory as opposed to context to determine strategy ..... 215
Table 35: Concluding points on the need for investment for a successful rejuvenation ..... 218
Table 36: Primary contributions from previous literature ..... 266

## LIST OF FIGURES

Figure 1: Guiding Conceptual Framework .....21
Figure 2: Fraser Institute Rankings - SA Investment Attractiveness.....73
Figure 3: SA's share of global exploration budgets .....74
Figure 4: Comparison of SA and Australia's Unemployment Rate .....76
Figure 5: Illustration of main drivers for AA's specific programme functions implemented in SA vs other countries of operation.....89
Figure 6: Illustration of main drivers for RT's specific programme functions implemented in Australia vs other countries of operation .....107
Figure 7: R&D expenditure comparison.....115
Figure 8: Exploration expenditure comparison.....115
Figure 9: Patent activity comparison from 2002 - 2022 .....116
Figure 10: AA collaboration partner driver .....117
Figure 11: RT collaboration partner driver.....117
Figure 12: Drivers of innovation behind each innovation programme function .....121
Figure 13: Operational impact of AA's innovation programme functions .....123
Figure 14: Operational impact of RT's innovation programme functions .....124
Figure 15: Heat map colour scale .....126
Figure 14: Heat map colour key.....127
Figure 17: Data Structure.....139
Figure 18: Grounded Model.....180

# CHAPTER 1: RESEARCH PROBLEM AND RESEARCH QUESTIONS

## 1. INTRODUCTION

### 1.1 BACKGROUND OF THE STUDY

It is well recognised that the mining industry is the historic bedrock of the South African economy (Cassim, Goodman & Rajagopaul, 2019; Jaessing 2022). However, since 2000 the industry has shown signs of decline that include, *inter alia*, a slowdown in growth and productivity (Mbazima, 2020). A recent report on 29 major mining companies in South Africa (SA) illustrated declining market capitalisation values for all companies analysed (PricewaterhouseCoopers [PwC], 2017). A 25% decline from R560 billion in 2016 to R420 billion in 2017 was evident in the figures (PwC, 2017). Compounding the issues mentioned in this report, is the problem of declining employment with the industry having lost 23 000 jobs between 2012 and 2019 (Bulbulia, 2021). In 2015 mining was the only loss-making sector of the South African economy with an aggregate net loss of R37bn (The Chamber of Mines, 2016). Mining production in South Africa has also fallen, with a decline of 3.5% year-on-year in June 2024, dropping below the expected decline of 0.8% (Trading Economics, 2024). In Addition to this, Minerals Council statistics indicate that mining net fixed investment in South Africa, was close to zero in 2021 (Fabricius, 2024).

Other mining companies around the globe have, however, seen vast increases in productivity (McKinsey&Company, 2019). In Australia, mining remains the single largest sector and a foundation of stability and profitability (Casey, 2021). Recent figures from the Australian Bureau of Statistics show that mining contributed to more than one tenth of the economy between 2019 and 2020, with a $202 billion contribution to Australian Gross Domestic Profit (GDP) (Zakharia, 2020) as well as resource exports reaching $221.2 billion in value over the same period (Casey, 2021). Mining's high export revenue has been one of the main factors that enabled Australia's economic recovery after the COVID-19 pandemic, with output increasing by 1.1% from 2019 to 2021 (Constable, 2021). Mining employment has also surged over the last five years, reaching a total figure of 278 800 in 2015 (Constable, 2020). With an increase of 25,000 jobs in 2022, this set a new record high (Minerals Council Australia [MCA], 2022a). The Australian government expects employment to increase by 6.2% over the next three years (CSIRO, 2021). Compared to this flourishing industry in Australia, the mining industry in SA

needs to focus on improving its cost-competitiveness to ensure that sharper declines in productivity are avoided in the future. McKinsey MineLens conducted research on different Productivity Indices for over 240 mining operations globally. They found that 42% of South African mining revenue and 47% of mining jobs are vulnerable and lie in the bottom quartile of the cost competitiveness curve (McKinsey&Company, 2019).

Many leaders in the mining industry suggest that the increased use of technology will arrest this decline and restore the mining industry to a stronger position in the South African economy (Evans, 2020; McKinsey&Company, 2019; Spooner, 2023). SA, unfortunately, lags behind its global competitors in terms of technological innovation and implementation (Oxford, 2015).

## 1.2 RESEARCH PROBLEM

Mining in the 1980s contributed 21% to the South African GDP, an all-time high, as gold production soared. Since 2000 the industry has shown signs of decline; currently the sector contributes only 8.2% to GDP mainly because of the decline in the production of gold (Buthelezi, 2021). In 2015, mining was the only loss-making sector of the South African economy with an aggregate net loss of R37 billion (The Chamber of Mines, 2016).

However, despite the decrease in mining productivity and output the mining industry remains a vital component of the South African economy. This can be seen in the vast mineral wealth of South African mining reserves that are estimated to be worth $2.5 trillion (Marshall, 2023) along with the amount of foreign savings attracted into SA, with mining contributing R1.9 trillion to the value of the Johannesburg Stock Exchange (Marshall, 2023). Additionally, according to the Minerals Council SA (MCSA), mining contributes almost 500 000 to direct employment in the economy that accounts for R186.5 billion spent in wages and salaries (Minerals Council SA [MCSA], 2023a). The paradox that such vast mineral wealth in a country can be coupled with crippling decline, is not easily understood. Additionally, the difference in success between the South African and Australian mining industries, and how the uptake of technology has influenced this difference, is not well understood.

South African mining, unfortunately, lags behind its global competitors in terms of technological innovation; it has been sluggish in its adoption of new technology as an aid to combat this decrease in productivity (Mining Technology, 2020). The research problem relates to the lack of knowledge regarding *why* and *how* the South African mining industry lags behind

its global competitors, and importantly, what the most appropriate approaches for closing this gap would be in light of specific contextual environments.

Innovation, including the adoption of new technology, is necessary if the mining industry is to be transformed (Mining Technology, 2020). Transformation in the South African mining industry should be particularly focused on, redressing the inequalities of the past; investing in initiatives to upskill the current and future workforce to ensure inclusive growth; protecting and uplifting the vulnerable in society; prioritising community growth and development and also achieving continued economic growth and industry competitiveness (Jansen van Rensburg & Moraka, 2015). More than half of the National Development Plan's (NDP) priorities for 2030 can be met by mining if its productivity is brought back on track (The Chamber of Mines, 2016). SA has some of the best mineral resources in the world and the industry has huge potential for growth (Government Communication and Information Systems, 2012). The world's largest known gold resource lies in the Witwatersrand Basin in SA (Department of Mineral Resources and Energy [DMRE], 2021). Over two billion ounces of gold have been mined from here since it was discovered and it has approximately the same amount that is yet to be exploited (AtlasObscura, 2021). Much of the gold remaining in the Witwatersrand Basin is currently considered uneconomical to mine because of its depth but it is speculated that autonomous mining could change that (MiningReview Africa, 2020). The increased use of innovative technology is considered to be one of the main driving points for a turnaround in the South African mining industry (The Chamber of Mines, 2016).

The urgency of this study is highlighted first by the important role mining plays in the South African economy (Cassim et al., 2019) and second, by the devastating effect it would have on so many aspects of the economy if the industry were to fail. A failing industry would include the inability to overcome challenges and make significant productivity improvements (Jaessing, 2022). To prevent failure the industry should focus on reducing operating costs and expanding investment in exploration and development (Stoddard, 2021). This urgency is exacerbated when one considers the great multiplier effect mining has on the economy and the number of indirect jobs it creates, even while it is running at a loss (Creamer Media's Engineering News, 2022). There would also be a vast amount of societal and environmental risk if mining were to decline further (Belster, 2022). This urgency is made even more apparent by the knowledge gaps that exist in existing literature regarding the application of technology in developing countries like SA. This includes a lack of knowledge about how differing

contextual factors may influence the strategic management responses of a firm to the use of technology, as well as the influence on the implementation of this technology.

Theoretical perspectives differ on what they might recommend, some suggesting a radical leapfrog approach and others an incremental one and this means that stakeholders have little idea of what will follow. This dissertation, therefore, considers the potential effect these differing contextual factors have on the tension that strategic managers face between whether to follow an incremental or radical strategy for the implementation of new technology (Guthrie, 2022). The practical cost of not doing this research would result in firms' management not having a clear theoretical understanding of how best they should manage the implementation of technology in a specific context if they are to catch up with global leaders.

This methodology focuses on analysing firm-level data and contextual factors to determine the most suitable method of implementing new technological advancements. It involves two main phases: Phase 1 involves a comparative case study analysis of a South African and an Australian mining firm, using archival documents from financial statements and company reports to track changes in their responses over time. Phase 2 comprises a qualitative analysis involving individual interviews to contextualize the findings from Phase 1. Through studying two firms in different contexts and understanding the differences between their behaviours (see Choudhury, 2016), this study aims to uncover whether South African firms should be using an incremental or a radical approach to leap frog (Yayboke, 2020) over stages of technological development, and to what extent these approaches can be combined.

### 1.3 RESEARCH QUESTION

The South African Department of Mineral Resources and Energy (DMRE) and the US Geological Survey highlighted that the mineral reserves held by SA are equal to the value of US$2.5 trillion, this including 16 commodities that are placed in the top 10 world-wide (Wits Mining Institute, 2020). However, despite the vast mineral wealth that SA is home to, the mining industry is still facing a declining productivity disaster (Wits Mining Institute, 2020). In order to combat these declines and catch up with its global competitors, South African mining firms need to increase their level of technological adoption (Cassim et al., 2019). A report on mining competitiveness conducted in February 2019 projected that increased adoption of technology would assist in rectifying the productivity decline in the South African

mining industry. It predicted that this could result in an extra R71bn in revenue and the saving of 52,000 jobs by 2030 (Brown, 2019a).

Unfortunately, the country's level of R&D has declined over the years resulting in a difficulty for mining firms since they no longer have access to leading-edge R&D and intellectual property (Wits Mining Institute, 2020). Science, technology and R&D play a crucial role in developing new technologies and mining methods to ensure that firms in the South African mining industry can overcome the decline in productivity (Wits Mining Institute, 2020). It is, however, important that the development of new technological mining methods consider people issues as well as infrastructure ones that exist in the operating environment (MacFarlane & Singh, 2017). Castellacci (2007) explained the importance of considering the neo-Schumpeterian dichotomy that may exist between the technology system and the socio-institutional system that can hold technology uptake back. New technological styles often create impulsive adoption practices in the techno-economic sub-systems. However, social-institutional systems usually require longer periods to implement necessary technological changes. The contradiction between these two sub-systems may delay the introduction of different paradigms. Proper diffusion to the economy, would first require changes in the socio-economic system. "Harmonic complementarity" is necessary for the new method of development to set in. This complementarity is created "as the socio-institutional system evolves" (p. 594).

The consideration of both systems will ensure that the needed technological development and innovation will be suited to the South African business environment (Jacobs & Webber-Youngman, 2017). Choosing the most appropriate approach to technological development in the South African context would include the decision whether to implement technology radically and leapfrog stages of development or do so incrementally. Although leapfrogging may be ideal, reality might require mines to follow insights from both the radical and incremental approaches.

Leapfrogging is not a simple matter (The Economist, 2008). In order for leapfrogging to be effective, careful consideration must be given to the technological advancement of a country, its economic framework as well as the resources and competencies of its public institutions and private sector. (United Nations Conference on Trade and Development [UNCTAD], 2018). A national innovation system is created through the combination of a variety of stakeholders.

These including firms, research centres, education systems, government entities, and society as a whole. The stakeholders in this system, along with the interrelationships between them and the supportive environment which they create for innovation, define a country's ability to make significant advancements in technology (Organisation for Economic Co-operation and Development [OECD], 2017). Leapfrogging should be encouraged through the implementation of strategic innovation policies. These policies should focus on improving the effectiveness of innovation systems, in order to promote and facilitate the deployment and adaptation of frontier technologies. This will allow for the development of capacity to meet production needs and to further advance these technologies (Letaba & Moeketsi, 2022). The potential to capitalise on and sustain a development trajectory through leapfrogging is contingent on the condition of the infrastructure and institutional capabilities in the country. Both of these factors are often lacking in many developing nations, especially in the initial phases of technological development (UNCTAD, 2018).

The decision of approaching technological implementation radically or incrementally, is very important in ensuring that the selected approach for managing technology is correctly aligned with and will support the firm's strategic objectives (Ohr, 2012; Velu, 2015). Technological change has path dependencies, so using the mining industry and comparing a South African firm embedded in a South African context and an Australian firm embedded in Australian context is a very useful way of investigating how technological change is contextually path dependant.

This leads to the overarching research question of this dissertation. How does a firm negotiate the tension between radical and incremental innovations, in light of contextual imperatives, in their management of technology aimed at closing performance gaps with global competitors?

## 1.4 STUDY AIMS

A study aim usually refers to a statement that indicates the general purpose of the research project and is used to answer the research questions (Lempriere, 2019).

This study aims to understand how differing contextual factors influence firm behavior that, in turn, have an industry-level effect. It aims to understand which theoretical approach, regarding technological change, mining firms could follow to properly navigate their technological trajectories, in light of contextual imperatives.

## 1.5 RESEARCH OBJECTIVES

The topic of this study has many interrelated and complex parts but by delimiting the scope of analysis (according to the contributions identified in the relevant section) it sought to manage this heterogeneity. This approach attempted to ensure that the gaps in existing literature were properly identified and that the necessary research objectives needed to fill these gaps were created. Below are the six research objectives (RO) of this dissertation.

RO1. Investigate the unique social institution of SA and assess which dimensions of this system are impeding the economic technological system and affecting the mining industry's ability to catch up with global leaders.

RO2. Compare the strengths and weaknesses of these systems with the systems of a developed country, to determine the best strategic approach for technological evolution in South African mining firms.

RO3. Analyse the R&D and technological efforts of a firm to assess the extent to which fixing the technological lag in SA is dependent on the firm, and/or the extent to which the firm is at the mercy of its context.

RO4. Determine if country contextual conditions (laws, culture, union and labour power) have created a certain path dependency that has trapped the firm in a particular technological trajectory.

RO5. Understand how technological trajectories in South African firms may be opposed to those in Australian firms.

RO6. Identify and characterise differences across technology implementation strategies between South African and Australian mining firms.

## 1.6 CHAPTER SEQUENCE

### 1.6.1 CHAPTER ONE: STUDY BACKGROUND, RESEARCH PROBLEM AND RESEARCH QUESTIONS

In this chapter, the background of the study is outlined and the research problem introduced. The lack of knowledge regarding the potential influence of contextual factors on the evolutionary theory of technological development as well as its influence on the technological trajectory of the industry is highlighted as a core aspect of the problem addressed in this research. After the background of the study and the research problem have been discussed the research question, the aims of the research, and the research objectives are introduced. The chapter is concluded with a summary of the chapters.

### 1.6.2 CHAPTER TWO: LITERATURE REVIEW

In this chapter, the guiding theoretical framework of the research is introduced. The predictions of Nelson and Winter's (1982) evolutionary theory of economic change as well as the predictions of the neo-Schumpeterian long wave theory (Castellacci, 2007) are discussed. The tension between the difference in implementation strategies of these two theories, one incremental and one radical, is introduced. This tension is then discussed with relation to the influence of contextual factors, as has been highlighted by technology-gap theorists (Castellacci, 2007; United Nations Industrial Development Organisation [UNIDO], 2015). The influence of contextual factors on the theoretical tension is extended further into discussing how this will shape and influence the technological trajectory of the industry.

The chapter then introduces literature specific to the historical development of the industry. For SA, this includes a particular focus on the deep-rooted effects of apartheid. This is followed by current day industry information on a global and local scale that includes an analysis of the important role mining plays in the economy. It considers some reasons for the industry's decline as well as the restrictive role contextual factors can play in industry success. This chapter includes reference to firm-specific literature that is concerned with company performance and labour productivity. It also discusses the importance of 4IR technologies and their influence on firm performance. Firm performance is linked to investment in R&D and human capital and this link is related to the importance of absorptive capacity. This chapter also touches on foreign direct investment (FDI), technology spillovers, and the notion of backward and forward linkages. This chapter additionally includes a summary of how the literature contributes to the existing body of knowledge as well as the gaps that exist in this,

followed by how this study will subsequently contribute to filling those gaps in the existing body of literature. A diagrammatic representation of the conceptual framework guiding the research is also provided.

### 1.6.3 CHAPTER THREE: RESEARCH METHODOLOGY

This chapter introduces the study research methodology. The first section discusses the research context and places the research in relation to ontological and epistemological perspectives, with a justification provided for the stance taken. Next, the chapter introduces the inductive research approach and qualitative research strategy used in the study that is based on a multi-method design consisting of two distinct phases. The appropriateness of combining these two phases to better understand the complexities of the study is discussed, and information regarding sampling, data collection methods and issues relating to the trustworthiness of the qualitative process (Guba & Lincoln, 1985) is offered. After this, the structure and approach to the within-case and cross-case analysis for Phase 1, followed by the coding and analysis processes for Phase 2 are outlined. The chapter then concludes with a consideration of the ethical procedures followed during the research.

### 1.6.4 CHAPTER FOUR: METHODOLOGY PHASE 1- CASE STUDY FINDINGS

This chapter introduces the case study analysis for Anglo American (AA) and Rio Tinto (RT), both of which consisted of a within-case as well as a cross-case analysis (Bourgeois & Eisenhardt, 1988). The within-case analysis incorporated detailed description type case study write-ups for each firm. The descriptions were structured around specific focus areas, suitable to unpacking and properly understanding each firm's interaction with its context and its innovation and technology activity. These narrative descriptions are coupled with extensive graphs and tabular displays. This is followed by the cross-case analysis that used a set of categories and dimensions derived from the study contextual framework to compare and contrast similarities, differences, relationships, and behaviours between the cases.

### 1.6.5 CHAPTER FIVE: METHODOLOGY PHASE 2 – INTERVIEW-BASED QUALITATIVE ANALYSIS FINDINGS

This chapter reports on and discusses the interview-based qualitative analysis undertaken in the study. The analysis in this chapter is aimed at inductively developing theory that can better explain the complex phenomena, such as the ones described in this research. Using a grounded

approach, and thematic content analysis, certain relationships around technological development, influential contextual factors, and technological trajectory are analysed.

### 1.6.6 CHAPTER SIX: DISCUSSION AND CONCLUSION

In this chapter, the results and study conclusion are discussed. A summary synthesising the results of chapters four and five is discussed in its presentation of a unified theoretically grounded narrative of the studies' discoveries. This synthesis will attempt to answer the underlying research question of the study. Lastly, a discussion of the theoretical as well as the practical implications of the research is discussed and concludes with the limitations that exist in this study as well as possible avenues for future research.

## 1.7 CONCLUSION

This chapter provided an overview of the study background and the research problem. It highlighted the knowledge gap regarding the influence of context over technological management approach. It also considered the limited understanding of how this influences industry technological trajectory. The chapter included the research aim, question, and objectives. The chapter concluded with a chapter sequence outlining the contents of the dissertation.

# CHAPTER 2: LITERATURE REVIEW

## 2.1 INTRODUCTION

This section introduces an overview of the main theories on which this dissertation is grounded. It also includes literature related to the relationships and processes in the study's conceptual framework (see Figure 1 on page 21). This includes literature on the historical development of the industry. It focuses on understanding the importance of mining to the economy. It considers specific literature that focuses on productivity and the influence of 4IR technologies. It also explains the significance of research and development (R&D) and human capital development. These initial frames of reference guide this dissertation. This chapter includes a contributions section as well as a diagrammatic representation of the conceptual framework guiding the research.

## 2.2 THEORETICAL OVERVIEW

The current state of theory that best describes the relationships being studied in this dissertation, is explained in two prominent theories: the Nelson and Winter evolutionary theory; and the neo-Schumpeterian long wave theory. These two theories, in predicting how technological change will affect firms, are concerned with mechanisms of technological development and innovation. They appear to be best suited to explaining the phenomena under study since they predict two extreme ways forward—either leapfrogging or slowly evolving. It seems that any technological changes made by a firm will fall somewhere between these two extremes, so these theories provide useful ways of thinking about the problems associated with technological change. However, their proposing different implementation strategies has led to tension that has, in turn, led to a lack of clarity.

### 2.2.1 THE NELSON AND WINTER EVOLUTIONARY THEORY OF ECONOMIC CHANGE

This theory of economic change is built on the idea that an organisation will grow in line with the evolution of its routines and habits (Castellacci, 2007). It suggests that heterogeneity of economic agents is necessary for the positive evolution of routines and habits, ensuring the growth and development of companies (Castellacci, 2007). The two important economic agents that facilitate the process of evolution are the presence of a strong competitive force in the firm's operating environment and technological innovations (McKelvey & Salter, 2016).

Routinised processes formed because of dynamic forces, such as innovations in technology and operating in a strong competitive environment, will lead to economic growth and human capital development, thus pushing the economic system forward (Castellacci, 2007).

It seems that South African mining companies have not prioritised dynamic forces and, instead, have been too focused on infrastructure and country related problems (Luzipho, 2014). It would appear that this focus has resulted in the evolution of organisational routines that deal largely with various country contextual problems at the expense of prioritising dynamic economic agents such as innovation and technological development that could play a key role in rejuvenating the mining industry. These problems include having many of the deepest underground mines in the world (Morris, 2017), binding infrastructure constraints such as electricity shortages and electricity prices trebling in the last seven years (Kotze, 2021), excessive wage demand pressure with wages increasing by >10% in the last five years, strikes, community disruptions, and illegal mining, amongst others (The Chamber of Mines, 2016). In addition to these problems, the sector is also faced with many challenges regarding the development of skills needed for mining (MCSA, 2023c). These challenges, including a poor basic education system and a lack of funding for tertiary education, have resulted in a workforce that is largely under-skilled (Mining Prospectus, 2019).

From the evolutionary perspective of Nelson and Winter (1982), and given a critical synthesis of the literature, it could be suggested that this negative focus could have caused the development of a different path in SA, one that is centred around the unique obstacles the country faces. In comparison to this, Australia can attribute its sophisticated mining technologies to decades of focus on investing in technological R&D as well as on a commitment to developing innovative combinations of people and technology that can transform natural resources into valuable exports (MCA, 2019).

Different evolutionary paths, discussed above, are further explained in terms of the notion of technological path dependency that suggests that the continual use of a product or process is often a function of historical preference (Banton, 2021). Once an organisation embarks on a specific course of action it can be difficult to reverse this and, therefore, a certain path of development is often the result of critical moments that shape the basic contours of that development (Liebowitz & Margolis, 1995). It would seem that the path dependent outcome in the Australian context is beneficial to its development since the initial critical moments that

shaped the development were centred on producing the best technological capabilities. However, in some situations, technological path dependency may result in a path dependant outcome that is not necessarily the best way forward and technological path dependence can cause a technological lock-in (Arthur, 1989). In other words, society may adopt an inefficient technology that becomes "locked-in" as part of the industry standards, and if there are significant network effects supporting this standard it can last for extended periods of time (Arthur, 1989). The QWERTY keyboard is a prominent example of how widespread emergence can cause path dependence. The layout persisted over time despite the development of more efficient keyboard layouts. This case provides an example of success that was more dependent on its historical path then on its optimality (David, 1985).

The Australian Minerals council believes that their competitive advantage did not occur by chance, but, results, rather, from years of developing their staff and technological capabilities. They believe that this has enabled them to become a technological leader in the mining industry. They acknowledge that development of innovative production methods will ensure future success (MCA, 2019). The first in the world, purpose-built, fully autonomous, underground gold mine, Syama in Mali, is owned by an Australian mining company. Various benefits have already been demonstrated, illustrating potential for other mines. These benefits include increased machine productivity whilst at the same time, reducing risk and bettering safety outcomes. It also decreased production costs per tonne, enhanced the ability to better control the mining process with less variation, and it resulted in a decline in wear and damage. It is also beneficial since it provides an opportunity to train and upskill the workforce to use these new technologies (Lombard, 2019).

The comparison between SA's focus on problems and Australia's focus on dynamic economic agents and the subsequent evolution of their dissimilar organisational routines, illustrates that the evolutionary perspective of Nelson and Winter (1982) is relevant in understanding how these differences evolved. However, as mentioned above, its proposed implementation strategy—an incremental approach—is opposed to the radical approach on which neo-Schumpeterian long wave theory is based, and this creates theoretical tension in relation to whether the best way forward to technological change is an evolutionary or a revolutionary approach.

### 2.2.2 NEO-SCHUMPETERIAN LONG WAVE THEORY

Neo-Schumpeterian theory combines the long wave theory developed by Kondratieff with the economic development theory developed by Schumpeter and has, as its focus, the capitalist development of technological processes (Tuncel, 2015). Long wave theory concludes that a country, along with its economy and businesses, goes through long waves of economic growth. It highlights the notion that it is critical to focus on radical innovations to ensure that a new wave is created that then promotes and sustains economic growth and development (Castellacci, 2007). This theory is comprised of two sub-systems: first the techno-economic; followed with the socio-institutional. These two sub-systems advance and co-evolve simultaneously to influence the mode of development and, subsequently, how the wave rises and falls (Castellacci, 2007). A change in either one of these two sub-systems will affect the other. The neo-Schumpeterian long wave theory supports the importance of radical technological innovations in the mining industry. Looking at the South African mining industry from a Schumpeterian perspective, waves of change (and breaks in routines) can be best suited to technological change. Firms would be able to leapfrog over their challenges by using technology according to the wave mechanisms suggested by Schumpeterian theory. This would ensure the creation of a new wave, thus making redundant the current labour-intensive methods and would introduce needed technological changes to increase productivity and sustain economic growth.

These two theoretical perspectives highlight the importance and necessity of technological development and implementation, but they support different implementation strategies. Applying the Nelson and Winter evolutionary perspective would suggest that the evolution of routines and processes will allow the incremental adoption of new technology and the development of human capital to occur simultaneously. The neo-Schumpeterian perspective supports the idea that sustained economic growth will be achieved through a disruption of current business practices and radical innovations that render redundant the current labour-intensive methods. This theoretical tension between two prominent contributors to the current state of theory, in presenting a choice between an evolutionary and a revolutionary approach to technological change, results in a lack of clarity since is unclear to what extent contextual realities shape the trajectory of technological change.

This tension regarding implementation is further exacerbated given that the use of either of these theories has not been discussed in relation to specific contextual terrains. This becomes

even more significant in the South African context since, as noted above, the mining industry is the historic bedrock of the South African economy in its provision of an economic foundation and support to many communities in the country (McKinsey&Company, 2019). Consideration of contextual factors is crucial to the selection of the process for implementation. The success of facilitating mine modernisation, through technological advancements (Jacobs & Webber-Youngman, 2017), is influenced by implementation. Understanding the interplay between context and implementation approach enhances the likelihood for success. This understanding will ensure technological development and innovation that suits the South African business environment (Jacobs & Webber-Youngman, 2017). This study will ensure that specific contextual terrains are considered in its tracking of responses of firms to their contextual conditions.

### 2.2.3 THE IMPORTANCE OF CONSIDERING CONTEXTUAL FACTORS

The necessity of considering the contextual factors of different terrains is highlighted by technology-gap theorists who state that economic and technological differences will certainly exist between countries (Castellacci, 2007) and, therefore, cannot be overlooked when theories of technological development are established and applied to business practice in these different countries (UNIDO, 2015).

Technology-gap theorists focus on the idea of catching up to the leading technological countries and that this could be achieved by innovating, creating new technologies, and using international diffusion (Castellacci, 2007). A company will use its technological capabilities to compete in various markets while a country is assumed to compete to become an economic leader (Castellacci, 2007). The technology-gap approach indicates clearly that a gap will exist between different countries, and this suggests that differences between Australia and SA will exist. This technology gap perspective identifies one of the main contributing factors of this gap as being the varying absorptive capacity of companies in different countries (Castellani & Zanfei, 2003).

Absorptive capacity considers the ability of an organisation to discover new knowledge and ideas and use them in business practice, making it an important contributor to performance (Cohen & Levinthal, 1990; George & Zahra, 2002). It is considered to be one of the most important capabilities of a company (Murtic, et al., 2019). Without absorptive capacity, a company is unable to acquire and apply new knowledge and be innovative in its business

practices (Murtic et al., 2019). In order for a firm to develop its absorptive capacity it is imperative that the firm prioritises investment in R&D (Lemonakis, et al., 2017) and human capital (Kenton, 2020).

The necessity of investment in R&D as well as in human capital, in order to develop an institution's absorptive capacity, is reinforced in Paul Romer's (1994) endogenous growth theory that expanded on Solow's (1985) growth model that suggests that the success of a country's growth is dependent on how well labour is combined with capital, known as total factor productivity (TFP). Solow's model highlights the importance of the capital portion of TFP believing it to be the secret to the growth of poor countries; countries that are more capital-scarce will be expected to grow faster (Solow, 1985). Romer (1994) however, suggests that TFP is driven instead by ideas (knowledge recipes) more than by capital. These knowledge recipes can be either created or copied. When we consider poorer countries, however, the obvious problem is that poorer countries do not have sufficiently skilled human resources to create effective recipes, nor do they have adequate absorptive capacity to copy recipes from other countries (Romer, 1994).

Absorptive capacity is clearly an essential factor to consider when formulating theoretical insights into the differences that exist between the strategic management responses of firms in different contexts. Considering contextual factors (such as absorptive capacity) acknowledges the idea that policy, government, and environmental contexts lie at the intersection of strategy.

### 2.2.4 THEORETICAL GAP

The Nelson and Winter and neo-Schumpeterian theories propose different implementation strategies and different ways of approaching the problems faced by South African managers in the mining context. If managers use either of these as a heuristic to help them understand technological change, they might apply different interventions. This creates theoretical tension between the evolutionary and revolutionary approach to technological change. This tension is exacerbated when neither of these theories is discussed in relation to specific contextual terrains and this results in a deficiency in theory in relation to the mining industry under study here. Since the mining era began, evolutions/revolutions in technology have contributed to the development of the industry. Differences in technological advancements would result in different influences on the industry's trajectory.

## 2.3 HISTORY OF THE GLOBAL MINING INDUSTRY

The history of mining technology started with miners using primitive tools for digging, then progressed to the application of fire to mined materials as the first innovative method to extract minerals. This was a technological breakthrough that proved to be one of the critical advancements of civilisation (Earth Systems, 2006). The Middle Ages saw another leap in mining technology with the introduction of explosives as a way of breaking up large rocks (Vogt, 2016). Technological advancements continued to improve the motorisation of mining tools over the years, eventually reaching the introduction of 4IR technologies (Trueman, 2023). Since the start of the industry, technological developments have produced beneficial improvements (Casey, 2019) and continue to function as a tool for transformation in the global mining industry today (McKinsey&Company, 2018).

## 2.4 THE GLOBAL MINING INDUSTRY TODAY

Mining plays a vital role in the economic and social development of many countries (Bravus, 2021), contributing to employment opportunities and income generation (Walser, 2002). In some countries such as Australia, the mining industry is believed to be the cornerstone of the economy in supporting its growth into a prosperous nation (Brunel, 2022). Mining in Australia facilitates highly skilled employment with almost one-quarter of a million people having jobs in mining. It attracts multibillion dollar investment and is one of the country's highest export revenues (Bravus, 2021). America is another country with a flourishing mining industry, bringing vast amounts of wealth into the country (AMS, n.d.). According to the U.S. Geological survey, US mines have experienced rapidly increasing productivity metrics, producing, in 2019, approximately $86.3 billion in minerals, which is more than $2 billion higher than the production totals in 2018 (U.S. Geological Survey, 2020). In Mongolia, the mining industry has supported and pushed the country's economy into being one of the world's fastest. The 2018 Extractive Industries Transparency Initiative report states that, on average for the last three years, the mining industry contributed 56,63% to the total industrial production of Mongolia (Extractive Industries Transparency Initiative, 2021).

In addition to economic and social growth and development, extracting mineral resources plays a massive role in the sustainability of our future (Malan, 2021). Many projects around the world require large amounts of raw materials to produce renewable energy technologies, such as solar and wind infrastructure. This means that the industry will play a greater role in the economy through its contribution to achieving a sustainable future (Hexagon, 2022). As the world slowly

transitions to decarbonised operations the production of green technology needs to increase significantly, and mining plays a central role in this revolution (Leary, 2022). The growth and sustainability of mining industries today depend on their ability to apply innovative and improved technologies (The World Bank, 2021), the application of which will not only assist the industries' growth through accessing new resources (Mining Technology, 2021) but will also act as a mechanism to assist the industry in dealing with the many risks it faces.

These risks include fluctuating commodity prices, health and safety issues, declining ore grades, declining levels of productivity, climate change, and various other factors (KPMG, 2021) all of which have demanded a transition in the sector (Berbner et al., 2021). The transition is predominantly focused on the three aspects of "electrification, digitalisation, and automation" (Goosen, 2021, para.1). Electrification focuses predominantly on creating safety improvements, lowering operational costs and reducing fossil fuel emissions (Goosen, 2021). Digitisation is focused on boosting productivity, minimising waste, and enhancing mine safety all while using resources sustainably. According to estimations, implementing digitalisation in mines could potentially generate a savings of $370 billion by the year 2025. As a result, this could not only increase productivity and decrease waste, but also promote safety in mining operations (McKinsey&Company, 2015). The current trend of automation also prioritises productivity and worker safety. As indicated by a recent industry analysis, the market for electrification and automation is forecasted to reach $15 billion by the year 2028 (Komatsu, 2019).

Innovation and technological development have very clearly been an important driver shaping the development of the industry and continue to influence how it progresses into the future. In addition to the influential role innovation and technology have played in this development, a number of important historical contextual factors also contribute to this. To understand fully the structure of South African mining industry today, it is important to grasp the role its social history has played in shaping the current context in which the industry operates.

## 2.5 HISTORY OF THE SOUTH AFRICAN MINING INDUSTRY

Mining in SA started in 1867 with the discovery of diamonds; the country progressed rapidly to producing 95% of the world's diamonds in the 1880s (AfricaMiningIQ, 2022). Despite the monumental offerings of the diamond industry, exploration and growth did not stop here; the diamond industry was very quickly eclipsed by the discovery of gold, the turning point in South

African history (Potenza, 2019). The discovery of gold was largely responsible for the boom in the South African economy since, amongst other things, it significantly increased trade between South African and the rest of the world as well as attracting large capital investments into the country (Sieff, 2016). It is apparent that the mining industry has significantly influenced and regulated the economic landscape in South Africa. This has been the case for numerous years, as the sector has served as the cornerstone of the South African economy (MCSA, 2023b). However, mining has not only been influential in shaping the trajectory of the economy but also of SA's political and social landscape (Brown, 2019b; MCSA, 2023b). This included of South Africans being displayed from their land and the creation of a cheap Black migrant labourer system, upon which the industry very quickly became reliant (Brown, 2019b; Casey, 2019).

"The number of gold miners employed in cheap black labour jumped from 14,000 in 1890 to 534,000 in 1986" (Casey, 2019, para.11). The history of apartheid and government policies that enforced racial segregation have significantly influenced and prolonged the dependence on cheap black labour. This has reinforced the divide between a privileged minority of white owners who run the majority of big mining companies and a larger population of black workers involved in the daily operations (Benson, 2016; Casey, 2019). As is the case with many political and social structures, the deconstruction of the migrant labour framework and the rectification of the harm it has caused, has continued to require even more tenacious efforts over relatively recent years (Vosloo, 2020).

Despite the fact that Apartheid is no longer in control of government policy development, its effects continue to be experienced throughout SA, particularly in mining (Casey, 2019; Goodman, 2017). The racially discriminatory legal system of Apartheid, that resulted in an enormous disenfranchised and poorly paid workforce, was only one of the many social injustices that have caused a structured inequality in the post-apartheid economy (Clark, 2014; Goodman, 2017). Apartheid sowed the seeds of societal polarisation that still plays out in many aspects of the industry today (CJPME Foundation, 2014). This is an important foundational block that should be considered in relation to the influence of context on the strategic choices of a firm and the way in which problem-solving activities should take place.

## 2.6 THE SOUTH AFRICAN MINING INDUSTRY TODAY

### 2.6.1 IMPORTANCE OF THE INDUSTRY

Notwithstanding the very negative influence the past has had on the industry's development, mining still plays a significant role in the economic growth and development of our nation today (Cassim et al., 2019). This significant role includes the many benefits received from the industry. In 2021 alone, mining contributed R78.1 billion in tax and R480.9 billion in GDP (MCSA, 2021a). Mining is also responsible for regional development, infrastructure development, economic growth through sector linkages, as well as community development (Bravus, 2021). All these benefits from mining are well aligned with reaching state development goals and are, therefore, significantly important for the future growth of our nation (Dorian & Humphreys, 1994).

### 2.6.2 THE MULTIPLIER EFFECT OF THE MINING INDUSTRY

In addition to all the direct impacts created through the mining industry, there are also a number of indirect impacts. These indirect impacts can be described in terms of the multiplier effect. A term derived from economics, a multiplier refers to an economic factor that, when altered, results in changes in multiple other connected economic variables (Clarine et al., 2022). Simply put, this means that changes in total output of a country are greater than the changes in spending that caused the increase in output (Boyce, 2023; Janse van Rensburg et al., 2021). The multiplier effect highlights all outcomes of a single job by measuring the related additional economic activity it causes (Clarine et al., 2022; Muro, 2012). This is well explained when thinking about the scenario of recruiting a geologist or a mining engineer to a city and analysing how this initiates a significant sequence of economic effects that hold particular importance for both skilled and unskilled labourers, both within and outside the mining sector (Muro, 2012). In doing so it creates a diversified and strengthened economy.

Mining, led by a significant amount of exploration, is considered as one of the most substantial economic multipliers (Creamer, 2021). Government should therefore make it a priority to put policies in place that support the prosperity of this multiplier and protect it from decline (Investopedia, 2022). In addition to policy development, government need to be committed to enhancing education and skills development practices (BusinessTech, 2022b) that will empower the youth to become entrepreneurs (Pillay, 2022) so that the vast number of jobs created as a result of mining are supported through an active economy (Creamer, 2021).

Through the application of the multiplier effect, mining in SA offers significant growth opportunities (Creamer Media's Engineering News, 2022). Although this is a powerful

mechanism for job creation in the South African market, the opposite is true, too. As was noted by the Chamber of Mines (2016) the multiplier effect of job losses in mining equated to 180 000 jobs being lost in other sectors related to mining.

## 2.7 DECLINE IN THE SOUTH AFRICAN MINING INDUSTRY

Research conducted as part of Business for SA's Economic Recovery Strategy (ERS) illustrated that the South African mining is in decline (Mbazima, 2020). A variety of factors have contributed to this decline, one of the very prominent ones being a lack of investment (Njini, 2023). The drying up of capital flows has resulted in, among others, two major issues in the industry. First, there is limited exploration of new mining opportunities with little investment in new mines. Second, the decreasing investment means that there is a very limited resource availability to develop and sustain existing mines (Mbazima, 2020). Limited exploration affecting the chance for future growth means that SA is operating out of a declining pool of resources, with little prospects for longevity (Faku, 2019). A declining resource pool will result in declining production and output will inevitably shrink, and this poses costly risks to the fiscus (Zwane, 2022). The ERS research, mentioned above, compared various metrics in the industry in 2010 and 2018, and found that real output value decreased by 10%, annual capital expenditure shrunk by 45%, and employment figures declined by 50 000 (Mbazima, 2020) all indicating that the industry is in decline (Kroll & Robinson, 2018). It is, however, important to note the nuance in this finding: not all commodities in the industry have been in decline and some have shown modest growth that was, unfortunately, outweighed by the significant decline of the larger sectors, such as gold (Mbazima, 2020). The decline of SA's gold mining sector has been evident for a number of years (Ruffini, 2010). The exceptional nature of the Witwatersrand Basin made it the single largest source of gold in history, from which was extracted approximately 40 percent of all gold ever mined (Callaway & Ramsbottom, 2019). This means that its decline had drastic impacts, and the effects of the 84% decline in production volumes have been felt across the entire South African mining industry (Callaway & Ramsbottom, 2019). To address this industry decline, significant intervention is needed (Mbazima, 2020).

It would appear that the limited investment to rectify this decline and develop new mines in SA is the result of the poor perception of the industry in relation to investment (Mbazima, 2020). According to the Fraser Institute's Annual Survey for mining, SA is ranked among the least attractive places in the world to invest into mining (Hattingh, 2022). In light of the

significant amount of unexplored mineral reserves still in SA, it is a shame that a country with so much potential for growth in resources is currently struggling to drive investment in the sector (Creamer Media's Engineering News, 2022). The MCSA expressed their deep disappointment regarding the ranking and believe that it "serves as a warning that we are headed in the wrong direction when it comes to attracting investment to the country's resources sector" (MCSA, 2021b, para. 1).

This poor ranking and the dismal levels of investment that also influence exploration in the industry are, to a large extent, influenced by the contextual terrain of the South African mining environment. There is a variety of different contextual factors in SA that have caused some level of complexity in the progression of the mining industry (Creamer Media's Engineering News, 2022).

## 2.8 COUNTRY SPECIFIC CONTEXTUAL FACTORS

Contextual factors are aspects that reflect a particular context that is unique to a particular group or society (IGI Global, 2022). Contextual factors make up the socio-economic and socio-political conditions in a firm's operating environment and they can either favour or inhibit various desired outcomes (Guzek et al., 2015). SA has many well recognised contextual challenges complicating its mining environment (Greyling, 2021). Some of these challenges will be considered in the literature analysis, and again in the case study analysis, in the consideration of the effect context could have on a firm's technological activity.

### 2.8.1 LIMITED BASIC EDUCATION

The education system in South Africa, despite a substantial budget allocation of R298.1 billion for basic education development in 2022-23, continues to struggle to provide quality education to its youth (Mail&Gaurdian, 2023). The system is plagued by a multitude of issues, including teacher shortages, inadequate infrastructure in schools, and overall lack of progress. A significant number of students, particularly 18-year-olds and 19-year-olds, are seen dropping out of school, with approximately 30% and 50% respectively, as reported by Stats SA. Poor academic performance contributes significantly to these dropout rates, affecting over 21.2% of cases (Mail&Gaurdian, 2023). Given the historical challenges rampant in the education system, ensuring a sufficiently skilled workforce and improved education remains daunting. If not effectively managed, this may impede the country's growth potential. Education stands as a

pivotal enabling factor that will shape the successful implementation of technology in the nation (Radcliffe, 2022).

### 2.8.2 HIGH UNEMPLOYMENT RATES

Apart from grappling with education challenges, South Africa faces a concerning rise in unemployment, with potential far-reaching societal consequences. The inability of a considerable number of adults to engage in the country's economy is further exacerbating social cohesion (Larkin, 2022). The resultant instability contributes to various issues, including protests and community unrest. Absa reported in July 2022 that the growing unemployment, combined with other factors, has the potential to incite civil unrest in South Africa. In light of this, PwC's recent data suggests a projected unemployment rate of 40% by 2030 (PwC, 2019). According to the group, this trend is driven by the labour force expanding at a faster pace than the economy, thereby rendering job creation insufficient to keep up. These dynamics indicate a profound societal challenge, with implications for both economic and social stability within the country (BusinessTech, 2022c).

### 2.8.3 LAGGING INFRASTRUCTURE DEVELOPMENT

SA has, over the past few years, been struggling with infrastructure concerns that hamper its ability to grow (National Planning Commission, 2023). SA has not yet been able to maintain and expand its electricity, water, transport, and communications infrastructure adequately to support the economic growth and social development goals of the country (National Planning Commission, 2023). Inadequate infrastructure is problematic for several reasons, one of the predominant ones being the limit it places on total production capacity. According to the MCSA, the declining capacity in Transnet’s rail and ports has resulted in opportunity losses of R50 billion in 2022 alone (Erasmus, 2022) and, in addition, costing the industry R35 billion in 2022 revenue (Zawya, 2022).

In recent years, it has been an important topic for both policy makers and academics to discuss the relationship that exists between infrastructure development and a growing economy. This has made it a very important area of concern for the South African government to address (Daw & Marutle, 2017). Another infrastructure related factor acting against the growth of the industry is the energy crisis. This situation of lagging infrastructure extends into the concern about the limited and unstable energy supply.

### 2.8.4 ELECTRICITY SUPPLY ISSUES

SA has been facing extended energy generation shortages (BusinessTech, 2022a). The output lost as a result of load shedding in 2019, is believed to be between R7 billion and R12 billion (Mbazima, 2020). This equates to around 4% of the industry's total output, which for most companies, will have an enormous negative affect on revenue. It also, additionally, creates vast operational complexities (Mbazima, 2020). Sibanye-Stillwater, the multinational mining company, expressed their concern around the fact that ongoing load shedding is forcing them to reduce their electricity demand, and subsequently hurting their production (BusinessTech, 2022a). This, of course, has a devastating effect on firm productivity and profitability in hampering its ability to utilise the benefits of economies of scale and increase its productive capacity (Abban et al., 2022).

Additionally, electricity price increases have been above-inflation in recent years, including an average increase of 15.63% in April 2021 and a further 9.61% in April 2022 (Moolman, 2022) negatively impacting both the profitability and the longevity of numerous operations (Mbazima, 2020). The combination of load shedding and electricity price inflation has created adverse working conditions for the industry and has contributed to SA now being ranked 97th in the world for electricity affordability and reliability, according to the World Economic Forum's Global Competitiveness Report 2019 ranking (Schwab, 2019). The losses in profit and the uncertain future caused by the energy crisis in South African is a massive deterrent to potential investors (McKay, 2020).

This uncertainty regarding a mine's ability to effectively and profitably operate in future, has played a key role in urging miners to access diversified sources of power that have a viable future (Whitehouse, 2019). The government's decision to increase the embedded power generation threshold, making it possible to generate energy from renewables, is arguably one of the most significant actions taken by the South African government to rekindle the entrepreneurial flame of the private sector (Kelly, 2022). However, despite the optimistic announcement made by the government regarding the increase in the licensing threshold for mines to run their own self-generating renewable energy projects, numerous mining houses still feel that allocating licenses to these renewable projects at the Minerals Department is still a "bureaucratic nightmare" that is replete with red tape (Faku, 2022, para. 1). The MCSA believe that this 3 is the reason for the delay in more than 30 mining industry self-generation projects (Creamer Media's Engineering News, 2022). Equally as challenging as this bureaucratic red

tape is the regulatory uncertainty in SA.

### 2.8.5 REGULATORY UNCERTAINTY

SA faces numerous recognised challenges, however, the fact that these challenges are compounded with a great deal of regulatory uncertainty, SA has not been able to effectively compete with other nations in attracting investments (Greyling, 2021; Seccombe, 2017). This regulatory uncertainty has to do with the numerous and ongoing iteration processes of the current Mining Charter (Mbazima, 2020). The Mining Charter III has gone through three iterations in the last 15 years, with every new version causing repeated, and sometimes new forms of, uncertainty concerning its implementation (Arnoldi, 2019). According to Mbazima (2020), the conversation around the uncertainty of mining regulations has overlooked a crucial and fundamental aspect. That is, that even if all uncertainties related to the current version of the Mining Charter were to be resolved, significant uncertainty would persist due to the mere existence of the charter itself. The very nature of the charter means that it can change at any time, thus creating a significant challenge for the industry (Mbazima, 2020).

The implementation of regulations for the mining industry using a highly malleable regulatory instrument introduces immense uncertainties, particularly when considering the fact that mining investments are long-term investments, usually 10 to 30 years (Mbazima, 2020). However, despite this valid point about the need for stable legislation that is difficult to change to govern the industry, the charter is still the industry's current tool that is used to address a long history of exploitation in mining (Bruce et al., 2017) and intends to steer the industry towards genuine empowerment (Tapula, 2012). Transformation and the upliftment of vulnerable groups in the community should be the overarching priority of all strategy and policy development for the industry. It is, however, imperative that the government make it a priority to establish a collective agreement, regarding all aspects of transformation, and have them hard-coded into legislation. This should include explicit commitments to stability, allowing potential investors to plan with utmost clarity and certainty, whilst still ensuring the country prioritises its transformation commitments (Mbazima, 2020). Compounding the issues surrounding regulatory uncertainty is the very difficult geology of many of South African mines.

### 2.8.6 DEEP MINES CREATING DIFFICULT MINING GEOLOGY

The initial phase of the mining process very obviously starts with the recovery of easy to reach resources and once these are depleted, the mining process progresses, if possible, to more difficult to reach resources (Pickering, 1996). As the difficulty of recovering the resource increases so the planning, extraction methods, and the technology employed must be improved if the cost of recovery is to be contained (Pickering, 1996).

Gold mining in the Witwatersrand goldfields started almost a century ago and this means that a large majority of the high-grade gold deposits have been depleted, leaving only lower grade deposits to mine (Neingo & Tholana, 2016). Many of the ore bodies that exist for mining today are shrinking. The option to counteract this problem of low tonnages with increased grades at deeper depths is also becoming limited. This is due to the exhaustion of the high-grade resources, either through previous extraction or current extraction efforts (Cornish, 2019). Difficulties experienced with accessing minerals at such great depths is particularly common in the South African context, with six of the world's 10 deepest mines located in different regions in SA (Mining Technology, 2022a). The co-director of the Mandela Mining Precinct, one of SA's leading research institutions, explained that "the outlook of the South African deep level mining sector is bleak [so] should there be no drastic change in the way this type of mining is conducted" (James, 2019, para. 1). The normal challenges faced by a mine, such as operating costs and worker safety are exacerbated at such great depths (Mavuso, 2013) with additional problems specifically related to deep-level mining, such as high earth temperatures and a high in situ state of stress (Konietzky et al., 2019). These challenges will be very difficult to overcome and achieve mining success without the introduction of new technology and without changing radically the current method of mining (James, 2019).

### 2.8.7 COST COMPETITIVENESS

Researchers from ERS have performed a comprehensive analysis of the unit production costs of all mines in South Africa. Through a comparison of the costs per unit of production with other significant mining jurisdictions, they discovered that over 60% of the country's mining output comes from mines that rank in the lower half of cost competitiveness (Mbazima, 2020). This consequently suggests that South African mines, usually, have greater costs in production for each unit of output and this implies that if commodity demand is reduced, output from SA will be among the most vulnerable (Mbazima, 2020). According to Cassim et al. (2019) all the difficult contextual factors, discussed above, are contributing factors to declining productivity

and thus cost-competitiveness. Productivity is commonly considered as an important factor that contributes to company performance and is a very important consideration for mining firms in SA (Cosmetatos & Eilon, 1983).

## 2.9 COMPANY PERFORMANCE

The term performance is described as the contributions of different business systems (organisational units of different size, employees, processes, and investment) that enable the company to achieve its goals (Chroqui et al., 2016). Company performance is concerned largely with how effectively and efficiently a company uses its resources to produce the highest-quality work (Chroqui, Ghalem, Okar & Semma, 2016).

Efficiency refers to how well a company can transform inputs such as material, labour, time, and capital into services and products that generate revenue (Indeed, 2021). It illustrates a company's ability to operate at a peak level of performance at which fewer resources are used to produce the highest possible level of output (Banton, 2020). Efficiency minimises the waste of resources and maximises economic benefits since resources are optimised to best serve the company (Banton, 2020). Efficiency is concerned with how to reduce input costs to increase profitability (Smith, 2016). Effectiveness refers to how well tasks are completed within a company, ensuring that output is in line with company objectives (Miksen, 2019). Effectiveness is important for company growth (Smith, 2016). Business efficiency and effectiveness can be measured in a number of ways. These include measuring return on investment (ROI), process and operational efficiency, eco-efficiency, labour productivity, and financial efficiency.

ROI evaluates the profitability of one particular investment compared to the profitability of different investments. It attempts to measure the direct return a certain investment will generate in relation to its cost (Fernando, 2021). Process efficiency and operational efficiency are additional measures that examine profit earned as a function of operating costs (Hayes, 2021). This is executed for each business process to determine if the cost to income ratio of this process can be improved (Indeed, 2021). Eco-efficiency measures the impact that business practices have on the environment. This is determined by calculating environmental impact as a percentage of business income (Indeed, 2021). Labour productivity measures a labourer's output in an average working hour (Rasure, 2020). This measurement is greatly influenced by the availability of technological tools and automation to this and other employees (Kromann et

al., 2011). Financial efficiency can be used to assess business efficiency and effectiveness by calculating what percentage of company revenue is spent on expenses (Indeed, 2021).

The possibility of achieving company success is dependent on how well the company implements strategies that will influence its ability to achieve company objectives (Randeree & Yousha, 2009). There are variables that influence the ability of a company to be effective and efficient. These variables include business model effectiveness, the efficiency of business processes, the level of skills possessed by the leadership force of the company (Almatrooshi et al., 2016), the skills and development of the workforce, and on-going innovation (Jabbari & Tohidi, 2012).

This study will focus on two of these variables, namely skills and the development of the workforce (investment in human capital) and on-going innovation (investment in technological R&D). It aims to explain the importance of managing and developing these variables in order to affect positively the labour productivity of the firm.

## 2.10 LABOUR PRODUCTIVITY

Labour productivity, also referred to as the productivity of the workforce, is known as actual economic output per hour of labour (Rasure, 2020). To put it differently, enhancing productivity entails either reducing the quantity of material and labour utilised in the process, or increasing the output level with the same quantity of input (Thompson, 2019). The growth in labour productivity is determined by three key elements which include ongoing investment into developing physical capital, implementing new technology, and developing human capital (Lumen, n.d.). Investment into physical capital encompasses the tools, equipment, and facilities that workers have at their disposal to produce goods. Advancements in technology, such as automation, employ novel approaches that combine inputs to yield greater output. Human capital development entails an ongoing commitment to enhancing the education levels and specialisation of the workforce (Rasure, 2020). Measuring labour productivity provides an approximation of the collective impact of these underlying trends (Rasure, 2020). Labour productivity is greatly influenced by workers' skills and education (Susanto, 2014). An uneducated or unmotivated labour force is, therefore, of significant concern for corporations (Schmitt, 2021). Additionally, being unable to catch up with technological progress elsewhere can leave productivity behind (Schmitt, 2021). In addition to labour productivity, another very useful productivity measure is multifactor productivity (MFP).

MFP, also known as Total Factor Productivity (TFP), measures the excess value embodied in the output of an economy after accounting for all the combined inputs (including labour, capital, services, etc.) (OECD, 2021). This metric is indicative of how well labour and capital resources are combined in the production process (OECD, 2021). This was identified by the economist Robert Solow as a key measure of efficiency in an economy, and, as a result, is sometimes called the Solow Residual (Schmitt, 2021). MFP is used as an indicator of the rate of return for all resources used in an industry (Apostolides, 2008). Both labour and MFP are important in a firm and for the larger economy, for several reasons, one being to improve competitiveness (Weidinger, 2021). It is essential for both governments and companies to consistently acknowledge the necessity of continuous improvement and investment into the three key factors: physical capital investment, education and training, and technological advancements.

1. **Investment in physical capital**: Increasing the amount of private sector and government investments into capital goods such as infrastructure will potentially enhance productivity whilst at the same time reduce the expenses associated with conducting business (Rasure, 2020). Many estimates show that the output multiplier for infrastructure investment is much higher than other fiscal interventions (Bivens, 2017). Infrastructure development can lead to tighter labour markets and effectively restore labour productivity issues (Bivens, 2017).
2. **Quality of education and training**: Providing skills development opportunities that allow employees to boost their skills through accessing affordable education and training. This is directly linked to increasing productivity in both a corporation and an economy (Radcliffe, 2022; Rasure, 2020).
3. **Technological progress**: Developing new technologies can enhance worker productivity (Rasure, 2020). Endogenous growth model pioneers, Lichtenberg (1992) and Romer (1990), suggest that the correlation between R&D expenditure and technology investment result in enhanced productivity and, subsequently, growth in an economy. Technological progress because of the 4IR can potentially be a huge contributing factor to improvements in labour productivity (Engel et al, 2015).

## 2.11 THE FOURTH INDUSTRIAL REVOLUTION

The concept of 4IR is used to denote the convergence of physical, digital, and biological realms (McGinnis, 2020). It can also be described as a novel industrial paradigm that encompasses a

range of future industrial advancements (Pretorius et al., 2021). These future advancements include a mixture of artificial intelligence (AI), big data, robotics, the Internet of Things (IoT), 3D printing, cloud manufacturing, quantum computing, augmented reality (AR), virtual reality (VR), genetic engineering and other related technologies (McGinnis, 2020). These technologies are all able to analyse, communicate with and act on incoming information. Thus, enabling organisations to make data-driven intelligent decisions, and being constantly aware of and responsive to new information (Deloitte, 2020).

A mechanism of dealing with declining productivity and cost-competitiveness, for many mining firms in SA, is through embracing applicable 4IR/digital transformation technologies (Engel et al., 2015; Pretorius et al., 2021), many of which will need to be revolutionary and disruptive to the current methods of mining (World Economic Forum, 2016). New innovation and the adoption of 4IR technologies is expected to bring a multitude of benefits to the industry including (1) improving productivity and cost competitiveness, (2) improving the safety of operations, and (3) improving the efficient, effective and productive extraction of minerals (Geschwindt, 2021). Some of the benefits 4IR in the mining industry include, but are limited to, the following:

**Health and Safety Improvements:** The integration of 4IR technologies, such as IoT sensors, wearable devices, and remote-operated machinery, can greatly enhance worker safety by removing the human from dangerous mining environments. Similarly, the use of drones and autonomous vehicles can reduce the risks associated with transportation and exploration dangers on site (Ramjack, 2024).

**Resource Efficiency:** The use and integration of 4IR technologies like AI for predictive maintenance, advanced robotics, and smart sensors will contribute to the mine's ability to precisely and efficiently extract mineral resources. This may contribute improving efficiency, optimising material handling, reducing waste and minimising environmental impact (METC, 2022).

**Innovation and New Business Models:** 4IR in the mining industry is responsible for creating new types of innovative business models. This is possible through the use of data to drive decision making and predictive analytics. This is particularly useful for exploration, and the

development of startups that are committed to creating mining-focused innovations, which spur on economic growth and diversification (4Sight, 2023).

**Community Development:** Through the implementation of 4IR technologies, a significant amount of local community development can be created through training and employment in technology-driven roles. This will support the economic development and capacity building in mining communities. This is beneficial for its impact in creating a skilled and diversified workforce (Innes, 2024)

**Global Competitiveness:** Embracing 4IR technologies positions the South African mining sector as a global leader, attracting investment, fostering international partnerships, and encouraging technology transfer. This enhances the industry's standing and competitiveness on the global stage (Pretorius et al., 2021).

**Data-Driven Decision-Making:** Advanced analytics, big data, and machine learning enable mining companies to make data-driven decisions which in turn lead to increased safety, optimisation of operations and ultimately an improvement in strategic planning and overall performance (Ramjack, 2024).

**Sustainable Operations:** The implementation of 4IR technologies enables real-time environmental monitoring which promotes the integration of environmentally responsible practices into mining operations. This is likely to result in a reduction og the industry's carbon footprint, and enhanced social responsibility, thus leading to mining practices that are more sustainably and ethically minded (Ramjack, 2024).

These positive aspects highlight the significant opportunity that exists for improving all aspects of the mining process through the integration of 4IR technology.

In the last decade, there has been a 7.6% reduction in MFP in South Africa. This is somewhat attributable to mining cost inflation consistently surpassing general inflation by 2-3% each year. This has led to two-thirds of production sitting within the top part of the mining cost curve globally. In addition to this, there has also been a 10% decline in mining output and an 11% decrease in minerals sales (PwC, 2021). The use of 4IR technology, if fully embraced, could

be a solution to the above-mentioned challenges (Geschwindt, 2021) and a key enabler in creating a modern, globally competitive sector (Mgojo, 2021).

However, despite the potential role 4IR technology can play, as a solution provider for the above decline, its wide-spread implementation can, in some instances, be controversial. This is because of the possible effect it can have on job stability. It is suggested that 4IR could impact 60% of jobs globally and such jobs would either become redundant or automated (Ukwazi, 2019). However, a different viewpoint suggests that 4IR technologies, that are implemented in a manner that is centred around people, will actually create new and different jobs. These jobs would have safer and healthier working conditions, they would include better pay and would be more fulfilling (PwC, 2021). To ensure this, a people-centred strategy that focuses on how 4IR can enhance the work of humans rather than posing a threat to them, would be required (PwC, 2021). This people-centric approach to implementing 4IR into the South African mining industry will require extensive regulatory changes that insist on a balance being achieved between this type of innovation and the socio-economic development of mining communities (Venables, 2022).

## 2.12 WHY INNOVATION MATTERS

Innovation is the starting point for a new technological development; there would be no progress without innovation (Idex, 2021). Innovation is one of the most important mechanisms available to combat critical risks, solve problems, and bring about change and advancements that improve the society in which we live (Brooks, 2015; Satell, 2017; WycKoff, 2015). History illustrates that technological innovation is an engine that drives modernisation and is one of the most important factors leading to progress in society (Idex, 2021). Cambridge University researchers suggested that the inadequate level of productivity growth in many Western countries, which has long been a concern for policymakers and economists, can primarily be attributed to the unequal dispersion of innovation throughout the economy (Hough, 2020).

Much in the same way that innovation is important for the growth of the economy, it is also crucial to the success of a firm (Emeritus, 2022). A preliminary examination into the significance of innovation in the industry can be achieved through analysing labour productivity (Bogliacino & Pianta, 2009). Generally, innovation and technological advancements have positive impacts on output. Technology enables an increase in production rates without a corresponding expansion of the workforce (Kylliainen, 2019).

Landsberg and Tilton (1999), as cited in Hartlieb and Sanchez (2020), conducted research into understanding the significance of prioritising innovation and the development of new technologies as inputs to promote growing labour productivity. This research was conducted using the case of the US copper industry and its decline and subsequent recovery from the 1970s to the 1990s. The results of this study found that the majority of increases that were seen in labour productivity in this time, were attributable to the incorporation of new and advanced machinery and technology. These including for instance, larger trucks and drills, more advanced and computerised scheduling systems and real-time process controls (Hartlieb & Sanchez, 2020).

Using a similar approach to the one discussed above, the Chilean copper industry was studied from 1978-1997, by Garcia (2001) as referenced by Hartlieb and Sanchez (2020), in order to better understand labour productivity growth. These findings too, suggested that around a third of productivity growth in that total period was due to innovative activities and the introduction of new and advanced technologies (Hartlieb & Sanchez, 2020). These findings were coherent with that of the previous study, both suggesting the important role innovation plays in the ability of the mining industry to remain competitive.

To complement these patterns seen in previous studies, the University of Houston has suggested that investing in innovation capacity significantly affects the profitability and share price of firms (Hough, 2020). Despite the decision many firms make to invest in and grow their innovation capacity, it can still be a frustrating process given the high failure rates of innovative activities. Even the activities that are successful often prove to be challenging in relation to sustaining performance (Krutz, 2020). Pisano (2015) believed that the difficulty in building and maintaining the capacity to innovate is mainly due to the insufficient development of innovation strategies at many firms. Research conducted by Deloitte (2020) produced survey results indicating that two-thirds of CEOs do not have formal strategies regarding their approach to 4IR or they are utilising ad-hoc methods for implementation. The survey data goes on to suggest that businesses are generally more successful when they have spent time developing well-rounded and inclusive 4.0 strategies (Deloitte, 2020). Part of developing an innovation/industry 4.0 strategy is understanding, among other things, which types of technology to use as well as the type of implementation process to follow for every innovation pursued (Pisano, 2015).

### 2.12.1 TYPES OF INNOVATION

Innovation types, among others, include the radical and the incremental (Talin, 2022). Radical innovations refer to changes in technology that are revolutionary and that drastically transform the way work is currently done (Kasmire et al., 2012). In contrast, innovations that are incremental in nature involve simple adjustments to current technology or business processes, and are responsible for creating minor improvements (Chandy & Tellis, 2000; Hall 1996). The fundamental distinction between radical and incremental innovations relates to the amount of novel technological advancements included in the innovation and thus, the extent of new knowledge embedded in the innovation (Rabiei, 2011).

These two types of innovation fall into the two different theoretical perspectives, highlighted earlier on: the Nelson and Winter evolutionary perspective; and the neo-Schumpeterian perspective. Both address the importance and necessity of technological development and implementation but support different implementation strategies. As mentioned earlier, Nelson and Winter's evolutionary perspective supports incremental and the neo-Schumpeterian one supports radical types of innovation. It is crucial for South African mining managers to understand which innovation approach is better suited to the mining environment, with a particular focus on how productivity can be increased in the challenging South African mining context. This understanding will ensure that the path of technological development chosen for the South African mining industry is capable of evoking positive change considering the environmental complexity. An understanding of how context may influence the technological trajectory of the industry is important for the correct strategy formation and investment into the most appropriate technological R&D.

## 2.13 INVESTMENT IN TECHNOLOGICAL R&D

Investment in technological R&D affects company performance in a variety of ways. It helps organisations differentiate themselves and gives them a competitive advantage over other companies (Purcell, 2019). Investment in technological R&D increases a company's knowledge and innovative capacity as well as its absorptive capacity that are all imperative to its survival and success (Lemonakis et al., 2017). Technological investments made by a company should be aligned to their strategic goals (Sodhi, 2022). This means different firms may choose to implement different groups of technology influenced by the technology needs of the firm, the benefits the firm hopes to realise from the new technology, and the firm readiness to implement this technology (Mbaya & Willie, 2020). Some of these technological

benefits that may drive the company's choice of technology investment, include the following: improved worker safety; minimised environmental impacts; reduction in operating costs; higher throughput; and significant increases in productivity (Cashman, 2022; Taylor, 2022).

Australian mining company, RT, at its East Pilbara operation in Western Australia (WA) is an example of how productivity, among other factors, drove their choice to invest in automation by introducing driverless trucks. This innovation created cost and time saving opportunities for the company and hence positively affected its performance (Macola, 2020). According to Casteel and Fiscor (2009) the Australian mining and mineral process R&D scheme is the reason that Australia is more technologically advanced than its global mining competitors. During the early 1990s, various programs funding mining R&D were established by the commonwealth of Australia. A few decades later, these programs are known for their excellence in science and engineering (Casteel & Fiscor, 2009). One of these program groups is the Commonwealth Scientific and Industrial Research Organisation (CSIRO), an internationally renowned authority in the field of mineral exploration and mining. CSIRO's Exploration & Mining Division continually works to ensure that the resource industry remains prosperous. It is a powerful partnership of science and technology, and of innovation and application (Casteel & Fiscor, 2009). The presence of such a powerful partnership that is focused on the application of science technology and innovation in the mining industry, plays an integral part in the operating environment of a firm like RT. It seems that this this kind of drive for excellence in innovation could have been a factor that influenced RT's drive to become advanced in automation.

Juxtaposed against this is SA's sluggish approach to fully embrace innovation and technology in the mining industry (Mining Technology, 2020). With the rising costs of extraction and transportation, it is imperative that SA makes some dramatic and fundamental changes to its current mining methods (Cornish, 2016). Many individuals involved in the leadership of the mining industry stress the fact that this can be achieved only by increased spending on R&D (MCSA, 2022). In relation to R&D expenditure from other industries, mining lags behind. The government has clearly stated that it plans to rectify this problem by increasing R&D country levels and using R&D to transform the South African economy (Ghebrihiwet, 2019). If the government plans to use R&D as a tool to transform the South African economy, it should focus on investing in and developing human capital, for its direct link to the success of the R&D activities (Martínez-Sánchez et al., 2020).

## 2.14 INVESTMENT IN HUMAN CAPITAL

Investment in human capital refers to the development of individuals in the workforce with the intention of increasing the economic value of their experience and skills (Kenton, 2020). Company performance and thus profitability are largely dependent on the abilities of the human workforce (Carlin et al., 2022). This means that if a company continually invests in its employees through increasing their educational levels and providing different forms of training, the company will increase its chances of being more productive and profitable (Kenton, 2020). However, despite this, it seems that the benefits of investing in human capital in a company are often overlooked (Lombard, 2018). It is the employees who are to thank for creating value throughout the value chain (Lombard, 2018). There is a robust correlation that exists between how a company and an economy succeed and grow with the development of human capital in that economy (Nickolas, 2021).

In spite of this, many individuals still argue that human capital will become redundant as the use of technology increases (Lombard, 2018). However, it is noteworthy that a company's capacity to innovate and implement new technologies depends on the capabilities of its workforce. New technologies will be useless without the human element (the intangible asset) that holds the knowledge that makes the implementation of these technologies possible (Alvarez & Perez, 2012). A company should therefore perform at its optimum level by combining the benefits of both types of investment and not focus merely on investment in technological R&D. As explained above, it is the human capital in a company that is responsible for the implementation of new ground-breaking technology, so human capital investment is essential (Carlin et al., 2022). Human capital development assists in achieving productivity growth through its ability to increase innovative capacity (by participating in R&D) as well as through its ability to increase the absorptive capacity of the firm or industry (Bye & Faehn, 2021). It is common to find that in small open economies, where sectors promote the interaction of human capital, R&D, and trade this enables technological absorption, and the economy tends to grow faster (Bye & Faehn, 2021).

Effective human capital development within an organisation is closely linked to a strong company vision that prioritises the integration of technology within to human workforce. A strong vision that advocates for the harmonious coexistence of human skills and technological advancements will assist in reshaping the culture that already exist in the organisation and create a mindset that is open to technological change. This ideal culture, the one that welcomes

new technological advancements, will influence the attitudes and willingness of employees to embrace technological change and will create a space for collaboration where human talent works alongside technological innovation (MOL Group Human Capital Vision, 2023).

## 2.15 ABSORPTIVE CAPACITY

Absorptive capacity speaks to the ability of a company to learn new knowledge that does not exist within the company's operations (The Oxford Review, 2019). It is one of the most important capabilities (Murtic et al., 2019). Without absorptive capacity, a company is unable to acquire and apply new knowledge and be innovative in its business practices (Murtic et al., 2019). The Cohen and Levinthal (1990) model of absorptive capacity suggests that the development of a construct is a process that consists of both the acquisition of external knowledge and the modification of internal business systems over time, enabling a competitive advantage and leading, subsequently, to increased company performance (Gutiérrez-Broncano et al., 2022).

To promote absorptive capacity in a firm, it is important to develop strong technology diffusion channels and interaction mechanisms (Chang et al., 2002). It also underscores the importance of continual investment in R&D and development of human capital to ensure a high absorptive capacity (Chang et al., 2002).

In addition to its ability to increase a firm's innovation capacity and thus its performance (Gutiérrez-Broncano et al., 2022) absorptive capacity also creates an enabling environment for FDI and technology spillovers (Murtic et al., 2019). The capability of a firm to absorb technology from foreign firms is dependent on the skill level of the workforce (Toner, 2011). This means that investments in human capital, and increased investment in R&D, enhance absorptive capacity and better enable a firm to reap the benefits from FDI technology such as technology knowledge spillovers (Ghebrihiwet, 2019).

FDI and technology spillovers are important in the mining industry since they allow developing resource rich countries to benefit from superior technological advancements (Abdramane & Seydou, 2021). Based on the empirical literature regarding FDI spillovers, the main influencing factors that determine the presence and the magnitude of these spillovers, is firstly the size of the technology gap in between foreign and domestic enterprises, and secondly is the ability of domestic firms to absorb such spillovers (Ghebrihiwet, 2019). As shown by Findlay (1978),

Blomström and Wang (1992) and Kokko (1994) as cited in Ghebrihiwet (2019), the absence of a gap in technology between foreign and local firms indicates the absence of potential for local firm advancement. Consequently, any FDI spillovers are unlikely to occur. Conversely, in the case of a significant technology gap, local firms may encounter challenges in harnessing the absorptive capacity necessary to gain from spillovers.

## 2.16 FOREIGN DIRECT INVESTMENT IN MINING

FDI happens when a business in one country invests in a business or organisation in another and is commonly identified as being a driving force of globalisation and a major force in the achievement of industry development (Adam, 2009; Antwi & Poku, 2013). The literature explains that FDI is an important part of a growth strategy for a firm and is necessary for economic development (Ayanwale, 2007). FDI acts as a driver of new business routines that create a better economic environment in which the company can operate (Forte & Moura, 2013).

Many countries are working to improve the attractiveness of their business environment to entice more FDI. The South African mining industry has failed to attract large amounts of FDI in recent years, the speculated reasons being related to an economy that is growing slowly, political instability, and constant changes to mining policies, as well increasing labour costs (Kumwenda-Mtambo, 2018). SA's president at the time of writing, Cyril Ramaphosa, is committed to implementing necessary measures to increase FDI levels in mining (Kumwenda-Mtambo, 2018).

Implementing measures to attract more FDI is useful to any country. However, this is particularly useful for developing countries, because of the technology spillover it produces (Fan, 2022). Transfer of technology and knowledge (technology spillovers) from multinational companies to domestic companies in developing countries allows the host country to imitate the new technology and increase business productivity (Forte & Moura, 2013; Zhu, 2010). If a host country has the necessary conditions and channels the full benefit of FDI, including technology spillovers, will be derived (Fan, 2022). It is important to understand which conditions should be present to support the absorption of technology spillovers (Fan, 2022).

### 2.16.1 TECHNOLOGY SPILLOVERS IN MINING

FDI is very clearly beneficial for a host country's growth, particularly in the area of transferring advanced technologies from a developed to a developing country (Akyuz, 2018). It is believed that a technology spillover will allow the receiving firm to implement the new technology with a greater amount of ease and in a timelier manner than if they had developed the technology on their own, thus increasing the chances of large-scale adoption (Tseng, 2022). The combination of these two benefits reduces the risks associated with implementing new innovative technology (Tseng, 2022). The beneficial effects of technology spillovers are dependent on various contextual factors in the host country, two very important ones being absorptive capacity and the availability of existing infrastructure (Hale & Long, 2006; Zhu, 2010). The fact that these two factors are necessary for a successful spillover, highlights the very influential role contextual factors have on technological success.

In addition to this, technology spillovers also positively impact the domestic economy through various channels including forward and backward linkages (The World Bank, 2019). These linkages in the mining value chain are of utmost importance since they ensure that value is retained in the host country. Using backward linkages to develop a supply industry for extractive operations may potentially lead to the formation of other industries through horizontal linkages (Ghebrihiwet, 2019). Linkages are believed to be one of the best solutions for benefitting employees, and a means of dealing with possible employment loss because of the increased use of technology in the sector (Leeuw & Mtegha, 2018).

## 2.17 CONTRIBUTION OF THE STUDY

The uptake of fourth industrial revolution (4IR) technologies in the mining industry is rapidly growing and has been receiving interest from academics in a range of disciplines (Harvey, 2019). Despite this focus there are still knowledge gaps. Academic understanding of the interplay between country contextual factors and evolutionary or revolutionary approaches to technological change and their combined influence on mining specific technological trajectories is still restricted in scope and in depth.

Previous studies, discussed in the contributions table (Appendix 1) have highlighted extensively the importance of innovation and the introduction of 4IR technology in the mining industry. A substantial body of literature exists on the usefulness of innovation and technology as a tool to improve productivity and performance, as well as to promote future growth and

development in the industry (Deloitte, 2018; Ghebrihiwet, 2019; Hartlieb et al., 2020; Hermanus, 2017; Kouma et al., 2017; Maisiri et al., 2021; Pretorius et al., 2021). The literature discusses adequately various factors that are necessary for the formation of an innovation ecosystem (Fessehaie et al., 2016; Olvera, 2021; Pretorius et al., 2021), as well as the barriers and drivers that exist in relation to the adoption of 4IR technologies (Maisiri et al., 2021; Olvera, 2021; Pretorius et al., 2021). To complement this knowledge, there are many studies that explain the importance of developing the correct management approach that will influence the successfulness of new innovation and technology (Deloitte, 2018; Olvera, 2021; Yulia et al.,, 2019). Several studies have investigated the factors that influenced the decline in the South African mining industry, coupled with research on contextual factors that may impede SA's adoption of new 4IR technology (Ghebrihiwet, 2019; Hermanus, 2017; Leeuw et al., 2018; Maisiri et al., 2021). Previous studies have also reported on technological trajectories in the mining industry and the necessary research and development (R&D) inputs that shape these trajectories (Bye et al., 1995).

Although prior research on this topic is extensive, there are some consequential gaps that would limit a mining firm's ability to optimise the introduction of new technology. These gaps exist for four reasons. 1) Not all studies have been completed in the South African mining environment and this makes their contribution limited since they lack contextual relevance. 2) Other studies that have considered the unique social environment of SA have merely listed the constraints with no attempt to provide solutions. For this reason, it is not fully understood how best SA should be approaching a catch up with global leaders, despite contextual difficulties. 3) The literature does not adequately discuss the theoretical tension that exists between evolutionary and revolutionary approaches to technological evolution in the mining industry, nor does it suggest how context may influence this choice. 4) In the context of the mining industry, the literature does not adequately explore the interaction between the contextual factors; the tension between technological evolutionary theories and technological trajectories. It is unclear to what extent contextual realities shape the trajectory of technological change, and subsequently a firm's ability to catch up with global leaders. This research sought to overcome the above limitations and fill the gaps in the literature in several ways.

First, previous studies conducted on the potential benefits that an increased use of technology may bring to firms as well as to the country were extended into the South African context to ensure the contextual relevance of the findings.

Second, previous studies regarding the importance of an increased use of technology that have already been completed in the South African context, were extended by introducing a solutions-oriented approach. Instead of focusing on the difficult contextual factors as an obstacle that prevented the increased use of technology (as many past studies have done), this study attempted to uncover the best management approach to overcoming the difficulties presented. This addition seeks to support the process of technological development and mine mechanisation in a manner that suits the South African business environment. It will suggest how SA could approach their catch up with global leaders in the best way possible, in spite of their difficult context.

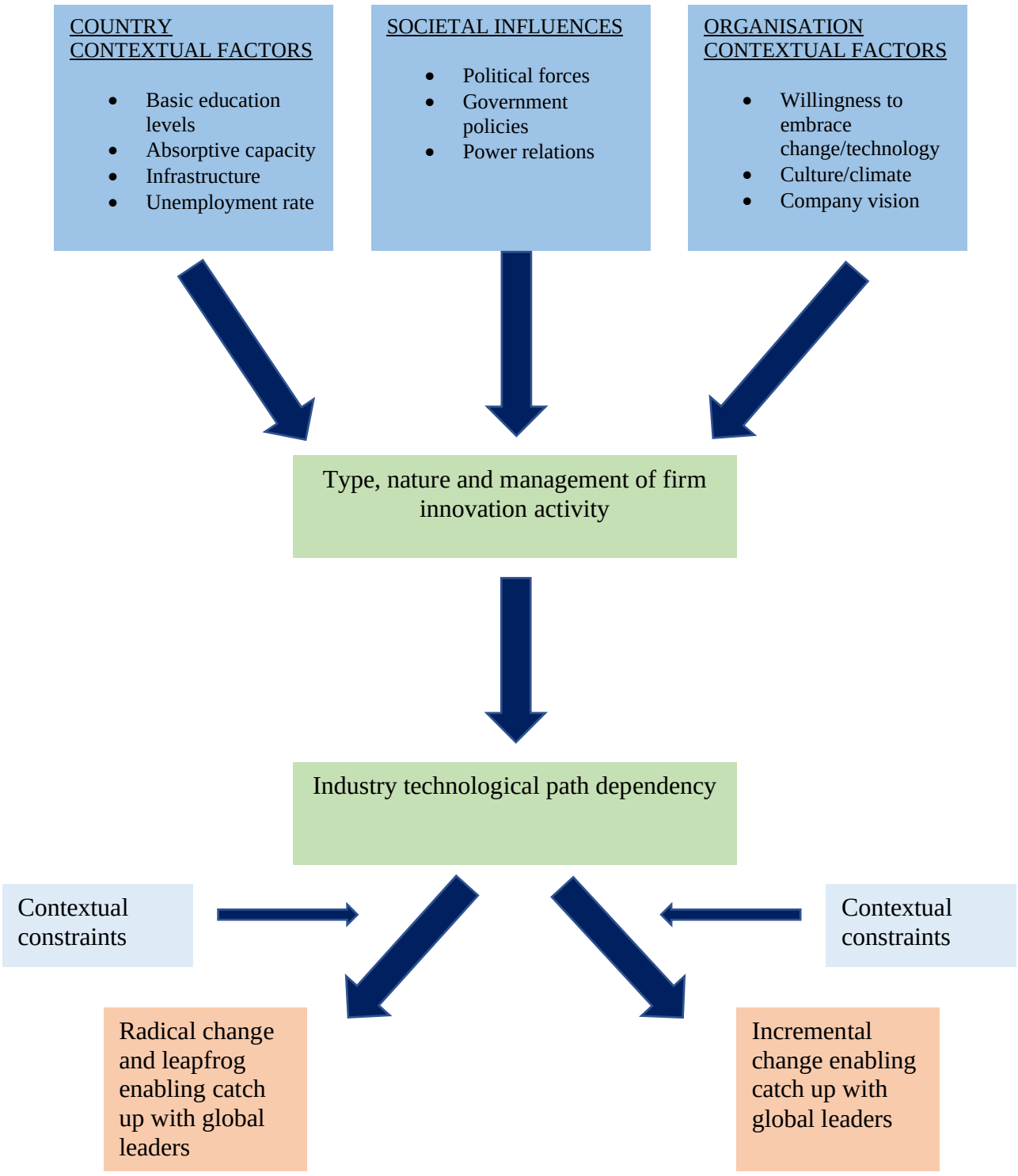
Third, previous studies with similar content to this one but that used a quantitative methodology, were extended in this study with the use of a comparative case study analysis. As is the case with Yazan (2015) this extension will allow for a deeper exploration and understanding of this complex phenomenon. The in-depth nature of a comparative case study method allowed this study to re-examine important study variables in an attempt to resolve the confusion and contradictions regarding these relationships in the current literature. Following Eisenhardt (1989), Glaser and Strauss (1967), and Yin (1989), in providing detailed explanations that quantitative approaches miss, these case studies will potentially produce novel insights into the connections between these variables. By tracing the evolution of technological developments at each firm, matched with the evolution of their respective contextual environment, the was able to cultivate a deeper understanding of the interaction between these two variables and their impact on technological trajectory. In this respect, the use of a comparative case study was useful because it is especially suitable for studying organisational changes as Poole and Van de Ven (1990) have illustrated.

In light of the above additions this dissertation aims to provoke novel thinking on how specific contextual factors may influence the choice to implement technology incrementally or radically and offers unique insights to mining managers on how to navigate this theoretical tension. It aims to uncover the uncertainties regarding the extent to which contextual realities shape the trajectory of technological change, and, subsequently, a firm's ability to catch up with global leaders.

These potential contributions will hopefully result in a study that offers novel insights, suggesting how South African mining firms should approach the implementation of technology. In addition to the possible contribution to management literature this firm level analysis will, in turn, also offer broader insights that are relevant at country level. This will be noteworthy given its potential to contribute positively to policy literature concerned with the socioeconomic upliftment of the South African economy.

The literature presented in the above literature review as well as the study aims and research objectives are in line with the behaviours and relationships evident in the guiding conceptual framework (See Figure 1 below). All of these aims either support the firm level analysis or help to understand the contextual factors affecting the firm. Chapter 4, the case study chapter, delves into a more detailed discussion of the components of the conceptual framework, particularly in the PESTLE analysis. While the literature review encompasses all aspects of the conceptual framework, it also receives a more comprehensive treatment in Chapter 4 to prevent duplication.

Figure 1: Guiding Conceptual Framework




Source: Author

## 2.18 CONCLUSION

In this chapter, the theory relating to different modes of technological development, both radical and incremental, has been discussed with a particular consideration of how contextual factors may influence this. Ideas arising from the technology gap theorists have also been discussed and considered in relation to the South African mining industry. This chapter, including reference to the literature on the historical development of the industry, focused on understanding the important role mining plays in the economy and considered firm-specific literature with a focus on productivity and the influence of 4IR technologies on this. It also explained the importance of R&D and human capital development, and their influence on FDI, absorptive capacity, and technology spillovers. This chapter included the contribution of this study as well as a diagrammatic representation of the conceptual framework guiding the research.

# CHAPTER 3: RESEARCH METHODOLOGY

## 3.1 INTRODUCTION

In this chapter, the methodological approach is introduced in terms of the contextual challenges posed by the complexity of the phenomena being examined and the epistemological and ontological assumptions of the study are presented and justified. The research approach is introduced followed by an account of the research strategy, research design, and the methods and techniques that were used to collect and analyse data. The chapter also includes an outline of the steps followed to ensure the rigour of, and data quality control in, this research. The chapter ends with a discussion of actions taken to ensure that the research remained ethical. According to the literature reviewed in the previous chapter, certain precedents guide this research. This chapter therefore builds upon the work that was completed in the previous chapter.

## 3.2 RESEARCH CONTEXT

South African mining reserves are estimated to be valued at $2.5 trillion (Marshall, 2023). Paradoxically, although they hold some of the world's most valuable and some of the largest deposits, the industry is still in drastic decline (Government Communication and Information Systems, 2012). Complicating this paradox is SA's seemingly sluggish approach to using 4IR technologies that could prevent further decline and capitalise on the vast potential the industry offers for future growth and development (Mining Technology, 2020).

The slow uptake of technology in the South African mining industry is clear when we compare SA with its global competitors (Oxford, 2015). This dissertation aims to provide strategic insight into this lag by comparing information, located in context, from SA with that from Australia at firm-level. The reason for the selection of Australia is based on its world ranking as a top mining destination (Jamasmie, 2020). It is ranked the highest in the world, in relation to the adoption of technology (Macola, 2020). Additionally, according to the annual global survey of mining conducted by the Fraser Institute, WA has been ranked as the most desirable location in the world for mining investment in 2021, with Southern Australia ranking in the top 10 (Aliakbari & Yunis, 2021). Juxtaposed against this is SA's poor 2021 Frasier Institute ranking, in its lying in the bottom ten least attractive mining investment jurisdictions in the world (Aliakbari & Yunis, 2021; Steyn, 2022). Unlike Australia's high and fast technology adoption rate, SA has had a slow process of adoption and has not yet fully embraced all the

benefits of technology adoption (African Mining, 2022). A South African Mining survey conducted by Accenture (2019), found that by not prioritising integrated platforms and advanced analytics, SA has missed out on nearly ZAR51 billion that was created from the opportunity arising from these two digital initiatives. This highlights the question of whether SA's technological lag is the result of limited technological firm activity or if the relevant firms are trapped in a certain path-dependant technological trajectory that has been created by its context.

## 3.4 RESEARCH PARADIGM

Paradigms, according to Burrell and Morgan (1979), are very specific belief systems that cannot be compared. Each one of these systems has its own central norms that are followed by different research communities. The paradigm chosen for this study was based on Biniari's (2007) doctoral study since it used a qualitative methodological approach to conduct research into understanding the complexities of corporate venturing processes. Biniari (2007) explained that her approach in selecting a paradigm was based on two processes; first, the investigation of ontological and epistemological expectations of different paradigms and second, the evaluation of the paradigm in terms of the research domain, the specifics of the research context, and the kinds of questions being asked in the current study. Following Biniari (2007), I considered various well cited literature on paradigms (e.g., Burrell & Morgan, 1979; Guba & Lincoln, 1994; Guba & Lincoln, 2000; Morgan, 1980) to establish where this study would fit. Technological development in the mining industry of SA is a highly contextualised phenomenon that requires the acknowledgement of the macro-economic context of the country, the organisational context, and the technological context. On these grounds, the paradigm approach most suited to this study is one that can explain how social interactions create various complex phenomena (Lawani, 2020). After a review the literature cited above, critical realism (CR) appeared to offer the best approach to explore the complexities inherent in this study.

### 3.4.1 CRITICAL REALISM

CR as a paradigm is an approach that differentiates between the world that may be described as real and the world that is observable (Warwick, 2020). CR acknowledges that a reality exists beyond human conception (Lawani, 2020). A critical realist believes that the events people observe are created by events that people are unable to observe, and therefore, society can only be properly understood if people understand what it is that causes the unobservable events (Warwick, 2020). This paradigm is concerned with social structures and human activity and

how their interaction forms the basis of a complex phenomenon (Lawani, 2020). Methods used in this paradigm seek to understand causal relationships between societal events. It seeks to gain deeper understandings of the issues at hand to give strategic recommendations that better address these social problems (Fletcher, 2007). CR scholars state that to obtain rich explanations of a phenomena and to thoroughly understand it, qualitative methods would be most useful (Bhaskar, 1998).

#### 3.4.1.1 RELEVANCE OF CRITICAL REALISM TO PHASE 1 OF THE STUDY

The CR approach analyses interactions between structural entities and contextual conditions to determine if a particular interaction could have generated a certain set of events that may be useful in explaining a given phenomenon (Williams & Wyn, 2012). Similarly, case studies are also used to explore and explain phenomena that occur in everyday life (Yin, 2009). Case study research seeks to understand what casual links may exist between different events that result in the creation of certain pathways (Yin, 2009). CR is, therefore, well suited to Phase 1 of this study's methodology.

#### 3.4.1.2 RELEVANCE OF CRITICAL REALISM TO PHASE 2 OF THE STUDY

Additionally, the critical realist paradigm is well suited to methodology Phase 2, the interview-based qualitative analysis, since CR is focused largely on understanding the complexities of social reality (O'Mahoney, 2016) as is an interview-based qualitative study. These reasons indicate that a CR paradigm is suitable for both Phase 1 and Phase 2 of this study.

### 3.4.2 ONTOLOGICAL ASPECT OF CRITICAL REALISM

The concept of ontology refers to underlying beliefs concerning the fundamental nature of a specific phenomenon being studied (Burrell & Morgan, 1979). Critical realists suppose that reality is independent of individuals' perceptions of it (Warwick, 2020) thus illustrating that human beliefs may sometimes be false (Barret et al., 2010). CR acknowledges that complexity is inherent in social phenomena (Bazeley, Haigh & Kemp, 2019) and it adopts a stratified ontology consisting of three domains: the empirical (that which can be seen); the actual (that which occurs); and the real (that which causes) (Bhaskar, 1998). CR suggests that causal relationships exist (Parvulescu, 2020) but an important distinction is made between their existence in a closed or open system (Bhaskar, 1998). In closed systems, a single causal mechanism can be identified, while in open systems it is more difficult to identify single causes of complex phenomena (Bhaskar, 1998). Many phenomena, for which we require in depth

knowledge, exist in open systems, and therefore cannot be made subject to *ceteris paribus* conditions; they need, instead, to be studied as holistically as possible (Parvulescu, 2020).

#### 3.4.2.1 ONTOLOGICAL ASPECT OF CRITICAL REALISM: STUDY PHASE 1

As explained above the ontological aspect of CR underscores the importance of comprehending the causal connections between structures and events (Wyn et al., 2012). In this approach, researchers aim to explain phenomena by pinpointing the mechanisms that drive observable outcomes (Structchbury, 2021). This outlook is particularly suitable for case study research, as it facilitates an in-depth understanding of the relationships and structures within the organisation under study, shedding light on how they interrelate and their impact on the organisation's technological trajectory.

#### 3.4.2.2 ONTOLOGICAL ASPECT OF CRITICAL REALISM: STUDY PHASE 2

Although the ontological aspect of CR acknowledges an objective reality, it also adopts a relativistic position on knowledge (Bazeley et al., 2019). It recognises that individuals may interpret and comprehend this reality differently, shaped by their social and cultural contexts (Strutchbury, 2021). This dual perspective enables a sophisticated exploration of intricate social phenomena. Hence, the ontological approach of critical realism proves to be well-suited for conducting in-depth interviews with industry experts, providing an opportunity to discern the varying understandings of the mechanisms described in the previous paragraph.

### 3.4.3 EPISTEMOLOGICAL ASPECT OF CRITICAL REALISM

The principles of epistemology refer to the inquiry of what qualifies as acceptable knowledge, or more specifically, what knowledge can be acquired, how this knowledge can be used in comprehending the world, and the manner in which it can be presented to others (Benton & Craib, 2001; Burrell & Morgan, 1979;). Critical realists believe that knowledge is obtained by experiencing, observing, and then interpreting different aspects of reality since these aspects must exist prior to the occurrence of an event that is being studied (Williams et al., 2012). The context in which something is observed or experienced will alter that experience and therefore cannot be considered as being objective (Heeks & Wall, 2018). Different viewers may report different experiences and interpretations based on their past experiences and their current perspective in the social structure being studied (Williams et al., 2012).

#### 3.4.3.1 EPISTEMOLOGICAL ASPECT OF CRITICAL REALISM: STUDY PHASE 1

As is explained above, the epistemological aspect of CR that is well suited to case study research is the idea of understanding that the context in which something is observed in will alter the experience of it and therefore cannot be objective (Williams et al., 2012; Strutchbury, 2021). This supports the importance of studying the effects of context on the strategic decisions of a firm in the case study research.

#### 3.4.3.2 EPISTIMOLOGICAL ASPECT OF CRITICAL REALISM: STUDY PHASE 2

The epistemological stance that different viewers may report different experiences and interpretations based on their past experiences and their current perspective in the social structure being studied (Williams et al., 2012; Strutchbury, 2021) is in line with the qualitative interviews being conducted in Phase 2, which aim to understand the impact pf these differing experiences on the technology adoption of a country or a firm.

### 3.4.4 AXIOLOGICAL ASPECT OF CRITICAL REALISM

Axiology refers to the values a researcher needs to consider when planning and conducting research. It considers inputs from different paradigm approaches that assist the researcher in making the correct decisions (Kivunja & Kuyini, 2017). CR is considered to have emancipatory values (Heeks & Wall, 2018) in recognising that social structures and mechanisms can sometimes cause outcomes that are oppressive and unfair (Heeks & Wall, 2018).

#### 3.4.4.1 AXIOLOGICAL ASPECT OF CRITICAL REALISM: STUDY PHASE 1

The emancipatory values that are associated with the axiological aspects of CR (Heeks & Wall, 2018) are well suited to support case study research that is aimed at improving the management of technology in mining firms, all with the aim of developing the human capital of the workforce and redressing the social inequalities of the past.

#### 3.4.4.2 AXIOLOGICAL ASPECT OF CRITICAL REALISM: STUDY PHASE 2

The axiological aspects of CR would be suitable for qualitative interviews with experts in the field, as it would promote that the researcher maintain a certain level of respect to the contextual sensitivity that exists in the social, cultural and historical context in which the research takes place (Williams et al., 2012). Awareness of this would ensure that the researcher has prepared their interview questions and approach accordingly, to account for the sensitivity that may exist around this topic.

## 3.5 RESEARCH APPROACH FOR PHASE 1&2: INDUCTIVE

Extending previous work by Al Shamsi (2020) this study followed an inductive grounded approach in its methods of collecting and analysing data in methodology Phases 1 and 2. In using inductive and qualitative research novel insights are formed that commonly suggests theory from vastly new directions (Bansal et al., 2018). Inductive theorising, which is firmly based on data, has the potential to expand the researcher's epistemological perspective through larger strides compared to hypo-deductive reasoning that relies on quantitative data. Thus, it has the capability to generate entirely new and innovative ideas (Bansal et al., 2018). This approach of inductive theorising, which utilises qualitative data, is particularly suitable in situations where there has been limited prior research conducted. As is often the case in complex and intricate challenges (Baer et al., 2018). As Bamberger and Pratt (2010) have pointed out, unconventional contexts have the ability to challenge our preconceived theoretical frameworks. This approach allows the theory to follow the data as opposed to the data following the theory. Consequently, it has resulted in the development of a nuanced and all-encompassing study focusing on the perceptions of participants regarding the phenomena being examined.

## 3.6 METHODOLOGICAL CHOICE FOR PHASE 1&2: QUALITATIVE

Qualitative research offers critical tools that advance an individual's ability to foster novel perspectives (Bansal et al., 2017). Through the process of inductive theory building, research utilising qualitative data provides valuable insights that challenge known theories and exposes new potential directions for theoretical development (Bansal et al., 2018). As we encounter more wicked problems in our world, it is becoming increasingly important that scholars adopt qualitative methods to understand and deal with these complex challenges (Bansal et al., 2018). Bansal & Corely (2011) highlighted the benefit to scholars of combining different qualitative methods in their study since they work towards effectively understanding and explaining new theory, so this study is based on the adoption of two forms of qualitative research—an inductive qualitative case study and an inductive interview-based qualitative analysis. Following Stake (2006) and Yin (2014), whose work also suggests the combination of qualitative methods, this combination of methods will add critical value to the study and ensure the triangulation of findings.

## 3.7 RESEARCH DESIGN

### 3.7.1 A MULTI-METHOD APPROACH

As mentioned above, this study employs a multi-method qualitative approach comprised of two phases. Phase 1 is case study research that is supplemented by Phase 2, an interview-based qualitative analysis.

Data collected from the case study was compared and contrasted with the findings of the qualitative interviews to strengthen the credibility of the outcomes, and, following Mujtaba and Shoaib (2016) who also compared and contrasted findings from different methodology approaches, resulted in the triangulation of the data (see also Karim, 2007). The convergence of these results across the different methods used resulted in greater confidence in the study findings and increased validity of the case study research (Campbell & Fiske, 1959; Huberman & Miles, 1994). Having many sources of data is useful for establishing chains of evidence and for discerning patterns. Such patterns are often able to record tensions, differences, and the dynamics of complex situations; this enabled the study to include different viewpoints (Ryan, 2012). The two methodological phases are both well suited to exploring and understanding complexities in real life situations (Avery et al., 2011; Corley et al., 2012) and this is ideal given the complex relationships described in this study.

This approach is derived from previous work using similar methodological approaches. Biniari (2007) and Al Shamsi (2020) both used qualitative case studies combined with an interview-based analysis as their methodological approach.

#### 3.7.1.1 PHASE 1 RESEARCH STRATEGY: CASE STUDY RESEARCH

Phase 1 of this research design is a case study. A case is a phenomenon that exists within a real-life context. This real-life context is often situated in a complex environment over which the researcher has limited control (Yin, 2002). According to Yazan (2015) this definition implies that certain approaches to conducting research such as history, experiments, surveys, and statistical tests alone are not able to inquire deeply enough into the specific topic at hand to gain the best possible understanding of the complex phenomenon. To implement mining automation in SA it is essential to consider a great many economic and societal obstacles that must be overcome (Hartlieb & Sanchez, 2020). This makes the digital transformation of the mining industry a complex task that would be best understood in the context of a comprehensive research strategy such as a case study (Yin, 2002).

Following the comparative approach of Chreim et al. (2020) this case study was also structured with a many-pronged, comparative design in mind. The comparison is between the world's leader in mining automation, Australia's RT (Nick, 2016) and one of SA's leading mining companies in automation, AA (Goodbody, 2021).

Comparative case studies are useful since they display the effects of context in different scenarios (Goodrick, 2014). They highlight the interaction between policy and the success of interventions (Do Amaral, 2022). Additionally, through the use of a comparative case study a deeper more nuanced understanding of the theory which influences the internal dynamics of the change process is developed (Brownson et al., 2013).

This comparison between two leaders in mining automation, one in a developed country and the other in a developing country, highlights the different approaches to innovation and their resultant outcomes. This approach is most appropriate for understanding areas in which South African mining companies can tailor their approach to increase the success of their programs. An altered approach may enable a catch-up to global leaders, like RT, in relation to productivity and automation levels (DeLorenzo, 2022). This case study analysis investigated qualitative data regarding the context in which each firm operates, as well as the many aspects of the firm's innovation and technology drive. It followed the comparative approach laid out in Gray and Yan (1994) of selecting firms in different contexts, as a useful approach to understanding and explaining the effects of context. The data collection for the within-case and cross-case analysis is discussed in detail below.

#### 3.7.1.2 PHASE 2 RESEARCH STRATEGY: INTERVIEW-BASED QUALITATIVE ANALYSIS

Phase 2 was a qualitative analysis based on a number of semi-structured interviews with many different stakeholders in the mining industry. This phase was intended to produce rich and detailed findings that were more targeted and that focused on more specifics than is usual in case study research. Qualitative interviews provide insights and understanding into the beliefs and practices as well as the experiences of others. Given the complexity of the phenomena being studied in this research, a qualitative approach to interviews was utilised to elicit understanding and deeper meanings (see Wengraf, 2001).

The benefit of this type of interview is its ability to be appropriately open and, when necessary, to be improvised in a way that still considers theory (Wengraf, 2001). An interview guide was created with a series of standardised open-ended questions. This was used to guide the discussion to ensure that various themes, concepts, and topics were covered (Appendix 2 & 3). The interview sampling process as well as data collection and analysis methods are all discussed in detail below.

## 3.8 SAMPLING

The process of sampling in a research strategy refers to carefully selecting a certain group from which you will collect data, ensuring that this group will provide you with the data that the study is looking for (McCombes, 2023). A sampling decision will include the size of the sample, and the technique used to select the sample.

### 3.8.1 PHASE 1: SAMPLING SIZE ESTIMATION

The sample size for Phase 1, the case study analysis, consists of two cases for the purpose of the firm-level comparative case study analysis. One case being an Australian firm, and one a South African firm.

#### 3.8.1.1 PHASE 1: SAMPLING TECHNIQUE

Purposeful sampling was used as the sampling technique for Phase 1 of this study. Purposeful sampling is a non-probability sampling technique (Crossman, 2020). This method was used to ensure the appropriate selection of the relevant, information rich cases that would enable useful comparisons (Alchemer, 2021).

This study selected AA and RT as the two cases for comparison and contrast. The reason behind the selection of these two firms was to analyse and compare the innovation drive and activity from two leaders in different contexts. The following aspects were considered in the selection of these two cases.

Table 3: Similarity criteria used in selecting each case

| **Characteristic** | **AA** | **RT** |
|---|---|---|
| Location of operations | Multinational with operations in SA[1] | Multinational with operations in Australia[2] |
| Commodities mined | Multi-commodity operations[3] | Multi-commodity operations[4] |
| 2022 market capitalisation | Considered a leading mining company. Ranking 3rd with a market capitalisation of 63.37 billion US dollars.[5] | Considered a leading mining company. Ranking 2nd with a market capitalisation of 146,75 billion US dollars.[5] |
| Are they committed to pioneering technology in their field? | Yes. Known to be amongst the top mining firms who are committed to innovation and technological development and change. They are part of the group of technological leaders, at the forefront of change in the South African context.[6] | Yes. They are at the forefront of many of Australia's ground-breaking technological advancements, including being the founder of one of the largest robots in the world, the autonomous haulage train.[7] |

Source: Author

### 3.8.2 PHASE 2: SAMPLING SIZE ESTIMATION

The sampling size for Phase 2, consisted of the 20 individual interview participants for the interview-based analysis that was necessary to contextualise the firm-level analysis. These 20 individuals included 13 South African and seven Australian participants working in mining or mining-related firms.

#### 3.8.2.1 PHASE 2: SAMPLING TECHNIQUE

The intention behind qualitative research is often to understand the reality of study participants, and this cannot be achieved in using large representative samples (Barnett et al., 2018). Participant reality is, instead, understood by selecting individuals within the study area that can share their unique slice of reality so that when all these slices are combined a more holistic understanding of a complex phenomenon may be achieved (Elmusharaf, 2016).

[1] (Statista, 2022a).
[2] (Statista, 2022b).
[3] (Anglo American, 2022a).
[4] (Rio Tinto, 2022b).
[5] (Statista, 2022c).
[6] (Anglo American, 2016).
[7] (Rio Tinto, 2022e).

Purposeful sampling was used as the sampling technique for Phase 2 of this study, building on the same methodological approach that was followed by Al Shamsi (2020). Purposeful sampling is a non-probability sampling technique (Crossman, 2020). This method is often used with qualitative research since it enables the selection of information-rich cases (Duan et al., 2015) and is, therefore, appropriate to the selection of the relevant interview participants (Alchemer, 2021).

The purposeful sampling followed a heterogeneous process of sampling. This process aims to find different types of respondents that can each offer unique and varying perspectives on the research problem (Crossman, 2020). This heterogonous sample included expert individuals involved in different sections of the mining industry who were selected since they could offer different angles on various issues to ensure that this study had many different perspectives and thereby increased its validity (Almeida et al., 2020).

The first group of eight interview participants were selected using purposeful sampling and the remaining participants were recruited using snowball sampling that selects samples based on rare traits that are insightful for the research topic (Ghaljaei et al., 2017).

## 3.10 DATA COLLECTION METHODS

This study used different methodological approaches for data collection purposes. The steps set out below, which include the collection of contextual data and company/institutional data complemented with individual interviews, is built on the methodology of a study conducted by Brownson et al. (2013) that used a mixed methods case study design to analyse how the implementation of services at children's mental health facilities could be improved. The researchers in Brownson's study included document review, individual interviews, and a cross-case analysis. The similarities between the data collection techniques used by Brownson et al. (2013) and the techniques planned for use in this study resulted in the decision to use this methodological approach in this context.

### 3.10.1 PHASE 1: DATA COLLECTION

Phase 1 data collection uses archival document review. This is split into two focus areas, one being archival document review of country contextual documents and two being archival document review of company documents.

#### 3.10.1.1 ARCHIVAL DOCUMENT REVIEW: COUNTRY CONTEXTUAL DOCUMENTS

In methodology Phase 1, country contextual and company documents were collected for both firms. Studying archival context documents as part of any case is necessary to understand the powerful and influential role context has on a firm.

Following the data collection approach of Bowen (2009) documents included in this section were journal articles, government publications such as reports, research reports, fact sheets, surveys, handbooks and manuals, presidential papers, national development plans, budget speeches, policy documents, and various pieces of legislation for both Australia and SA. This document review adopted an approach based on maximum heterogeneity to get as much evidence as possible. However, despite this choice, the large number of available documents necessitated including some and excluding others. The Political, Economic, Social, Technological, Legal and Environmental (PESTLE) analysis structure was followed as a framework for the inclusion and exclusion of certain documents so pertinent topics that explained the most variance in the situation were selected. Including the PESTLE analysis structure as a framework for evaluating contextual factors was extended from a previous study that used the same approach. Kangwa and Mutambo (2018) conducted case study research to investigate the potential of mining Zambia's low-grade copper ore deposits. This case study used PESTLE as a mechanism to gather information and documentation on specific contextual variables to analyse Zambia's strategic context and determine its potential. So, although many topics could have been selected as forming part of the PESTLE analysis structure, the inclusion was limited to the ones that most explain the differences in context. The contents of the document review highlighted the contextual differences between the two firms and the effect this had had on the firms' ability to be technologically oriented.

#### 3.10.1.2 ARCHIVAL DOCUMENT REVIEW: COMPANY DOCUMENTS

Archival company documents including company annual reports, financial statements, company sustainability reports, company innovation reports, company transformation reports as well as media press releases were used to investigate and compare various aspects of each firm's innovation activity. All these archival documents were used to track company changes over time, enabling a comparison of strategic responses by these two firms to their different contextual imperatives.

### 3.10.2 PHASE 2: DATA COLLECTION

The data collection technique for Phase 2 consists of qualitative individual interviews.

#### 3.10.2.1 INDIVIDUAL INTERVIEWS

In methodology Phase 2 interview data from a variety of stakeholders in the mining industry was collected. All the individuals interviewed held fairly senior positions, had an understanding of the strategic context and were able to give strategic input. As mentioned above, the purposeful sampling approach used in this study was adapted from Al Shamsi's (2020) work.

The participants were from a variety of positions along the mining value chain, including academics, mining engineers, mining attorneys, geologists, executives at big mining houses and at research institutions. These professionals were selected across a range of commodities to ensure that opinions were not influenced by the commodity group in which they generally operate. The interview sample in consisting of both South African and Australian participants ensured further triangulation of data and rich conclusions. See Table 1 below for participant information.

Table 1: Interview participant information

| Country | Participant | Position | Commodity |
|---|---|---|---|
| SA | 1 | Ex-Director General at the Department of Minerals Resources and Energy | Many commodities |
| | 2 | Mine owner/manager | Gold |
| | 3 | Established mining house CEO | Gold, Platinum, Lithium and Base Metals |
| | 4 | Managing Director & Geologist | Many commodities |
| | 5 | Research Institute: CEO | Many commodities |
| | 6 | Research Institute: Manager, specialising in development innovation | Many commodities |
| | 7 | Research Institute: Manager, specialising in advanced orebody knowledge | Many commodities |

| Country | Participant | Position | Commodity |
|---|---|---|---|
| | 8 | Managing Director & Engineer | Many commodities |
| | 9 | Academic | Many commodities |
| | 10 | Acting CEO of established mining house | Gold |
| | 11 | Research Institute: Manager, specialising in innovation and technological development | Many commodities |
| | 12 | Mine manager: Technical & Operations manager | Many commodities |
| | 13 | Research Institute: Manager, specialising in exploration activities | Many commodities |
| Australia | 1 | Chairman of established mining house | Gold |
| | 2 | Managing director of established mining house | Vanadium |
| | 3 | Non-executive chairman of established mining house & Mining attorney | Many commodities |
| | 4 | CEO of established mining house | Many commodities |
| | 5 | Non-executive chairman of established mining house & Academic | Gold |
| | 6 | Academic | Many commodities |
| | 7 | CEO of Minerals exploration and development company & Geologist | Many commodities |

Source: Author

#### 3.10.2.1.1 THEORETICAL SATURATION

Throughout the interview process, it was necessary to be aware of the point of theoretical saturation. Theoretical saturation of data has its origin in grounded theory (Glaser & Strauss,

1967; Locke, 2002) as a criterion in qualitative research signalling that the data collection process can be discontinued. This point is reached when theoretical categories have been adequately developed and further data collection will not add more value to the relationships already found (Baker et al., 2018; Hennink & Kaiser, 2019).

According to Glaser and Straus (1967) theoretical saturation should be achieved when the following process has been completed. First, the researcher will use an existing theoretical framework of local concepts as a point of reference to start the collection of codes. This will guide the initial stage of research. Patterns, suggesting some theoretical relationships, begin to emerge from the codes collected and this will become the new point of reference that guides the rest of the research process (Glaser & Straus, 1967). At this point relationships emerge between the original theoretical framework and the one that has developed. As these relationships emerge, the developed theoretical framework will "confirm, challenge, or extend existing ways of conceptualising the phenomena of interest" (Locke, 2002, p. 38). The last stage before achieving theoretical saturation involves the category development process. This stage requires the assumption that through this process the core conceptual categories have been obtained and that they are adequately expressed in the developed theoretical framework. It is at this point that some sort of theory has developed and collecting additional data will not add value since this is the point of theoretical saturation (Locke, 2002). Reaching theoretical saturation means reaching the "empirical limits of the data, the integration and density of the theory, and the analyst's theoretical sensitivity" (Glaser & Strauss, 1967, p. 62).

There are a variety of different models of saturation that exist, each made up of different theoretical and methodological assumptions (Baker et al., 2018). This study used theoretical saturation (discussed above) and inductive thematic saturation models to guarantee that the saturation criterion was reached. The inductive thematic saturation model suggests that saturation is reached when additional data does not result in new emergent themes, nor does it lead to any new codes in the data (Saunders, 2019). To ensure that saturation was attained, 20 interviews of approximately forty-five minutes in duration were conducted and were all digitally recorded. Simple hand-written notes were taken while each interview was in progress and after the interview was complete, a verbatim transcription method was used to document the entire interview for analysis. The verbatim contributions were lightly edited in the interests of grammatical integrity.

The interviews followed a grounded approach that used an organised set of techniques and procedures. This allowed the identification of certain concepts and patterns to build theory from the data, as Corbin and Strauss (2008) have recommended. They suggested that a researcher starts by asking a broad question on a specific area of interest, and then collects all the relevant data about that area. As this data is collected each piece of information is reviewed and contrasted with others. This constant process of comparison will result in similarities and dissimilarities becoming clear, and, ultimately, theory that can explain different observations is inductively developed (Depoy & Gitlin, 2016; Glaser & Strauss, 1967). In this approach, as Glaser (1992) has explained, the interview questions need to be broad, at least initially, because if they are too focused and narrow they may produce inadequate data to formulate theory. For this reason, each interview followed a semi-structured format (that included similar opening, center, and closing questions) to direct the discussion in a certain way but that also allowed for probing for additional information (Brownson et al., 2013). The similar questions asked in each interview were guided by the existing theories in the theoretical framework of the study, the study's conceptual framework, as well as by the study's aims and objectives. The similar studies in the contributions table (Appendix 1) assisted in narrowing the scope of the qualitative interview schedule in order to obtain the data specifically needed to answer the questions that these other studies have not answered.

## 3.11 DATA QUALITY CONTROL

To ensure scientific rigour for qualitative data, it is important to prioritise increased levels of trustworthiness (Stiles, 1993). Trustworthiness is one of the ways in which researchers can reassure themselves and other readers that their research is of a high standard and should receive some attention (Guba & Lincoln, 1985).

Guba and Lincoln (1985) set out four important criteria to promote trustworthiness and rigour. These criteria are: credibility (internal validity); transferability (external validity); dependability (reliability); and confirmability (objectivity).

1. **Credibility** – This is achieved when a study is interpreted accurately to represent the researcher's experience and their findings in a true and believable manner (Guba & Lincoln, 1985). This study achieved credibility through the triangulation of many techniques of data collection such as collecting referential adequacy material, following a process of member checking, keeping a reflexive journal while the data was being

collected and analysed and by using participants' actual words in the final report. Prolonged engagement with interview participants was also used to promote credibility; the interview process was conducted for a period of six months, with some participants being interviewed a second time when further clarification or probing was needed (see also Al Shamsi, 2020)

2. **Transferability** – This is achieved when the results from a study can be extended or transferred into other settings (Guba & Lincoln, 1985). Transferability was achieved with the provision of thick descriptions enabling others, using their own judgement, to transfer the findings of this study. A strict process of purposeful sampling was followed to form nominated samples producing useful and relevant data thus increasing the ability to transfer the findings (see also Al Shamsi, 2020).
3. **Dependability** – A study that is dependable means that its results can be transferred to another similar context or situation within the same group of participants while maintaining the conclusions from the original study (Guba & Lincoln, 1985). In this study triangulation of many techniques of data collection ensured dependability. Dependability was also enhanced by including rich descriptions of the study methods and protocols followed throughout the research including the establishment of an audit trial that included a detailed track record of the process used for data collection. Dependability of the results was strengthened by including participants from different fields and different institutions in the interview-based qualitative analysis that allowed similarities in certain themes to emerge, even across such diversity (see also Callaghan, 2013).
4. **Confirmability** – To achieve this a study needs to ensure neutrality and the accuracy of the data. It needs to be confident that the study results would be confirmed by other researchers (Guba & Lincoln, 1985). Confirmability in this study was achieved by keeping details of the motivation behind each decision made in the research process. This included keeping an audit trial and a reflexive journal (see also Moules, 2017). Additionally, the choice to follow a grounded qualitative approach ensured that the relationships that were most important for each participant would emerge from the data without the imposition of any prior theoretical frameworks (see also Callaghan, 2013).

## 3.12 DATA ANALYSIS METHODS

### 3.12.1 PHASE 1: DATA ANALYSIS METHODS

The process of developing the case study analysis method was supported by the work of a set of prominent authors. These including methodological inputs from Bourgeois and Eisenhardt (1988) who developed the within-case and cross-case analysis techniques and included inputs from Glaser and Strauss (1967) that detailed the importance of using comparative methods to ensure the development of grounded theory from a case study. As well as from the work of Miles and Huberman (1994) that outlined a variety of useful techniques for visual analysis of qualitative data. Their work included useful tools such as graphs and tabular displays for organising and presenting qualitative data.

To this end, methodology Phase 1, the case study, consists of a within-case analysis as well as a cross-case analysis (Bourgeois & Eisenhardt, 1988). The within-case analysis included case study write-ups, containing a large amount of technical detail, for each firm. These write-ups were simply descriptions, but as suggested by Pettigrew (1990) they play a pivotal role in generating insight as they assist researchers in managing the extensive amount of data during the analysis process. The descriptions included specific focus areas for each case study that were suitable to properly understanding and being able to explain the firm's interaction with its context and its innovation and technology drive. Following the data analysis and display methods from the work of McHugh and Mintzberg (1985) the narrative descriptions were coupled with graphs and tables tracking firm expenditure on R&D, firm exploration expenditure, the number of patents filed by each firm and so on. Additionally, this within-case analysis followed work from Barton (1988) as cited in Eisenhardt (1989) who used graphs and tabular displays of information regarding each case.

The second stage of the analysis consisted of a cross-case analysis. As suggested by Eisenhardt (1989) a common approach in cross-case analysis is to identify categories and dimensions that are relative to your research question, and use them as examination points to consider inter-case similarities and differences. The categories and dimensions used for this exercise were based on concepts in the conceptual framework. Following a similar comparative case study layout to Brownson et al. (2013), which included a number of tabular displays of similarities and differences, this approach successfully enabled comparisons to be made across each case, allowing for meaningful information regarding similarities, differences, relationships, and firm behaviours to emerge from the data. The information from the within-case and cross-case

analyses were combined and used to formulate theoretical predictions in the form of propositions. This way the data collected from the case study was utilised in building theory inductively (rather than deductively). "The theory is emergent in the sense that it is situated in and developed by recognising patterns of relationships among constructs within and across cases" (Eisenhardt & Graebner, 2007, p. 25).

#### 3.12.1.1 WITHIN-CASE ANALYSIS LAYOUT

The following five focus areas, with their corresponding analysis points were used to guide the within-case analysis. The numbering of these focus areas does not correlate with the conceptual framework – they are however, in line with the concepts discussed in this framework and are all designed to assist in generating a deeper understanding of how contextual factors, societal factors and organisational characteristics will influence the method chosen to implement innovation and how this will subsequently affect the ability of a country to catch up to global leaders. The selection of these focus areas was partly based on methodology used previously by the Australian Government to conduct their "2016 Australian Innovation System Report" (Australian Government, 2016). This report presents a compilation of evidence pertaining to the framework and performance of Australia's innovation system, drawing upon a variety of key indicators. Some of the indicators used in their methodology were extended into this study to better understand the innovation activity of each firm in relation to its respective context.

This selection aims to better understand the complexities that may exist between a firm's ability to further its own innovative capacities, coupled with the very influential (either permissive or restrictive) role its operating context plays on this ability. Potentially, this will assist in creating a deeper, more holistic understanding of the extent to which innovation progression is dependent on firm activity versus the extent to which it has to do with the influence of the context in which the firm is operating. See Table 2 below for the within-case analysis criteria.

Table 2: Within-case analysis criteria

| **Focus area** | **Analysis point** |
|---|---|
| One: Understanding the context in which the firm operates | PESTEL analysis to unpack aspects of the firm's contextual operating environment |
| Two: Understanding how innovation fits into the identity of the firm | Is the mention of innovation part of the firm identity? |
| | Does the firm's purpose include a link back to innovation? |

| Focus area | Analysis point |
|---|---|
| | Does the firm's strategy include an innovation aspect? |
| | Do the firm's values include a connection to innovation? |
| | Does the firm develop a culture that supports innovation and technological change? |
| Three: Tracking firm activity in the innovation system over time | Firm R&D expenditure |
| | Firm exploration expenditure |
| | Number of patents filed by the firm |
| | Number of patents granted to the firm |
| Four: Understanding the type and nature of innovation and technological activity pursued by the firm | Impact of the innovation on operations |
| | Drivers of innovation behind the development of each innovation/technology program |
| | The nature of the innovation: the type of technology group, and whether it creates incremental improvements or radical change |
| | The "why" behind the firm's innovation |
| Five: Understanding the firm's involvement in developing networks and collaborations | Business to business collaborative research approaches |
| | Business to research sector collaborative research approaches |
| | Business to university collaborative research approach |
| | Business to government collaborative research approach |
| | Support and development for local Small, Medium and Micro Enterprises (SMMEs). |
| | Human capital development to prepare workforce for the digital future |

Source: Author

#### 3.12.1.2 CROSS-CASE ANALYSIS LAYOUT

As mentioned above, the categories and dimensions used to assess inter-case similarities and differences were based on the guiding conceptual framework. These include:

1. Level of firm commitment to developing technological capacity;
2. Main firm driver for innovative change;

3. Nature of the technological investments made by the firm;
4. Influence of country contextual factors on firm path dependant technological trajectory; and
5. Firm culture regarding technological development

## 3.13 PHASE 2: DATA ANALYSIS METHODS

Methodology Phase 2, the semi-structured interviews. produced qualitative data that was collected and analysed inductively using a thematic analysis approach as themes emerged from the grounded analysis (see Heydarian, 2016). Ethics Approval was obtained to appropriately conduct these interviews, see Appendix 6.

Thematic analysis is a method for scientifically studying and offering insights into the patterns and themes that emerge from a dataset (Braun & Clarke, 2012). Utilising an inductive approach for thematic analysis means following a process that is bottom up and allows the content of the data to determine which themes and codes are derived (Bruan & Clarke, 2012). Thematic analysis was approached using the following steps set out by Caulfield (2020). First, familiarisation with the data was achieved by transcribing the audio from the interview and summarising the documents collected. Second, the data was coded by labelling and organising it so that themes and relationships could be recognised. Next, once themes had developed, they were re-examined to confirm that they represented the data accurately. This then led to the creation of sub themes. These sub themes were created through on-going analysis that was transformed into an interpretable piece of writing. This was all well-articulated and it supported the study aims and research question.

An important aspect of the analysis is data coding (step two above) and the continual comparison of data that allows patterns to emerge (Glaser & Strauss, 1967). Coding lies between collecting qualitative data and developing valid theory from the data (MAXQDA, 2021). This study used open coding progressing to axial coding and then selective coding (Corbin & Stauss, 1990).

As observed by a number of qualitative researchers, the separation of interviewing and analyses is somewhat meaningless, as they typically progress together (Guba & Lincoln, 1985; Langley, 1999). A large amount of participant terms, codes, and categories emerged in the open coding phase (see Corbin & Strauss, 2008). In this first-order analysis, faithful adherence to terms

mentioned by informants, with little attempt to condense categories (Corley et al., 2012) was achieved. Open coding aims to uncover as many relevant and possible categories and link them loosely by their similar or dissimilar dimensions (Rezat & Vollstedt, 2019). Each line was coded in the open coding phase, in order to verify and saturate categories so as to result in theory that fully fits the data collected (Glaser, 1967). The main focus of open coding is to conceptualise and categorise phenomena by intensely analysing the data (Rezat & Vollstedt, 2019). Once the initial open coding phase was complete, axial coding was undertaken.

During the axial coding phase, similarities and differences common to the different categories (Corbin & Strauss, 1998) were sought along with attempts to construct linkages between codes in order to achieve more structured categories and subcategories (Medaugh & Scott, 2017). This process highlighted the relevant categories, reducing them to a manageable number (Corely et al., 2012) that were then given labels (preferably retaining informant terms) and a single one deeper structure in this array was sought. Following the instruction of Corley et al. (2012) it was at this point that the researcher appeared to herself as a knowledgeable agent who could think at many different levels simultaneously. These levels include thinking about codes that were produced from informant terms, the themes that these codes were categorised into whilst at the same time contemplating how all of these pieces of information come together forming a larger narrative that answers the overarching question of “what’s going on here?” theoretically. Formulating tentative answers to these questions through the use of a gestalt analysis (Chittipeddi & Gioia, 1991) resulted in the formation of new questions during subsequent interviews. These new questions were more focused on the concepts and relationships that were tentatively developing from the interviews (through a process that Glaser and Strauss (1967) refer to as theoretical sampling).

In this second-order analysis, at the level of the theoretical realm, questions arose about whether the emerging themes are indicative of concepts that can accurately describe and explain the observed phenomena. This has led to a particular focus on developing concepts that may not have sufficient theoretical foundations within the existing literature (Corley et al., 2012). Once a practical collection of themes and concepts had been established, and the theme and concept development process had reached what Glaser and Strauss (1967) referred to as "theoretical saturation," an investigation commenced to determine the possibility of further breaking down the second-order themes into second-order aggregate dimensions, a procedure known as selective coding (Corbin & Strauss, 2008).

## 3.14 ETHICAL CONSIDERATIONS

The research proposal was submitted to the University of the Witwatersrand's Ethics Committee for approval and clearance was obtained before the interview process began. All ethical requirements of the interview process were met, see Appendix 6. Interviewees and the data collected and reported remained anonymous (see Arifin, 2018). A letter and a consent form were also sent to all prospective interviewees to gain their written consent to conduct an interview with them as well as their consent to record the interview (Appendix 4 & 5). This letter gave an in-depth explanation of what this study was about, ensuring that all interviewees fully understood and were comfortable with each aspect of the interview.

## 3.15 CONCLUSION

This chapter demonstrated and justified the methodological rationale that was adopted in the study. It did this by highlighting why the particulars of this study are well suited to the chosen paradigm and methodological approach. This chapter illustrated how the combination of the two research approaches seemed to effectively explain the complexities of this study. It discussed the data collection and analysis processes followed for each methodology phase. This chapter ended with the ethical considerations of the study.

# CHAPTER 4: CASE STUDY FINDINGS

## 4.1 INTRODUCTION

As mentioned above in the methods section, this case study consists of a within-case analysis followed by a cross-case analysis (see Bourgeois & Eisenhardt, 1988). The within-case analysis includes narrative case study write-ups for each firm that analyse specific focus areas. The cross-case analysis examines the similarities and differences between cases. This was done through the selection of categories and dimensions based on the guiding conceptual framework. Following a similar layout to Brownson et al. (2013), Chreim et al. (2020), Gray and Yan (1994) and Snihur and Zott (2020) this approach enabled comparisons to be made across each case thus allowing for meaningful information regarding similarities, differences, relationships, and firm behaviours to emerge from the data. The majority of the examination for the within-case and cross-case analysis was conducted within tables. This approach was selected following Cloutier and Ravasi (2020) who suggest that tables are useful for their ability to promote trustworthiness in qualitative research, through increasing transparency of the data collection and analysis process. They also suggest that they are useful for effectively organising and analysing large volumes of data (Cloutier & Ravasi, 2020). This approach is additionally supported by Miles and Huberman (1994) who advocate for the extensive use of tables within qualitative research. They believe that the utilisation of this tool is beneficial for a variety of reasons, including data summarising and display but more importantly they suggest that tables are particularly useful for analytical purposes, which enable researchers to compare data and detect similarities, differences and patterns (Miles & Huberman, 1994). The extensive use of tables within this case study additionally followed previous work from Eisenhardt (1989) who favoured the use of tables as an analytical tool throughout her study. This chapter concludes by combining all information to formulate theoretical predictions in the form of propositions.

### 4.1.2 INTRODUCTION TO EACH CASE

AA, a leading global mining company, produces various commodities including diamonds, copper, platinum group metals, iron ore, thermal coal, and nickel. The company which has its headquarters in London, was by Ernest Oppenheimer in 1917. AA operates in multiple countries around the globe and has approximately 90,000 employees globally. AA is widely

regarded as one of the largest mining companies, who have significant influence on the extraction and production of natural resources worldwide (Anglo American (a), 2022)

RT is also a leading global mining and metals company that is involved in the exploration, mining, and processing of a variety of mineral resources, including aluminium, copper, diamonds, gold, industrial minerals, iron ore, thermal and metallurgical coal, and uranium. RT also has its headquarters in London and was established in1873. RT employs around 47,000 individuals worldwide and is one of the largest and most influential corporations in the mining industry (Rio Tinto, 2022b).

Both AA and RT are known for their leadership in technology development and innovation within the mining industry (Anglo American, 2016, Rio Tinto, 2022e).

## 4.2 FIRM A – ANGLO AMERICAN WITHIN-CASE ANALYSIS

As was discussed in the methodology chapter, the following five focus areas with their corresponding analysis points were used to guide the within-case analysis. These focus areas were utilised to better understand the innovation activity of each firm in relation to its respective context. This selection aims to better understand the complexities that may exist between a firm's ability to further its own innovative capacities, coupled with the very influential (either permissive or restrictive) role its operating context plays on this ability.

### 4.2.1 FOCUS AREA ONE: CONTEXT

A significant focus of the case study analysis was on understanding and explaining the effects of context. Studying archival context documents was necessary to understand the powerful and influential role context has on a firm. The Political, Economic, Social, Technological, Legal and Environmental (PESTLE) analysis structure was followed as a framework for the inclusion and exclusion of certain documents so pertinent topics that explained the most variance in the situation were selected.

Table 4: SA - Political & Legal Context

| PESTLE[8] | **Influencing factor** | **Explanation** | **Effect on Industry** |
|---|---|---|---|
| Political + Legal | Mineral and Petroleum Resources Development Act (MRPDA) | In 2008, the MRPDA (49 of 2008) was passed to allow for the fair access to, and maintainable development of, natural resources in the country.[9] However, it was only certain aspects of this Act that were brought into force in June 2013. 2013 also saw the Amendment Bill into parliament.[10]<br><br>In 2015, the President at the time, Mr. Zuma, submitted the Amendment Bill to be reconsidered by the National Assembly to address constitutional issues, including the absence of adequate public participation and consultation with the National House of Traditional Leaders. As a result of these concerns, the finalisation of the Amendment Bill was delayed until 2018. This lengthily period of time in which the Amendment Bill remained unresolved created a sense of regulatory uncertainty within the industry.[11] | This regulatory uncertainly is detrimental to investment in the mining sector.[12] |
| | The Mining Charter | The main problem regarding legal uncertainty in the mining industry was not only the lengthily period of time it took to finalise the Amendment Bill but also the implementation of the new reviewed Broad-Based Black-Economic Empowerment Charter for the Minerals Industry. [13] This led to the MCSA commencing a review application to prevent the introduction of the new Mining Charter (Mining Charter III) since they believed the process that was followed by the DMRE in developing this version had been unfair.[14]<br><br>Eventually the new Mining Charter III was released in 2019, and it came with some highly controversial additions. One of these was the ability of the minister to make discretionary changes. The added requirements enforced by the Amendment and Guidelines only worsened the already existing uncertainty. Some of the issues with the Charter were made even more complicated by the Guidelines. [15] | Mining Charter III (2017 version) caused a significant amount of uncertainty and controversy.[16] It resulted in various High Court applications, motivated suggestions for a change in political leadership at the DMRE, and created investor uncertainty.[17] These occurrences all encouraged the negative ratings SA received from sovereign credit rating agencies.[18] |
| | Policy on land expropriation | Another concern causing a great deal of regulatory uncertainty was the report released by Joint Constitutional Review Committee that suggested a modification of section 25 of the Constitution of the Republic of SA to enable the expropriation of land without compensation.[19] Although this report has been implemented, there has been no bill introduced to Parliament. This creates uncertainty regarding the possibility of expropriation without compensation in the future.<br><br>The government's actions around providing clarity on land reform in SA will directly influence SA's ability to attract | The discussion of ownership created investor concern.[23] |

[8] PESTLE – Political, Economic, Social, Technological, Legal, Environmental
[9] (Republic of South Africa, 2008)
[10] (Republic of South Africa, 2017).
[11] (Creamer Media's Engineering News, 2019).
[12] (Matlou, 2021).
[13] (Jansen van Vuuren, 2017); (Vella, 2022); (Adonisi-Kga et al., 2017); (Ancer, 2017).
[14] (Creamer Media's Engineering News, 2018).
[15] (Leon et al., 2019; Mining investment, 2021).
[16] (PwC, 2018).
[17] (Creamer Media's Engineering News, 2019).
[18] (Leon et al., 2019).
[19] (Ngcukaitboi, 2019); (Parliament of the Republic of South Africa, 2018).
[23] (Phakathi, 2018).

| PESTLE[8] | **Influencing factor** | **Explanation** | **Effect on Industry** |
|---|---|---|---|
| | | foreign investment.[20] Moody's, a rating agency, has expressed their concern that all of this uncertainty is harming short-term investment.[21]<br><br>Despite these concerns, President Cyril Ramaphosa reassured the mining sector that their property will not be taken from them. It is imperative that the government stipulate detailed legislation and policies that are inclusive and sustainable.[22] | |

Source: Author

Social transformation is a crucial aspect of policy development in SA (Jansen van Vuuren, 2018). In certain circumstances, a compromise may be necessary between competing objectives, potentially resulting in prioritising health and safety concerns, social initiatives, or environmental advances over economic performance. However, it is important to ensure that when developing mineral policy, that the impact of this policy is considered for both the non-economic, social contribution type objectives as well as the economic contribution objectives. They both need to be sufficiently measured (National Treasury, 2019). There seems to be an ongoing issue of misalignment between the regulatory demands and the assistance required from the industry to facilitate transformation and the growth of the economy (Burger et al., 2019; Deloitte, 2018a & Mabikwa, 2018). The widespread belief that growth and transformation are mutually exclusive; that growth prevents transformation and that transformation inevitably leads to a loss in growth has been a prominent aspect of many debates in the South African mining industry (Eunomix, 2018). There is no evidence to suggest that this hypothesis is correct. However, it seems to have influenced policy formation. The lack of robust data and analysis on this matter contributes to the sector's ongoing debates and undermines the effectiveness of policy both in its formulation and execution (Jansen van Vuuren, 2018). Regardless of this widespread debate about socio-economic objectives affecting the quality of policy development, recent policy interventions have still fallen short of achieving some of the key socio-economic objectives they set out to achieve, so the overall usefulness of SA's volatile mineral policy has been low (Eunomix, 2018). It is imperative that transformation and inclusivity are at the heart of policy development, and the South African government should be commended for their efforts on working to improve this across society. This, however, needs to be addressed in a manner that is sustainable and not in a way that

[20] (Oteng, 2019).
[21] (Oteng, 2019).
[22] (Phakathi, 2018).

prevents investments and causes an even greater negative affect on achieving transformation goals. The lower policy efficacy displayed in Table 4 above suggests that if the mining sector is committed to rejuvenation, it will have to develop a stronger competency in how it regulates the industry (Leon et al., 2019; Mining Investment, 2021).

Table 5: SA - Economic Context

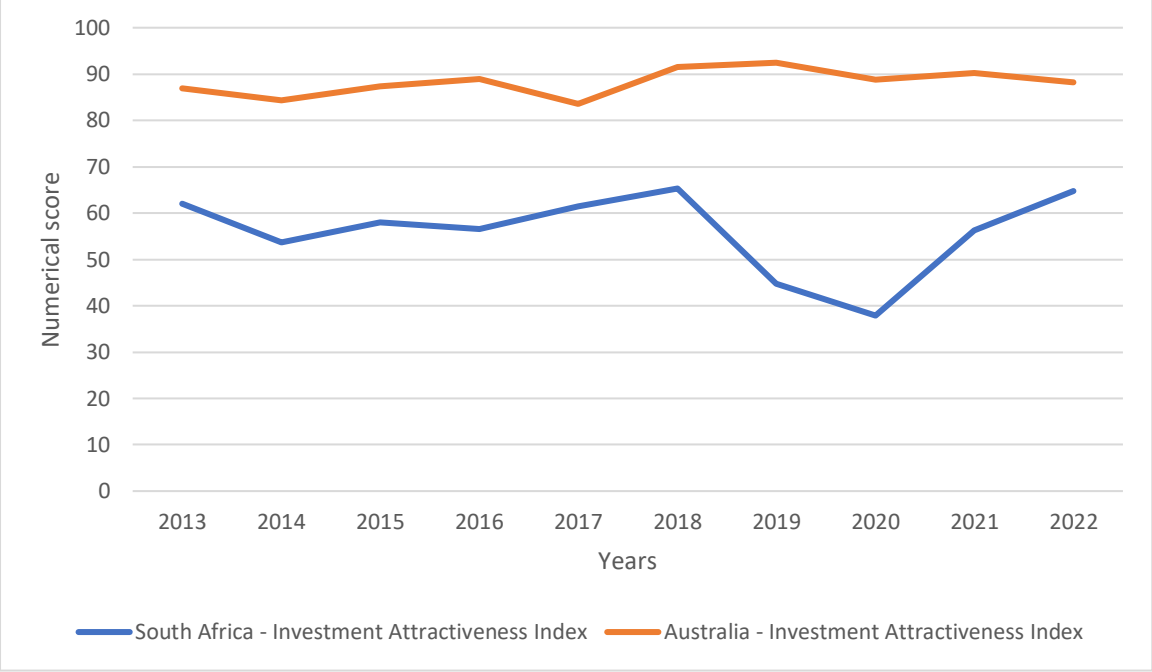
| PESTLE | **Influencing factor** | **Explanation** | **Effect on Industry** |
|---|---|---|---|
| Economic. | Declining FDI | In April 2022, the Fraser Institute released the "Survey of Mining Companies 2021". This survey details the opinions of investors regarding the influence of the mineral prospects of a country and public policy factors (like taxation and regulatory uncertainty) on their choice to invest into exploration activities of a country.[24] According to respondents, 40% of their investment decisions are influenced by policy factors, while 60% are influenced by the mineral potential of a jurisdiction. Unfortunately, despite SA having extensive experience in mining and abundant mineral resources, they ranked in the bottom 10 jurisdictions. WA ranked 2nd in the top 10.[25] (See Figure 2 below.) | A decline in FDI will reduce the finance availability for infrastructure development as well as inhibit the formation of projects which are necessary for poverty reduction and sustainable economic growth.[26] |
| | Declining exploration budgets | SA's exploration budget has been declining since 2007. It was approximately USD 400 million in 2007, which dropped all the way to just under USD 100 million in 2018. This 2018 figure meant that SA held approximately only 1% of global exploration budgets.[27]<br><br>To better reap the benefits of the mineral wealth in SA, the DMRE produced a set of strategic initiatives and actions to be followed that would promote mining exploration. These included securing at least 5% of the global exploration budget within the next 5 years. [28] South Africa, in 2021, accounted for only 0.80% of global exploration expenditure, three years after the DMRE aimed for 5% share. (See Figure 3 below.) | Limited exploration means that SA's current mining output is produced from a set of reserves which are declining and infrastructure that is dated.<br><br>Depleting current reserves, with limited development of new mines, means that output will inevitably shrink.[29] |
| | Generally limited tax incentives for the mining industry | The Income Tax Act contains a tax incentive, section 12I, which is intended to promote and support business development initiatives in SA. This benefit is something that many mining companies may qualify for. In addition to the benefits from this incentive, there is also a R&D tax incentive, the Section 11D. This allows companies to deduct 150% for their expenditure on technological R&D. This seems to be more easily accessible for larger mining companies, rather than smaller ones. This is however something that the MCSA has been in the process of ensuring that these benefits are more accessible by all size companies in the industry.[30] | Mining requires large capital investments to be operational. Additionally, a significant portion of this investment is into exploration and development, which is considerably high risk. For this reason, tax incentives to promote mining investment |

[24] (Myburgh & Sakebate, 2022).
[25] (Steyn, 2022).
[26] (Steyn, 2022).
[27] (MCSA, 2020).
[28] (MCSA, 2020).
[29] (Mbazima, 2020).
[30] (MCSA, 2017-2022).

| PESTLE | **Influencing factor** | **Explanation** | **Effect on Industry** |
|---|---|---|---|
| | Insufficient tax incentives for mining exploration | The current Act provides capital amounts paid upfront to taxpayers, for prospecting and development expenditure.[32] When a mine is in the process of exploration and prospecting, the Act offers a tax incentive whereby the taxpayer may deduct a portion of expenditure incurred during prospecting activities from their mining income.[33] However, this deduction can be made only on income produced from mining. If the exploration activities of the taxpayer are unsuccessful and do not yield any income, the tax payer will be unable to deduct this income.[34] The prospecting expenditure is also not ring-fenced between separate mining operations. For this reason, if a taxpayer conducts mining operations at various sites, the expenditure incurred for prospecting may be deducted from any of the existing mining operations which are income-bearing. This may enhance the exclusivity that exists in mining exploration, for larger mining companies that have the benefit of utilising their existing operations which are already generating income and can be utilised for deducting expenditure.[35] | should be a strategic priority for government. When this is not present it increases perceived investor risk and creates negative impacts for the entire industry.[31] |

Source: Author

Figure 2: Fraser Institute Rankings - SA Investment Attractiveness

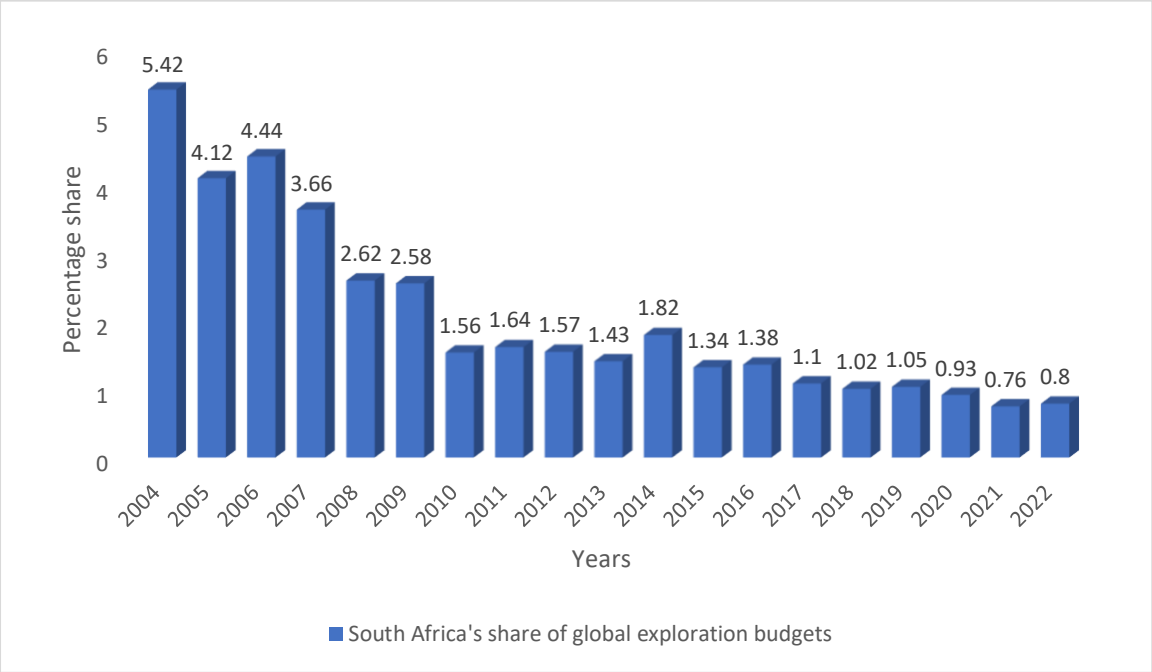



Source: Author

*Data: Fraser Institute, Annual Survey for mining companies.*

[32] (Creamer Media's Engineering News, 2015).
[33] (Deloitte, 2023).
[34] (The Davis Tax Committee, 2016).
[35] (Creamer Media's Engineering News, 2015).
[31] (OECD, 2018).

Figure 3: SA's share of global exploration budgets




Source: Author

*Data: S&P Global IQ*

Table 5 above, and the above figures, both analysing SA's economic context, illustrate the poor investment perception of SA. Figure 2, above, speaks to the declining investment attractiveness of SA's mining industry. This illustrates the substantial gap that exists between Australia as an attractive investment region versus SA's failing investment attractiveness. In conjunction with this, Figure 3 above illustrates the insufficient share of global exploration budgets that SA holds. The limited FDI and declining exploration budgets, displayed in Table 5 above, appear to severely influence SA's potential for economic growth and development as well as industry rejuvenation. As Table 5 above points out, limited exploration means that SA is mining out of reserves with declining orebody availability and existing, old mine infrastructure. This meaning that output will inevitably shrink.

Table 6: SA - Social Context

| PESTLE | **Influencing factor** | **Explanation** | **Effect on Industry** |
|---|---|---|---|
| Social. | High unemployment rate | PwC recently published data suggesting that the unemployment rate in SA will be 40% by 2030. The group believe that this is due to the labour force growing at a faster rate than the economy, and job creation is therefore unable to keep up. [36] (See Figure 4) | The inability, of a large number of adults, to participate in the country's economy is adding to the |

[36] (PwC, 2019).

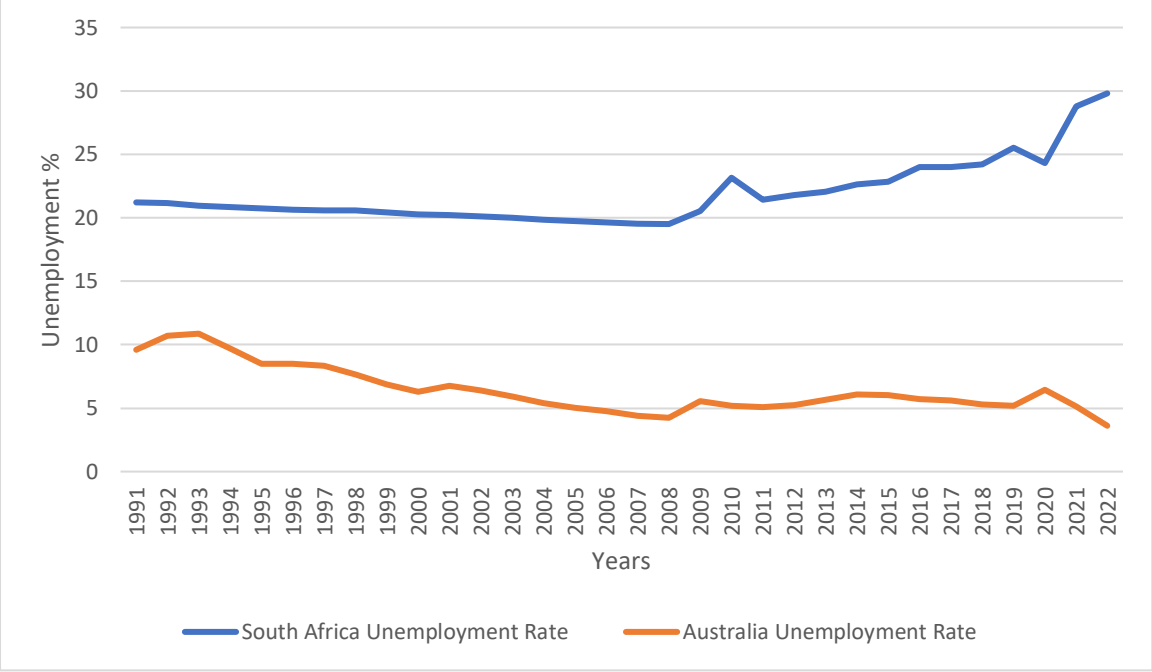
| PESTLE | **Influencing factor** | **Explanation** | **Effect on Industry** |
|---|---|---|---|
| | | | deterioration of cohesion in society. This increases instability in the country causing issues such as protests and community unrest.[37] In July 2022, it was reported by Absa that this increase in unemployment, combined with other factors, could potentially result in civil unrest in SA.[38] |
| | Labour unrest | Labour unrest in the South African mining industry has been ongoing since 2012.[39] The Transnet port and rail strike in 2022 was one of the most recent, and has severely affected the South African mining industry. It caused immense bottlenecks at the ports that resulted in economic losses worth millions of rand, for individual businesses and the economy as a whole.[40] | There is significant concern amongst many economists that the ongoing strikes in prominent mining companies may have adverse effects on the economy of SA and stunt its growth, employment, and investment opportunities.[41] |
| | Poor standard of education | Despite budgeting R298.1 billion for developing basic education in 2022-23, South Africa is still struggling to provide a quality education for its youth. The education system is riddled with issues such as teacher shortages, dilapidated schools, and a lack of progress.[42]<br><br>A recent report by Stats SA has disclosed that almost 30% of 18-year-olds and nearly 50% of 19-year-olds have dropped out of school, with poor academic performance being a major factor for over 21,2% of these cases.[43] | With a long history of a poor education system, there are many challenges that will come with ensuring work force skill and education levels are adequate. However, if it not correctly managed it will prevent the country from growing. Education is a key enabling factor that will determine the successfulness of technology implementation.[44] |

[37] (Larkin, 2022).
[38] (BusinessTech, 2022c)
[39] (Smith, 2013).
[40] (Zawya, 2022).
[41] (Sidler, 2014).
[42] (Mail&Gaurdian, 2023).
[43] (Mail&Gaurdian, 2023).
[44] (Radcliffe, 2022).

| PESTLE | **Influencing factor** | **Explanation** | **Effect on Industry** |
|---|---|---|---|
| | Developing human capital | SA has improved in its human capital development, with its recent move in rankings. In 2015 out of 124 countries it ranked 92nd, then in 2018 out of 137 countries it ranked 61st.[45] However, there has still only been a minor improvement in graduation numbers, research outputs, and employment of graduates in the mining sector.[46]<br><br>University rankings for universities offering mining-related qualifications has also improved. Wits University ranked 15th and the University of Pretoria ranked 33rd out of 60 universities.[47]<br><br>Although the above points are both noteworthy achievements, SA still only had 20% of all students from the ages of 20-24, in 2017, enrolled in a Science, Technology, Engineering and Maths (STEM) or mining related course. This number is relatively low when looking at the same metrics for countries such as Australia and Canada, who also have strong mining jurisdictions.[48] | This is a useful advancement for the industry. It will positively influence the investment attractiveness image, and enhance the industry's ability to innovate, grow and develop. However, regardless of this improvement, the limited activity in STEM related activities could still be a concern that limits technological uptake for SA. |

Source: Author

Figure 4: Comparison of SA and Australia's Unemployment Rate




Source: Author

[45] (Pols, 2019).
[46] (MCSA, 2017-2022).
[47] (MCSA, 2017-2022).
[48] (MCSA, 2017-2022).

*Data: World Bank.*

Table 6 above, along with Figure 4, indicates the very different operating environments in the South African and Australian industry. The high unemployment rates highlight the huge responsibility SA holds as a job creator, something that Australia is also responsible for, but not to the same extent. Table 6 points out that this large unemployment rate is complicated by labour unrest and poor education levels in the South African workforce. These concerns combined, all reinforce the idea that SA, to a certain extent, may be restricted given the type of technology it chooses to implement. The pattern emerging from the data in Table 6 suggests that this would most probably include less labour reducing technology such as automation and more workforce enhancing technology to protect and enhance employment. This is very different in Australia where there are fewer individuals depending on the industry for employment. This different scenario will result, potentially, in the freedom to choose the most suitable technology to match the industry's needs.

Table 7: SA - Technological Context

| PESTLE | **Influencing factor** | **Explanation** | **Effect on Industry** |
|---|---|---|---|
| Technological | Country level R&D intensity | SA's R&D intensity has declined from 0.75% in 2018/19 to 0.62% in 2019/20.[49] When compared to Australia (1.83%) and Canada (1.70%) who, as mentioned earlier, have similar mining climates to SA, this amount is unfortunately much lower. [50] | Continual commitment to innovation and R&D activities will increase the chances of overcoming industry challenges. Advancements in technology will also drastically change the way of mining. This will potentially increase safety, profitability, efficiency, and the ability to adhere to stricter regulations.[51] Although there has been an increase in R&D employment there still seems to be limited R&D activity in SA. This will negatively affect chances for growth. |
| | Country level R&D employment | In a positive light, SA's number R&D employees has increased 5.3% from the 2016/2017 period to the 2017/2018 period.[52] | |
| | Total early-stage entrepreneurial activity | SA has a relatively low total early-stage entrepreneurial activity (TEA) rate OF 10.8% in 2019. Additionally, out of 54 economies SA ranked 49th when measured in the National Entrepreneurship Context Index. [53] | |
| | Ineffective patent and IP allowance systems | Due to the establishment of the National Intellectual Property Management Office in 2011, SA saw an increase in the number of patent applications submitted, until 2017. Since then the number of patent applications received has been gradually decreasing.[54] | |

Source: Author

[49] (Mzekandaba, 2022); (The World Bank, 2022).
[50] (MCSA, 2017-2022).
[51] (Olvera, 2021).
[52] (Republic of South Africa, 2019).
[53] (MCSA, 2012-2022).
[54] (MCSA, 2012-2017).

The limited R&D expenditure and patent activity as well as SA's low TEA, discussed in the above Table 7 above, all point to an underdeveloped mining innovation ecosystem. This pattern of limited R&D activity in SA negatively affects chances of growth. Although Table 7 illustrates that through the increase in R&D employment, there is a possibility for the development of partnerships that may support future collaboration, it also points out that processes in the public sector and inadequate policy interrupt innovation (MCSA, 2017-2022).

Table 8: SA Environmental Context

| PESTLE | **Influencing factor** | **Explanation** | **Effect on Industry** |
|---|---|---|---|
| Environmental | The South African energy crisis & Infrastructure bottlenecks | There are a number of areas where SA is experiencing infrastructure failure, posing a significant threat to the mining industry.[55] The industry is faced with worsening energy and transport infrastructure. This is due to government inactivity coupled with various limitations restricting mining companies from building their own infrastructure to counteract these failures. The industry is also facing the problem of deteriorating public water infrastructure and subsequently water supply issues. These concerns have created a noteworthy threat to the mining sector.[56]<br><br>The increase in the threshold for electricity, generated without licence (Electricity Regulation Act, 2004) was passed to help reduce the impacts of this problem.[57] The Presidential plan to overcome the energy crisis focuses on promoting innovation, especially related to developing renewable energy. Additionally, The White Paper on National Rail Policy (2022) intends to allow access to third parties to Transnet's freight rail. If this plan is successful, it will hopefully eliminate bottlenecks and lower transportation costs.[58] | These uncertainties have created an unwillingness amongst companies and individuals to invest in SA's mining industry.[59] |

Source: Author

The data in Table 8 highlights the pattern of failing infrastructure which creates significant risk for the mining industry. This includes dilapidated energy and transport infrastructure, limited infrastructure development and water supply issues. The sources in the Table 8 show that additional investment into new infrastructure, along with increased investment into information and communication technology (ICT) infrastructure is still needed to ensure ongoing growth and development (MCSA, 2017-2022). ICT investment is necessary to build up an environment

[55] (Mbazima, 2020); (Bartlett, 2022).
[56] (Gumede, 2022).
[57] (Republic of South Africa, 2021).
[58] (MiningReview Africa, 2022); (Republic of South Africa, 2023).
[59] (Leshoro, 2023).

that supports local technology stat-up companies, which may assist in growing the innovation ecosystem and assist the mining industry become more technologically advanced (MCSA, 2017-2022).

Despite the negative impact this lack in supportive infrastructure has had on the industry, the Presidential plan to tackle the energy crisis through renewable energy and the introduction of the White Paper on National Rail Policy (2022) have the potential to revitalise rail and energy infrastructure in SA.

### 4.2.2 FOCUS AREA TWO: HOW INNOVATION FITS INTO THE IDENTITY OF THE FIRM

AA is a leader amongst the global mining companies. They produce products that are needed for almost all aspects of everyday life. They have a number of high class operations around the world, many of which have implemented certain advanced technologies which, amongst others, enable their ability to mine more sustainably; achieve carbon neutrality and progress towards the development of prosperous communities (Anglo American, 2022a). This portfolio is supported by AA's purpose which is to "re-imagine mining to improve people's lives." Another way to express this purpose is by saying that AA wish to change the way they currently mine, to create a better future for people around them. They believe that this will be possible through embracing the "smart future" that mining has to offer. This smart, "ultimate mine of the future" would be the scenario where AA is able to utilise technology in a manner that makes their mining practices more sustainable (Anglo American, 2022b, para. 1). AA currently have an innovation-centered strategy combined with a number of firm values, particularly that of innovation and collaboration, which assist them in achieving their goals for this smart future (Anglo American, 2022c). AA believe that innovation focused on safety, sustainability, and operating performance is at the core of their strategy (Anglo American, 2012-2022).

The data suggests that AA understands the importance of developing the right working culture to enable the introduction of new, innovative ideas. To ensure that this is created, they have included people as one of the three tiers that make up their strategy. This focus on people claims to create a working environment that is inclusive and encourages growth and strong performance (Anglo American, 2022c). One of the methods that AA believe is effective at monitoring and subsequently building this innovative, culturally inclusive environment is through conducting yearly employee engagement surveys. These surveys track many different aspects of an employee's perception of their working environment (Anglo American, 2022i).

### 4.2.3 FOCUS AREA THREE: FIRM ACTIVITY IN THE INNOVATION SYSTEM

The following indicators were selected to better understand the extent and intensity of firm activities that will develop their technological capacity and aid in the creation of an innovation ecosystem. The selection of these indicators was partly based on methodology used previously by the Australian Government to conduct their "2016 Australian Innovation System Report" (Australian Government, 2016). This report presents a compilation of evidence pertaining to

the framework and performance of Australia's innovation system, drawing upon a variety of key indicators. Some of the indicators used in their methodology were extended into this study to better understand the innovation activity of each firm in relation to its respective context. Understanding the kind of effort, the firm is putting into growing their innovative capabilities will be useful in the creation of future innovation strategies.

Table 9: Tracking of firm innovation activity over an eleven-year period

| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Firm R&D expenditure[60] (US$million) | 80 | 103 | 101 | 83 | 63 | 78 | 90 | 107 | 123 | 144 | 167 | 1139 |
| Firm exploration expenditure[61] (US$million) | 206 | 207 | 181 | 154 | 185 | 184 | 228 | 246 | 195 | 257 | 322 | 2365 |
| Number of patents filed by the firm[62] | 341 | 274 | 153 | 146 | 231 | 145 | 166 | 150 | 248 | 123 | 101 | 2078 |
| Number of patents granted to the firm[63] | 296 | 189 | 147 | 109 | 124 | 116 | 81 | 95 | 127 | 121 | 102 | 1507 |

Source: Author

Table 9 above, shows AA's consistent innovation efforts. Over the last eleven years AA has increased their R&D expenditure, more than doubling from US$80 in 2012 to US$167 million in 2022. They have also consistently invested in exploration activities and the development of patents. Table 9 tracks data only from 2012-2022, but patent activity from 2002-2022 shows that AA has filed 4422 patents in total, of which 2492 (56.35%) have been granted (Greyb, 2022a). However, the majority of AA's patents are filed in the UK; of the 4422 patents filed only 160 of them have been filed in SA (Greyb, 2022a). Overall, AA is appropriately active in the innovation system.

### 4.2.4 FOCUS AREA FOUR: TYPE OF INNOVATION AND TECHNOLOGICAL ACTIVITY PURSUED BY THE FIRM

AA has expressed its commitment to the creation of a new trajectory for mining, using technology and innovation at the centre of many activities (MiningMagazine, 2021). This is

[60] (Anglo American, 2012-2022).
[61] (Anglo American, 2012-2022).
[62] (Greyb, 2022a).
[63] (Greyb, 2022a).

achieved predominantly through the combination of their Operating Model, which is well-rounded and includes a focus on innovation; Voxel, their digital transformation platform; and various other innovation focused programmes. This study will focus on two of AA's main innovation programmes, P101 and FutureSmart Mining (see MiningMagazine, 2021).

VOXEL is AA's digital transformation platform which has been developed to facilitate data-driven decision making. This function utilises inputs from AA's Operating Model combined with AI and machine learning to collect data across AA's entire value chain (Brightmore, 2021). A key focus of VOXEL is on Digital Operational Planning and tools for providing feedback, such as Stable & Capable Analysis. Through these elements, business data is better consolidated in order to enhance business processes and management systems (Anglo American, 2012-2022). The functionalities of VOXEL are utilised in both P101 and FutureSmart Mining.

#### 4.2.4.1 THE IMPORTANCE OF P101

P101 is AA's productivity programme (Anglo American, 2012-2022). This programme is focused on improving the productivity and performance of all aspects of the mining value chain (Creamer Media's Mining Weekly, 2020; MiningMagazine, 2021). Its objective is to optimise the performance of processes in their value chain to obtain existing benchmarks, then work to ensure that their capabilities move past this benchmark. Thus, creating new industry benchmarks (Anglo American, 2012-2022). The approach of this programme includes a variety of different focus areas, all of which seek to remove operational instability and system constraints (Anglo American, 2012-2022). Each one of these P101 functions will be discussed in more detail in Table 10 below.

Table 10: P101 Functions[64]

| P101 function | How is this function achieved? | Has the programme been implemented in SA? | Impact of technology programme |
|---|---|---|---|
| Tactical Mine Design | 1. Using the existing equipment to plan the design of the mine.<br>2. Ensuring that safety is properly incorporated into all aspects of mine design. | Yes | This has been one of the main factors enabling over 25% improvement in shovel productivity at SA's platinum mine, Mogalakwena. |
| Blasting Design | 1. Fragmentation models ensure that designs are fit-for-purpose, | No | Los Bronces incorporated model design changes and subsequently delivered a |

[64] (Anlgo American, 2012-2022); (Anglo American, 2022g); (Anglo American, 2022h); (Anglo American Technical & Innovation Report, 2021); (Mining Magazine, 2021).

| P101 function | How is this function achieved? | Has the programme been implemented in SA? | Impact of technology programme |
|---|---|---|---|
| | resulting in enhanced fragmentation that produces improved truck and shovel payload sand milling rates. | | 14% improvement in fragmentation; 20-50% reduction in the number of weekly blasts and a 50% improvement in shovel loading. |
| Blasting Practices | 1. Real-time, in-field digital platforms installed to promote improvements. | No | Real-time, digital platforms enabled a 50% improvement between the execution and the plan for drill and blast.<br><br>This improvement also increases worker safety and social performance. |
| Haul Road Digital Twins | 1. Improvement of existing haul roads, through proper analysis and identification of existing problems. | Yes | 23% reduction in haul time cycles as well as 40% truck speed improvements was seen as the Mogalakwena platinum mine in SA. |
| Maximising Processing Value Drivers | 1. The purpose of P101 is to maximise all processing value drivers for throughput, run time and recovery.<br>2. **For throughput:** Performance is optimised through the use of dynamic process modelling to ensure that no bottlenecking will occur.<br>3. **For throughput:** Performance is optimised through reconfiguring and streamlining processes within the existing infrastructure. | No | The Minas Rio iron ore mine in Brazil has seen a 7% increase in throughput rate. |
| | 4. **For run time:** Performance is optimised through reducing the time needed for asset maintenance and possible shutdowns, by remotely monitoring assets and anticipating maintenance needs. | No | The Moranbah coal complex in Australia has increased its weekly direct operating hours by 12%. |
| | 5. **For the recovery stage:** Performance is optimised through utilising Geometallurgical modelling to better understand the properties of the ore being mined. This will enable a tailor-made approach for mining and processing strategies. This may include, for instance, circuit reconfiguration and operating parameter adjustment. | No | Minas Rio achieved a 2% higher mass recovery. |
| Creating stability in plant processes. | 1. AA believe that in order to sustain their productivity improvements, they need to achieve stability in their processes.<br>2. Stability can be achieved through automating various processes. AA has achieved this with the | Yes | Minas Rio has increased stability in float circuit by 48% and lifted throughput by 4%.<br><br>Los Bronces copper mine in Chile, with the use of its semi-autogenous grinding (SAG) system, has seen a 32% |

| P101 function | How is this function achieved? | Has the programme been implemented in SA? | Impact of technology programme |
|---|---|---|---|
| | introduction of advanced process control (APC). | | improvement in stability combined with 17% reduction in energy needed.<br><br>APC also resulted in 4% water reduction at the Los Bronces grinding mills, as well as increased water efficiency. |

Source: Author

#### 4.2.4.2 THE IMPORTANCE OF FUTURESMART MINING?

FutureSmart Mining is a programme focused on developing business innovation. It supports collaboration between technology, digitisation, and sustainability, paving the way for a more efficient and responsible industry (Anglo American, 2022g). This programme aims to assist in achieving more sustainable mining practices, reduce the physical footprint of the company, increase safety in operations and contribute to meeting community needs (Anglo American, 2022j). The four aspects of AA's FutureSmart Mining programme are: 'Concentrating the Mine'; 'Water-less Mine'; 'Modern Mine'; and 'Intelligent Mine.' The combination of these programmes will enable AA to meet their Sustainable Mining Plan ambitions, with a particular focus on reducing water and energy usage and achieving carbon neutrality in operations by 2040 (Anglo American Technical and Innovation Report, 2021).

Table 11: FutureSmart Mining Functions[65]

| FutureSmart Mining function | How is this function achieved? | Has the programme been implemented in SA? | Impact of technology programme |
|---|---|---|---|
| Concentrating the Mine | The focus of this programme is the optimisation of all mining processes. Through the use of advanced technologies AA plan to mine more precisely, using less capital, less water and energy whilst also producing less waste. The technologies for this programme include bulk ore sorting (BOS), coarse particle recovery (CPR), fines flotation, dry processing, and novel classification. | Yes | The use of these technologies will improve grade feed, eliminate waste and reduce water and energy consumption, thus lowering their physical footprint and the unit cost of production. This reduction in waste and ultra-fine mineral losses will increase recovery rates by up to 3%.<br><br>The Sensor Fusion Loop was also implemented in SA. The purpose of this plant is to develop breakthrough sensing and sorting algorithms which could generate as much as a 5% improvement in metal yield. |

[65] (Anglo American, 2012-2022); (Anglo American, 2022f).

| FutureSmart Mining function | How is this function achieved? | Has the programme been implemented in SA? | Impact of technology programme |
|---|---|---|---|
| | | | Part of concentrating the Mine, AA has also been utilising microwave energy to precondition ores. This produces benefits such as increased throughput and recovery, a reduction in energy and water and a reduction in the hardness of various ores, such as platinum (5-25%) and copper (8-12%). Los Bronces, Mogalakwena, Collahuasi, and Quellaveco are currently implementing this technology. |
| Fresh Waterless Mine | The intention of this programme is for AA to reduce their dependence on water and associated tailings facilities, with the ultimate goal of achieving full recovery recycling. Through a combination of various technologies such as CPR and hydraulic dewatered stacking (HDS) they are successfully reducing the amount of freshwater used in operations and potentially moving towards running dry processing in operations. | Yes | A pilot at Copper's El Soldado mine has measured water recovery of more than 80% with the potential for this to progress to as much as 85%.<br><br>Mogalakwena North has also constructed A full-scale CPR plant, with start-up beginning in late 2023. This brownfield trial aims to understand how water quality and quantity can be improved. |
| Modern Mine | Safety is the number one priority for AA, and that is what the Modern Mine is focused on achieving. AA has developed a number of engineered controls that reduce risk in the working place and assist in achieving zero harm. These engineered controls use remotely operated machinery such as automated drilling to remove people from dangerous environments. | Yes | As part of this programme AA has their first fleet of fully autonomous mining trucks and autonomous mining drills controlled from remote operations centres in Quellaveco and Los Bronces.<br><br>During 2022 a number of autonomous drilling installations took place at Mogalakwena, Sishen (Kumba Iron Ore) and Kolomela operations in SA<br><br>The Group Geographic Information System (GIS) platform, which aims to increase accessibility to accurate geospatial data, is available at all operations.<br><br>The Modern Mine also includes a hydrogen truck and solar plant project. At Mogalakwena, AA has launched its first trial of a 300-ton hydrogen fuel cell truck. This initiative is expected to bring about significant benefits, such as potentially eliminating 46% of diesel-related greenhouse gas emissions and will also create opportunities for new local economies and jobs. |
| Intelligent Mine | The Intelligent Mine is a data-driven programme, that utilises VOXEL to integrate data across the entire mining value chain. This will enable data-driven decisions that drive safety, environmental | Yes | Through the use of VOXEL and a system of digital twins, AA has been able to fully optimise its mining operations across the entire value chain.<br>Through the use of data-driven decisions, |

| FutureSmart Mining function | How is this function achieved? | Has the programme been implemented in SA? | Impact of technology programme |
|---|---|---|---|
| | and productivity improvements. | | AA has also been able to automate a significant amount of processes, creating a 40% improvement in stability and productivity. These improvements were delivered at Minas-Rio, Los Bronces, Kumba and Mogalakwena. AA plan to further this improvement, to reach 95% of all processes automated.<br><br>AA have also used data-driven decisions combined with AI, AR and remote-operation technology to enable Los Bronces mine to be run remotely. |

Source: Author

Table 10 and 11 above explain the functionality of the main innovation programmes at AA as well as each programme's impact. Through several changes/improvements to mining processes, the P101 functions delivered various productivity increases, such as improvements in shovel productivity. However, only three of the six P101 functions were implemented in SA, one of which also delivered environmental improvements through reductions in energy and water consumption. A pattern that emerges from the data in Table 10 and 11 above, highlight AA's reduced productivity focus in SA, compared with its other countries of operation. FutureSmart mining, the second innovation programme at AA, is predominantly responsible for environmental and waste reduction as well as safety improvements. These programmes are all somewhat active in SA, either fully operational or partly so through the introduction of pilot tests. Most of FutureSmart Mining functions are driven by integrated digital systems and intelligent data. FutureSmart Mining is predominantly focused on safety and the environment, telling the story that AA operations in SA have a much larger focus on innovation programmes that prioritise safety and the environment than what they do for productivity.

In order to better understand the innovation activity of each firm, it is useful not only to analyse the innovation impact but also to understand the main driver/reason for the firm's choosing to implement each programme, as well as to understand what type of technology the innovation involves and the manner in which it influences operations.

Table 12: Drivers and Nature of Innovation

| Innovation Programme | Specific programme function | Main driver for the specific programme function | Type of technology group | Effect on the way of work | Has the programme been implemented in SA? |
|---|---|---|---|---|---|
| P101 | Tactical Mine Design | Productivity and Safety | 3D design tools | Incremental improvement | Yes |
| | Blasting Design | Safety | No new technology – just changes to the blasting design | Incremental improvement | Yes |
| | Blasting Practices | Productivity and Safety | Real-time in-field digital platform integrated with autonomous drilling fleets | Radical change | No |
| | Haul Road Digital Twins | Productivity | Digital twins | Radical change | Yes |
| | Maximising processing value: Throughput | Process efficiency | No new technology, just changes to pumping and piping to modify the circuit and eliminate bottle necks | Incremental improvement | No |
| | Maximising processing value: Run time | Productivity | No new technology, just changes to strategies and tactics used for asset maintenance | Incremental improvement | No |
| | Maximising processing value: Recovery stage | Efficiency through reducing material loss | No new technology, just a combination of system reconfiguration and de-bottlenecking | Incremental improvement | No |
| | Creating stability in plant processes | Environmental through water and energy efficiency | Automation | Incremental improvement | Yes |
| FutureSmart Mining: Concentrating the Mine | Bulk ore sorting | Environmental through reducing energy consumption, water usage, and unit costs in the process | Sorting technology and equipment | Incremental improvement | Yes |
| | Modular ultra-fines recovery | Efficiency through reducing material loss and energy footprint | Sensing and sorting technology and equipment | Incremental improvement | Yes |
| | Microwave energy to precondition ores | Environmental through water and energy efficiency | Microwave energy technology | Incremental improvement | Yes |
| FutureSmart Mining: Water-less Mine | Course particle recovery, innovative | Environmental through reducing freshwater usage | Course particle recovery and dry | Incremental improvement | Yes |

| Innovation Programme | Specific programme function | Main driver for the specific programme function | Type of technology group | Effect on the way of work | Has the programme been implemented in SA? |
|---|---|---|---|---|---|
| | flotation process and hydraulic dry stacking | | stacking technologies | | |
| FutureSmart Mining: Modern Mine | Fleet of autonomous haulage trucks | Productivity | Automation | Radical change | No |
| | Autonomous drilling unit | Productivity and safety | Automation | Radical change | Operational in other countries, installation phase in SA. |
| | GIS | Safety through enhanced decision making | GIS technology | Incremental improvement | Yes |
| | Hydrogen fuel cell truck, with a hydrogen plant as well as a solar photovoltaic (PV) installation | Environmental through reduction in greenhouse gas emissions | Hydrogen and battery storage technologies | Radical change | Yes |
| FutureSmart Mining: Intelligent Mine | Haul road digital twins | Safety | AI/Machine learning | Radical change | Yes |
| | APC | Productivity and safety | Automation | Radical change | Yes |
| | IROC, AI, AR, and remote-operation technology to enable the mine to be run remotely from the IROC | Safety, enhanced and efficiency through decision making | AI | Radical change | No |

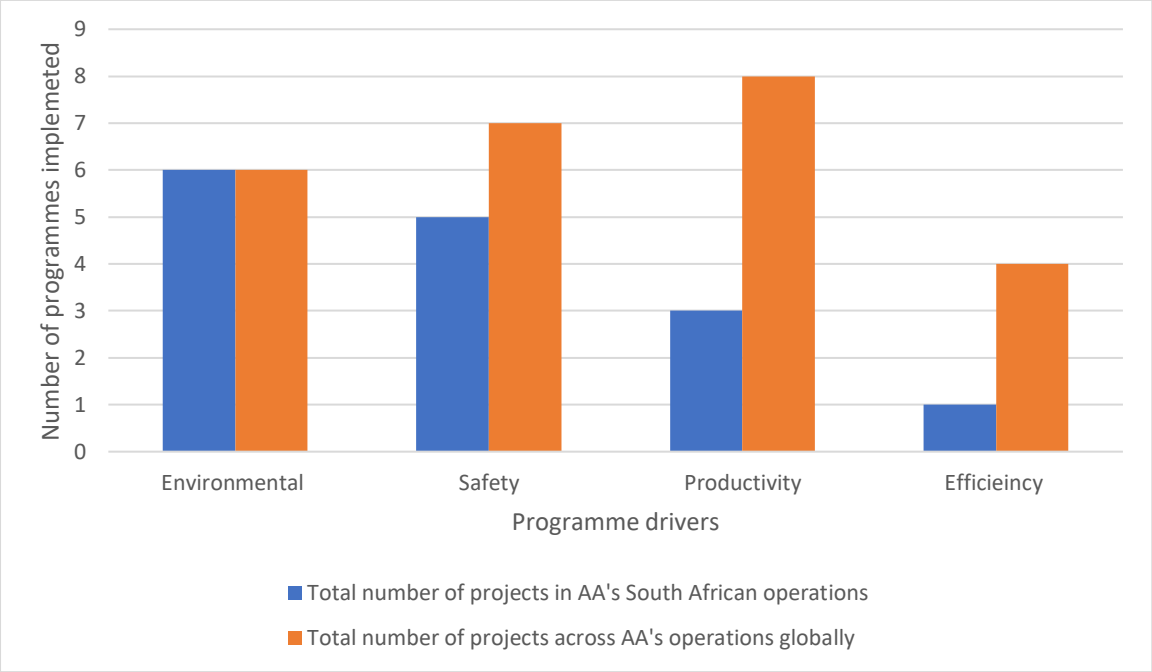
Source: Author

*Data: Information from the above tables all accessed from various AA sites*.

Table 12 above suggests that AA's main innovation drivers for the specific programme functions worldwide are well spread across safety, environmental benefits, productivity, and efficiency. However, not all these specific programme functions have been implemented in SA (see Figure 4 below). When considering the various drivers mentioned above and their implementation in SA, it is important to note that only one out of three (33%) programme functions targeting efficiency; three out of seven (43%) targeting productivity; five out eight (63%) targeting safety and all six (100%) programme functions targeting environmental benefits were implemented in SA. This tells us that SA appears to have a limited focus on prioritising innovations that will produce large scale productivity improvements, and is instead predominantly focused on environmental and social causes. It also highlights that SA's

innovation strategy is not as well rounded as could be, which could affect its ability to rejuvenate.

Figure 5: Illustration of main drivers for AA's specific programme functions implemented in SA vs other countries of operation




Source: Author

*Data: Information from the above tables all accessed from various AA sites.*

From this, it is clear that environmental factors are the main drivers behind SA's innovation programmes, followed by safety, productivity and then efficiency.

As mentioned earlier, in conjunction with understanding drivers of innovation, it is also useful to understand the type of technology utilised for each innovation, examples of which include automation, machine learning, AI, etc. as well as understand the manner in which the innovation influences operations either through incremental improvements or through a radical change to the current way of work. Understanding these two aspects of a firm's innovation activity is necessary to analyse any patterns that exist with regards to how they choose to innovate. As can be seen in Table 12 above, AA utilises a wide range of different technologies, including automation, AI, and GIS. However, they also have a number of innovations that do not utilise any 4IR type of advanced technology but, rather, employ new equipment or include

additions to current processes that create an improvement. An example of this includes a combination of system reconfiguration and de-bottlenecking to improve efficiency and reduce material loss. Most of the functions performed by AA's innovation programmes appear to create incremental improvements in their operations, with only eight out of 19 (42%) functions radically changing the current way of work. This data suggests the existence of a pattern in the way AA approaches the development of its innovation strategy. The large number of innovations excluding any type of 4IR technology, at AA, combined with the fact that the majority of innovations provide incremental improvements to operations may suggest that AA is currently not prioritising transformative innovation strategies. Of which would include an extensive focus on the 4IR and the implementation of radical technologies.

#### 4.2.4.3 THE *WHY* BEHIND THE FIRM'S INNOVATION

To better understand the driving factor behind why AA chooses to implement various innovations was assessed through company documents, but also by analysing statements made publicly by different AA senior executives. This section includes both sets of information.

First, AA reports commonly mention that their commitment to transforming the industry through various innovation lead programmes is based on the intention to create a mining environment that is safer, more efficient, and with a much-reduced environmental footprint (Anglo American Sustainability Report, 2021). In an interview with Cremaer Media's MiningWeekly, AA CEO, Mark Cutifani, mentioned the important role that reducing the environmental footprint and reaching carbon neutrality plays in their drive behind FutureSmart Mining.

> FutureSmart Mining is about changing the way that mining is carried out so that we can ultimately get to carbon neutrality. (Cremaer Medias, 2020, para. 2)

AA believe that technology, digitalisation, and sustainability work together to support industry transformation and successfully reduce their physical and societal footprint (Anglo American, 2022f). They also acknowledge the important role automation plays in achieving this sustainability goal and the impact it has had on transforming the human and machine interaction. Donovan Waller, head of automation and remote-control technology development at AA's Mining and Technology unit, said,

> Automation is a process through which safety and productivity are optimised using machines, control systems and information technology. (Anglo American, 2022k, para. 3)

However, despite acknowledging the role automation has played in reducing AA's environmental and physical footprint and its ability to be a massive driver for positive change, AA does not necessarily view automation as the ultimate solution to be applied in all scenarios. This can be seen in the extract below from Dave Bentley, AA's Group head of technology and development.

> The automation of motor vehicle functions is driven mainly by safety considerations. In the mining industry, safety, health and productivity motivate the drive to move forward in the automation process. **We do not automate for the sake of automation**. We target mundane and tedious tasks for the next level of automation, as well as tasks that require accuracy and precision for a quality outcome. (Anglo American, 2022d, para. 4)

Various AA operations in SA are currently testing automated equipment including a bulldozer at New Vaal and a drill at Mogalakwena platinum mine. This equipment has been fitted with automation kits and thus far has been successful in benchmarking future developments towards safety and productivity. However, despite these developments that came about as a result of automation, Bentley is still clear on the fact that,

> [o]nly in exceptional circumstances would one move to fully automated trucks as the norm, and such a move would be dictated by operating conditions which pose a threat to driver safety, geographical remoteness, severe weather conditions or unusual circumstances which might cause operator fatigue. (Anglo American, 2022d, para. 9)

AA believes that automation may be no panacea, but that it will be welcomed if it can make certain jobs less repetitive, safer and more efficient (Anglo American, 2022d). This approach to technological change could suggest that AA is being very careful to ensure that they do not reduce vast amount of employment opportunities and is rather focused on developing/adopting technology that is not labour-replacing.

It would appear that AA is far more driven to achieve environmental and safety outcomes rather than large improvements in productivity. Their slight reluctance to introduce automation as widely as possible into their operations, even though it is well linked to productivity improvements, is further indication of this.

### 4.2.5 FOCUS AREA FIVE: FIRM INVOLVEMENT IN DEVELOPING NETWORKS AND COLLABORATION

Highly networked innovation systems allow businesses to collaborate and share knowledge, resources, and ideas for innovation. Developing a networked innovation system includes prioritising collaboration, supporting SMMEs, and developing workforce digital literacy. Networking and collaboration activity is essential for a high-performing innovation system (Australian Government, 2016).

Table 13: AA's existing collaboration partners in 2022[66]

| **Collaboration form** | **Collaboration intention** | **Impact area** |
|---|---|---|
| Business to business collaboration | Partnership with Envusa Energy to launch 600MW of wind and solar projects and progress their renewable energy involvement | Environmental |
| | Partnership with Nippon Steel to improve steelmaking decarbonisation | Environmental |
| | Partnership with Aurubus to create a copper value chain that is environmentally friendly and sustainable | Environmental |
| | Partnership with Thyssenkrupp Steel to develop technologies that can be utilised for decarbonising the steelmaking process, resulting in green steelmaking | Environmental |
| | Partnership with Greyrock, to work on converting gas to liquids as catalysts to generate power to run a vehicle but without the harmful emissions usually produced through engine combustion, such as CO2 | Environmental |
| | Partnership with First Mode, to design the largest fuel cell electric vehicle in the world. Once this design was complete, they partnered with NPROXX for the development and | Environmental |

[66] (Anglo American, 2012-2022).

| Collaboration form | Collaboration intention | Impact area |
|---|---|---|
| | manufacturing of the parts needed for this innovative new hydrogen fuel tank. | |
| | Partnership between AA and TechnoServe. This has an entrepreneurial focus and intends on contributing to economic growth, with a large focus on agricultural activities. Over the past decade this programme has helped many entrepreneurs and has earned $111 million. | Social |
| | The Impact Catalyst was created through the partnering of AA, Exxaro, the Council for Scientific and Industrial Research and World Vision SA. Its main intention is ensuring socio-economic development across a number of different areas of need. Some of which include education, social empowerment, economic development, the environment and service delivery. | Social |
| Business to government | AA's new Isaac wellbeing partnership is intended to prioritise mental health issues and offer support services in this regard. | Social |
| | AA formed a partnership with Department of Higher Education and Training to launch the Northern Cape's first ever university. This will assist with introducing young people in the Northern Cape to research, technology, computer sciences, agriculture, development science, and engineering. | Social |
| | AA has formed a partnership with the Department of Basic Education in order to make a significant contribution towards ensuring that all children have access to education. It is believed by AA that a quality education is crucial in improving the lives of individuals, and it is through this improvement that South Africa can effectively address many of its challenges. The organisation emphasises that inequality, unemployment, and poverty are common topics in South Africa, and they suggest that these issues can begin to be resolved through the improvement of education. | Social |

| Collaboration form | Collaboration intention | Impact area |
|---|---|---|
| University to business collaboration | AA and New Vaal University have recently formed a partnership to promote entrepreneurial development. To achieve this, they are supporting students with a combination of different business development and financial skills. This initiative is offered in both Gauteng and the Free State province, where there are currently around respectively 46% and 38% economically inactive people. | Social |
| | AA is committed to improving education, particularly regarding engineering standards and for this they have invested substantial amounts to the Wits Chamber of Mines, including R9 million for the 4th Quadrant Engineering Building Project. | Social |

Source: Author

Table 13 indicates that AA is an active collaborator, with most of their collaboration activity being focused on environmental and social developments. Business to business collaboration is their highest activity area, followed by business to government and then business to university. AA has no collaboration partnerships with research institutions, active in 2022. Limited collaboration with research institutions could adversely affect the firm's technical capacity and subsequently its ability to absorb external technological knowledge. This may limit the easy adoption of new ideas and technology into the firm.

In addition to the important role collaboration plays, The Australian Innovation Report (2016), on which aspects of this case study methodology are based, also highlights the critical role of SMMEs. The report found that start-up activity was at the heart of employment growth in Australia, and that the bulk of this growth was driven by a relatively small number of high-growth businesses that could be found across all sectors of the economy. It also found that SMMEs and innovative entrepreneurship were forces of creative destruction, and important contributors to the development of an innovation ecosystem.

Table 14: AA's 2022 SMME development[67]

| SMME investment | Includes a focus on technology development | Main impact area |
|---|---|---|
| Zimele Enterprise Development programme. | Not necessarily | Many areas, with most in agriculture |
| Zimele Supplier Development programme. | Not necessarily | Many areas, with most in manufacturing |

Source: Author

Table 14 indicates that through its Zimele Programme, AA does support SMME development in its operating environment. Zimele is focused on creating sustainability in business; mainly focused on developing the sustainable livelihoods of the individuals in their host community. This programme intends to develop entrepreneurship in the youth, through mentoring as well as supplier and enterprise development. SA's high unemployment rate is an important driver behind this development programme. This initiative has limited focus on technological advancements; it does not prevent assistance in this area, but it is not necessarily a focal point when developing each SMME. The Zimele programme is useful for developing the environment in which the firm operates as well as strengthening the value chains that work in conjunction with the mining value chain. However, because of its lack of focus on technological development, it is not necessarily the type of SMME development that is going to have major impacts on the innovation ecosystem in which AA operates. This data suggests that there could be a pattern around what type of investments AA prioritises. It is possible that the majority of investments made by AA are into initiatives that are non-disruptive in nature and will not be labour-displacing. Enhancing productivity does not appear to be the focus of any of these investment methods.

Similarly, to the above analysis point, another important factor necessary to support the development of an innovation ecosystem is a workforce that is educated in digital literacy. This is important for increasing the firm's absorptive capacity and enabling the adoption of new technological advancements. Table 15 below analyses AA's involvement in the development of digital literacy in its current and future workforce.

[67] (Anglo American, 2012-2022),

Table 15: AA's efforts to enhance digital literacy in the current and future workforce[68]

| Skills development initiative focus area | Initiative summary | Enabler for implementation of advanced technology in the workplace |
|---|---|---|
| Digital literacy skills | In 2022, VOXEL was implemented as a means to bolster the employees' digital literacy skills. A total of over 3,000 personnel successfully completed digital training, with 75 individuals graduating from the specialist nanodegree programme. As a result, they have acquired the competence to independently perform data science and analysis tasks. | Yes |
| Information and communications technology (ICT) | AA has been intentional about rolling out ICT programmes to 109 schools around its mining operations. This will hopefully provide a large number of students and community members with the digital skills needed for the changing job market. | Yes |
| AR and VR training | AA has been implementing new technology and training for this, in the Human Resources Development (HRD) Domain. This is important to ensure that all members of staff are in line with the digitisation drive at AA. Training also promotes involvement and employee willingness to engage with the new technology. As part of HRD digitalisation initiative, AA has been developing training tools that use AR and VR technology. | Yes |

Source: Author

As indicated in Table 15 above, AA has an ICT programme directed at school learners, ensuring the development of digital skills for the future workforce. Additionally, AA has two programmes running to develop the digital literacy skills of their current workforce. Although these programmes are beneficial and will contribute to workforce ability to absorb new technology, it may not be enough. Given the poor state of SA's education system as a contextual constraint, this could be a bigger focus area for AA to prioritise. This data presents

[68] (Anglo American, 2012-2022); (Anglo American, 2022e).

a pattern which is that of an overwhelming need for human development before the development of technological innovation may be prioritised.

## 4.3 FIRM B – RIO TINTO WITHIN-CASE ANALYSIS

### 4.3.1 FOCUS AREA ONE: CONTEXT

RT is a leader in the global mining and metals sector. The company has a variety of minerals in its portfolio including aluminium, copper, gold, and more. RT was established in 1873 in Spain, and now has its headquarters in London. RT has around 47,000 employees worldwide, and creates substantial influence on the global mining and metals sector (Rio Tinto, 2022b).

Table 16: Australia's PESTLE Context

| PESTLE | **Influencing factor** | **Explanation** | **Effect on Industry** |
|---|---|---|---|
| Political & Legal | Policy and regulatory stability | The Australian government recognise the very important role mining plays in the economy, and for this reason policy development is generally geared towards developing an environment that will be suitable for foreign investment.[69] | A stable environment will be inviting to investors, and will be beneficial for mining companies to grow and operate profitably. |
| | Resource 2030 Taskforce | The Resources 2030 Taskforce, was created recently with the intention of gathering a group of industry experts who will be responsible for drawing up an "AI based strategy" that can be used to inform policy development, ensuring that Australia remains a leader in the industry, even as it becomes more AI intensive. This team will monitor various trends in the industry, such as the big move to automation, ensuring that Australia is ready for the transition.[70] | In terms of industry longevity and sustainability of operations, these forward-looking activities, to correctly shape policy, are beneficial to ensure that Australia is well prepared. |
| | Australia's AI Action Plan | The AI action plan is another forward-looking initiative that intends on creating a vision for how Australia can correctly implement AI. This will ensure that AI implementation is protected, ethical, responsible and benefits all Australians.[71] | |
| Economic | FDI | Government policy includes a system of laws and procedures that are well-defined, providing significant clarity to potential investors. This is supported by a number of initiatives such as Australia's foreign investment policy.[72] Australia consistently ranks highly in the Fraser Institute's Annual Survey of Mining Companies. In 2020 Australia ranked as the most attractive region in the world for mining investment considering both policy and mineral potential.[73] | FDI is an important component that supports the growth of the Australian mining industry. A strong economy with useful patent and exploration tax incentives is beneficial for the development of Australia's image as an attractive investment |
| | Patent Tax incentive | During the 2022-23 Budget Speech, the Government set its intentions to broaden the scope of the patent box tax regime in Australia. The goal of this initiative is to | |

[69] (Herbet Smith Freehills, 2021).
[70] (Australian Government. Department of Industry Science and Resources, 2018); (Lampriere, 2018); (Mining Technology, 2018).
[71] (Australian Government. Department of Industry, Science & Resources, 2021a).
[72] (Australian Government. Department of Foreign Affairs and Trade, 2022): (Australian Government. Department of Foreign Affairs and Trade, 2023); (Australian Government. The Treasury, 2021).
[73] (Fraser Institute, 2020).

| PESTLE | **Influencing factor** | **Explanation** | **Effect on Industry** |
|---|---|---|---|
| | | encourage investment into R&D and promote the commercialisation of research within the country.[74] | destination. |
| | Junior Mineral Exploration Tax Credit | The government has implemented a policy for distributing a refundable tax credit, for Junior Mineral Exploration, from tax losses incurred during greenfield exploration.[75] | |
| Social | Low unemployment rates | Australia's unemployment rate was as low as 3.5%, in 2022, the lowest that is has been in 50 years. This significant decrease in unemployment signifies a strong demand for employee recruitment and retention. This has created concern in the country, regarding persistent labour shortages.[76] | The labour shortages in Australia create a potential threat for the sustainability and longevity of existing operations. Australia is actively pursuing options to address these challenges. These efforts include the increased use of automation in operations, promotion of remote working and prioritisation of STEM education.[77] |
| | Labour shortages | A recent study published by the Australian Resources and Energy Employer Association has indicated that the mining industry will require a total of 24,000 additional employees, within the next five years, to sustain operations across the nation. The report highlighted that if this problem is not addressed, approximately 107 projects could be adversely affected by declining size of the workforce, causing vast negative impacts on productivity.[78] | |
| Technological | Significant R&D commitment | Australia is one of the world leaders in R&D investment.[79] This is partly due to the vast amount of money invested into innovation over a relatively short period of time, Australia has invested around R500 billion into R&D since 2005.[80] Australia's 2021 SRI Budget tables indicated that $11.8 billion dollars was spent on R&D in the 2021, 2022 period.[81] | Australia's commitment to R&D investment has assisted in creating a favourable environment for developing needed innovations. For this reason, Australia usually ranks highly as an attractive investment destination.[82]<br><br>All of this commitment to R&D and innovation type activities have created the presence of a strong innovation ecosystem for Australia's mining industry to operate in.[83] |
| | Strong patent activity | Australia additionally has a strong patent activity, with many of its universities, that offer mining-related qualifications, ranking in the world's top five.[84] | |
| | Significant university research funding | As was highlighted in the Portfolio Budget Statements 2022-23, Australia has significant grant funding available for university research, reaching approximately $2 billion in the 2021–22 period.[85] The government intend part of this funding to be in support of industry-university collaboration, with the aim of increasing commercialisation of research outputs.[86] | |
| | Advancements of STEM fields | The budget speech also pointed out the government's commitment to advancing STEM courses in universities, allocating approximately $45.4 million, over a five-year period, to achieving this cause.[87] | |

[74] (Budget Review Index, 2022-2023).
[75] (Australian Government. Australian Tax Office, 2021).
[76] (The Guardian, 2022).
[77] (Constable, 2018), (Pickles, 2022).
[78] (Treloar & Waterson, 2022).
[79] (Mining Technology, 2022b).
[80] (MCA, 2022b); (MCSA, 2017-2022).
[81] (Australian Government. Department of Industry, Science & Resources, 2021b).
[82] (Fraser Institute, 2020).
[83] (MCA, 2022b).
[84] (MCSA, 2017-2022)
[85] (Budget Review Index, 2022-2023).
[86] (Budget Review Index, 2021-2022).
[87] (Budget Review Index, 2021-2022).

| PESTLE | **Influencing factor** | **Explanation** | **Effect on Industry** |
|---|---|---|---|
| | Significant R&D employment | In the 2020-21 period the Australian government allocated a collective sum of 15,047 person years of effort (PYE) towards full-time R&D. This figure represents an increase of 526 PYE (4%) compared to the 2018-19 period.[88] | |
| | Large focus on AI as an important technology | Other than the mining industry, Australian firms are not at the forefront of the adoption of AI and automation. To rectify this problem, the government announced in the budget speech that they will be committing $124.2 million to the Digital Economy Strategy, to elevate Australia's AI capabilities. Part of this investment will be specifically to developing a Next Generation AI graduate Program.[89] | |
| Environmental | Excellent port infrastructure | Australia has 70 properly functioning, strong and well managed ports which support all of the transport needs of the industry. This infrastructure is owed by the private sector and is managed by the government. [90] Government management of this infrastructure is well regulated by federal competition laws, ensuring that a certain standard of excellence, regarding its functionality, is maintained.[91] | This availability of high-quality, well-functioning infrastructure is a contributing factor to Australia's thriving minerals industry and attractive investor climate.[92] |
| | Strong and innovatively driven rail sector | Haulage and transportation is another important factor that enables that development of a competitive industry. Australia's rail sector consists of a large network of railway tracks, connecting all of their major ports and playing a significant role in achieving industry success.[93] This rail network is also not only known for being a reliable transportation mechanism but also for prioritising innovation and technological development. RT in Australia was the first to develop and implement the one of a kind, Auto Haul autonomous trains.[94] | |
| | Regulatory certainty for rail and port infrastructure | The management of rail infrastructure in Australia is stringently regulated, producing a great deal of regulatory certainty for potential investors. [95] The Central Queensland rail network is an example of one of the many important railways in Australia. In an attempt to provide further certainty over this rail infrastructure, it has recently been confirmed as a monopoly until 2040, indicating a strong relationship between the rail network and the mining sector. [96] | |
| | Reliable energy supply | To adhere to the world's shift to less carbon intensive methods of electricity generation and to ensure a reliable supply of energy at all mining sites, Australian mines have been encouraged to follow a hybrid approach to electricity generation.[97] | |

Source: Author

[88] (Budget Review Index, 2021-2022).
[89] (Budget Review Index 2021-2022), (Budget Review Index 2022-2023).
[90] (Chen, 2013).
[91] (Herbet Smith Freehills, 2021).
[92] (Fraser Institute, 2020).
[93] (Aurizon, 2023).
[94] (Rio Tinto, 2022e).
[95] (Herbet Smith Freehills, 2021).
[96] (Iannucci, 2020).
[97] (Australian Renewable Energy Agency, 2018).

The information in Table 16 above, indicates an environment that is supportive of and prioritises the growth and development of the industry. The sound regulatory regime, competitive taxes, highly skilled workforce with extensive investment in advanced technologies and innovative practices, Australia has created an environment that is attractive to investors (Iannucci, 2023). Every aspect of the data in this PESTLE analysis suggests the very influential role context plays in enabling growth, development and innovative practices in mining firms. It points out a pattern of needing to positively develop society in order to improve context and enable the introduction of necessary, growth enabling technology.

### 4.3.2 FOCUS AREA TWO: HOW INNOVATION FITS INTO THE IDENTITY OF THE FIRM

RT is one of the global leaders in mining. The group is committed to processes along the entire mining value chain, starting with finding the minerals, then mining, and lastly processing. RT make explicit mention of their commitment to fostering innovation. They admit to being proud of the fact that they don't only operate in mines but also largely in data centres, R&D labs, and with AI (Rio Tinto, 2022b). To achieve their purpose of providing the materials central to human progress, RT has five key activities, two of which are innovation and technology focused. The first activity is utilising top quality and the most advanced exploration technologies in the world to locate new minerals. The second is channelling innovation activities in order to develop all potential opportunities and achieve long-term productivity while minimising risks (Rio Tinto, 2022b). These activities are both supported by RT's three tier strategy that includes one component centered solely on increasing their investment in R&D. This clear drive towards developing the firm's innovative capacity is underscored by one of the firm's three values – which is cultivating curiosity to collaborate, learn and innovate. RT supports the idea that curiosity, diversity of ideas, and collaboration produce the best results (Rio Tinto, 2022b). At RT, innovation is core to everything they do (Rio Tinto, 2012-2022).

The cultivation of an excellent culture is something that supports innovation activity at RT. RT believe that a dynamic culture allows for better and stronger partnerships and a greater chance at innovatively addressing industry challenges (Rio Tinto, 2022f). RT believes that the establishment of an innovation-oriented culture not only involves attracting highly skilled individuals, but also necessitates ensuring that existing employees in the mining industry understand the advantages of adopting new technological practices (Turner, 2018). In order to

achieve this, RT has initiated the Pioneering Pitch programme, which promotes internal transformation by motivating employees to embrace innovative solutions (Rio Tinto, 2012-2022). This programme is inclusive, which is implemented on a global scale, aims to capture the creative ideas of RT personnel and promote the development of innovative solutions. This is accomplished by providing financial resources to foster the development of these pioneering ideas. To date, RT has invested over $8 million in their employees' ideas and projects, having funded a total of 47 initiatives (Rio Tinto, 2012-2022).

### 4.3.3 FOCUS AREA THREE: FIRM ACTIVITY IN THE INNOVATION SYSTEM

The following indicators were selected to better understand the extent and intensity of activities being undertaken by the firm that will aid in the creation of an innovation ecosystem. Understanding the kind of effort, the firm is putting into growing its technological capabilities will be useful in the creation of future innovation strategies.

Table 17: Tracking firm innovation activity over an eleven-year period

| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Firm R&D expenditure[98] (US$million) | 129 | 231 | 112 | 104 | 60 | 58 | 45 | 45 | 45 | 65 | 76 | 970 |
| Firm exploration expenditure[99] (US$million) | 1,971 | 948 | 747 | 576 | 497 | 445 | 488 | 624 | 624 | 719 | 896 | 8.038 |
| Number of patents filed by the firm[100] | 263 | 220 | 351 | 243 | 149 | 86 | 89 | 111 | 88 | 29 | 4 | 1633 |
| Number of patents granted to the firm[101] | 131 | 109 | 150 | 27 | 32 | 83 | 115 | 121 | 122 | 100 | 28 | 1018 |

Source: Author

Table 17 above, indicates RT's consistent innovation efforts. They have constantly invested large amounts into exploration activities. RT has also been active in the development of patents. This table tracks data only from 2012-2022, but when we look at patent activity from 2002-2022, we can see that RT has filed 5121 patents in total (Greyb, 2022b). Most of the patent

[98] (Rio Tinto, 2012-2022).
[99] (Rio Tinto, 2012-2022).
[100] (Greyb, 2022b).
[101] (Greyb, 2022b).

applications from RT have taken place in Australia, with RT filling 788 out of 5121 patents in Australia. RT has been granted 2401 (46.9%) of all of their patent applications. Unfortunately, over the last 11 years RT has decreased their R&D expenditure, from US$129 in 2012 to US$76 million in 2022. However, in a recent investor seminar, RT highlighted that their in-house R&D has changed slightly over the years and is now augmented by an ecosystem of partners across the globe including universities, government research labs, and start-ups (Investor Seminar, 2022). This external innovation ecosystem support could be a reason why RT's internal R&D spend has decreased since they no longer need to spend huge amounts on their own. Overall, RT is sufficiently active in the innovation system.

### 4.3.4 FOCUS AREA FOUR: TYPE OF INNOVATION AND TECHNOLOGICAL ACTIVITY PURSUED BY THE FIRM

RT approaches innovation through the three main channels of automation, smart mining, and AI, all of which are supported by the fourth channel of partnering to innovate (Rio Tinto, 2022h). Channels one to three are discussed in this focus area while the fourth channel is discussed in focus area 5.

#### 4.3.4.1 WHAT IS AUTOMATION, SMART MINING, AND AI?

In order to make their operations safer, more environmentally friendly and more efficient, RT has employed emerging technologies in the form of automation and robotics, across all of their mining processes (Rio Tinto, 2022d). Automation has been a central business aspect contributing to RT's successfully run operations, for more than a decade (Rio Tinto, 2022d). In conjunction with their extensive use of automation, RT also utilises AI to collect valuable data along their entire mining value chain. This data enables smarter work for a number of tasks, such as organising equipment dispatch to predicting maintenance needs. and improves safety and efficiency. By combining data from daily operations with sophisticated analytics, AI, machine learning, and automation, RT has been able to enhance the safety and productivity of their business (Rio Tinto, 2022c).

Table 18: Automation Functions[102]

| Automation | How is this function achieved? | Implementation in Australia or other country of operation? | Impact of technology programme |
|---|---|---|---|
| Autonomous trucks | RT operate an Autonomous Haulage System with more than 130 autonomous trucks. These trucks do not operate with a driver, they are instead run by a supervisory system and a central controller. Predefined GPS courses to enable the automatic navigation of roads and intersections are used. It additionally has knowledge of actual locations, speeds, and directions of all vehicles at all times. | Australia | The implementation of automation has significantly enhanced productivity and efficiency within RT's operations. In 2022, it was reported that each autonomous haul truck operated for an additional 1000 hours, while also demonstrating a 15% reduction in load and haul unit costs when compared to conventional haul trucks. RT has achieved a 34% increase in productivity through the utilisation of autonomous trucks.[103] |
| Autonomous trains | AutoHaul is the first heavy-haul, long-distance autonomous rail operation. It transports minerals from RT operations to Pilbara region in WA, where RT's ports are located. AutoHaul has a number of benefits, including safety, productivity and environmental benefits. | Australia | AutoHaul has been successful in its ability to increase average speeds by 5-6%. The average journey time has also decreased by removing the needs to have the driver shift changes. The train running on automation rather than staffed has also decreased the runtime variation between each AutoHaul service. This has allowed for better and more accurate train scheduling. This has been useful for reducing bottlenecks and increasing productivity.[104] |
| Autonomous drills and charge trucks | RT currently operates the most extensive autonomous drilling fleet, worldwide, consisting of 26 autonomous drills. These drills are utilised to safely and precisely drill blast-holes from a remote location. An operator, located at the operations centre, is responsible for planning the activities for an entire shift, for each drill – rather manually conducting the work on site. Additionally, RT has incorporated innovative smart charge trucks into their operations which automate the process of pumping explosives into the designated drill holes. The trucks are run from computer systems using data analytics to determine the appropriate quantity of explosives needed for each drill hole. This is effective in | Australia | The pilots that began in 2019, have been successful in operating drills autonomously from remote locations. This has improved safety and reduced unit cost of production. It has also improved productivity by approximately 20% compared to manual drills.[105] |

[102] (Rio Tinto, 2022d); (Rio Tinto, 2022e); (Rio Tinto, 2021).
[103] (Francis, 2018).
[104] (Smith, 2019).
[105] (Moore, 2021).

| Automation | How is this function achieved? | Implementation in Australia or other country of operation? | Impact of technology programme |
|---|---|---|---|
| | minimising unnecessary waste and enhancing the overall efficiency of the blasting process. | | |
| Operations Centres | RT's operations centres allow all processes to be controlled remotely from a single room. The team is able to work in a room with screen displaying the entire operation, from mining all the way to rail systems and port management, in real time. This combined with predictive tools and powerful software, RT has many opportunities for improvement. | Australia | Access to real time data from operation centres all around the world has made a significant improvement to the speed at which decisions can be made. This enables safety and productivity improvements with limited disruption in operations.[106] |
| Drones and remotely operated vehicles (ROVs) | RT use drones and ROVs for equipment inspections as well as real time 3D mapping. This functionality can also be beneficial for safety purposes such as checking walls for cracks or signs of rock movement. Some more dangerous jobs are better suited to drones than people, therefore by using drones, RT are reducing potential harm for their employees. | Australia | No recorded impact |
| Robotic process automation (RPA) | RPA, also referred to as Bots form part of the Information Systems & Technology team at RT. Through the application of various technology behind the scenes, Bots are responsible for making everyone's jobs easier. Bots complete repetitive tasks data entry, filing in forms, opening emails and attachments and making calculations. An example of a Bot in action is at the Hope Downs 1 mine in the Pilbara where they have developed a Bot for logging maintenance requests for that site. This has saved significant time in each shift and simplified the handover process between shifts. | Australia | One of the primary advantages of automation is the enhancement of safety. Machines can't become tired, nor do their attention spans waiver after many hours of work. This is beneficial as it reduces room for accident. Robots also assist in lowering operating costs. This is through the reduction in operating staff needed on site as well as increased throughput due to less downtime needed. Combined these two improvements will save billions of Australian dollars in productivity.[107] |

Source: Author

[106] (Brightmore, 2021).
[107] (Nick, 2016).

Table 19: Smart Mining Functions[108]

| Smart Mining | How is this function achieved? | Implementation in Australia or other country of operation? | Impact of technology programme |
|---|---|---|---|
| Virtual reality (VR). | RT's VR has multiple workforce safety benefits. Through the use of immersive surroundings, events can be analysed from a different perspective, creating a vantage point for the operators and reducing the chance of accident. Through using VR, RT has also been able to locate the cause behind why an accident took place and quickly progress the actions needed to make sure that a similar incident does not take place again.[108] | Australia | No recorded impact. |
| Mine automation system (MAS) | The primary focus of this innovation is to analyse data and convert it into operational insights. This functionality is similar to a network server application which gathers data from 98% of RT's locations and scans it to acquire information. This information is presented in a standardised format and can be visually represented using RT's visualisation system (RTVis) or through traditional display formats such graphs, charts, and tables. With the use of automation, RT is then able to transform this information into useful outputs such as generating orebody models or forecasting and regulating blasts. This has been successful in optimising speed of processes, reducing queue time for autonomous trucks and significantly improving productivity.[108] | Australia | RT have successfully utilised data mining to allow ore crushers at iron ore processing plants to automatically inform the trucks when they need more ore. This has also been successful at the bauxite mine in Weipa, where special mathematical software was implemented to assist with managing hundreds of ships a year on port schedulers. Through this application RT has reduced energy use, minimise downtime and cut operating costs.[108] |
| 3D visualisation. | RT has created visualisation capabilities within operations using a 3D gaming engine, called RTVis. With this functionality, RT is equipped to perform aerial inspections of a site and gather in-depth information. These capabilities allow for precise examination of equipment such as excavators and haul trucks, as well as comprehensive assessments of ore bodies. This software seamlessly integrates data from various sources, and using the analytics tools available with this capability, RT is able to make better informed decisions.[108] | Australia | The implementation of RTVis has created many benefits in RT's operations. This includes more accurate drilling and blasting as well as reduced explosive use. Through these benefits, RTVis have increased productivity and lowered costs.[108] |

Source: Author

[108] (Rio Tinto, 2012-2022); (Rio Tinto, 2022j)

Table 18 and 19 above, explain the functionality of the main innovation programmes at RT as well as the impact of each programme. They point out how these programmes created positive impacts for RT across a variety of business areas. Automation, alone, has had a particularly large impact on productivity and safety of operations, with a 34% productivity increase just though using their autonomous trucks. Complementing the improvements from automation, are the impacts of the Smart Mining programme. This is, among other factors, responsible for reducing operating costs, producing data-driven insights and increasing productivity, all of which create value for RT and enhance their competitive edge. RT's Smart Mining is driven through the application of AI.

Table 20: Drivers and nature of Innovation

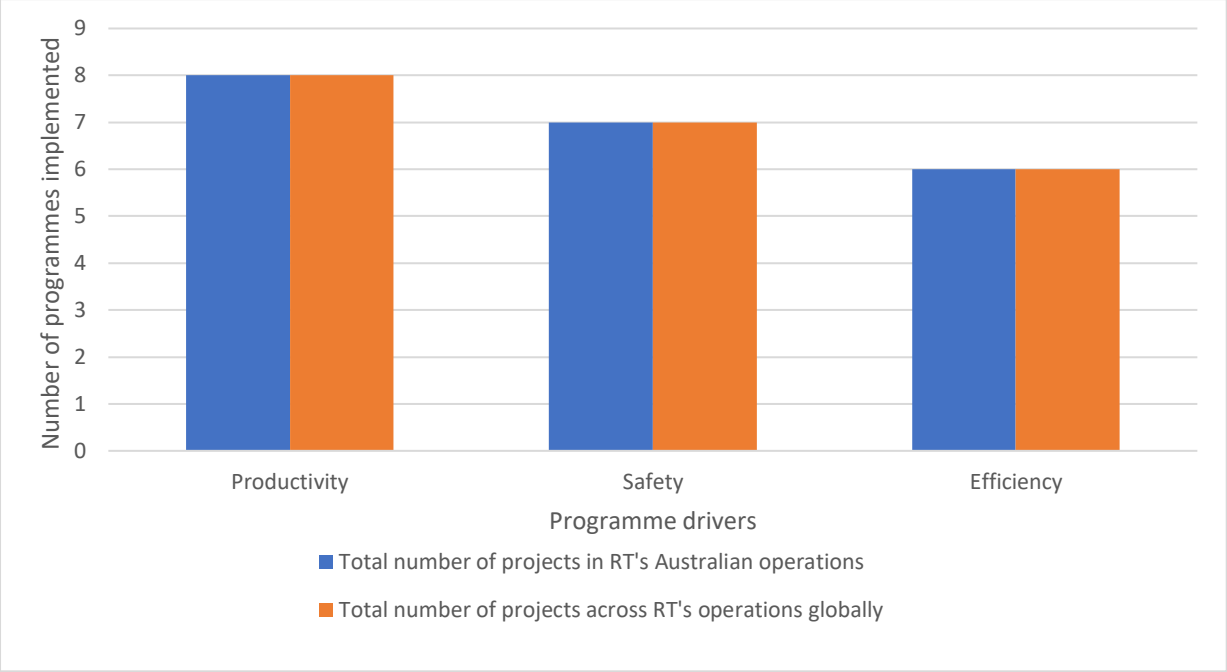
| **Innovation Programme** | **Specific programme function** | **Main driver for the specific programme function** | **Type of technology group** | **Effect on the way of work** | **Has the programme been implemented in Australia?** |
|---|---|---|---|---|---|
| Automation | Autonomous trucks | Productivity and efficiency | Automation | Radical change | Yes |
| | Autonomous trains | Productivity, safety, and efficiency through waste reduction | Automation | Radical change | Yes |
| | Autonomous drill and charge trucks | Productivity, safety, and efficiency through waste reduction | Automation and Machine learning | Radical change | Yes |
| | Operations centers | Productivity, safety and efficiency | IoT and Machine learning | Radical change | Yes |
| | Drones and remotely operated vehicles | Safety | Drone technology and Automation | Radical change | Yes |
| | RPA | Productivity, safety, and efficiency through cost reduction | Automation, Robotics and Data analytics | Radical change | Yes |
| Smart Mining | VR | Safety | VR | Incremental improvement | Yes |
| | MAS | Productivity | IoT, Automation and Data analytics | Incremental improvement | Yes |
| | 3D visualisation tools | Productivity and efficiency through better decision making | VR, IoT and Data analytics | Incremental improvement | Yes |
| AI | Controllers | Productivity and safety | AI and Automation | Radical change | Yes |

Source: Author

Table 20 above, suggests that RT's main innovation drivers worldwide, for the specific programme functions, are well spread across productivity, safety and efficiency. 100% of all of these specific programme functions have been implemented in Australia (see the figure

below). This means that, in relation to the various drivers mentioned above, Australia's RT operations have 80% (8/10) of their programme functions geared towards productivity, 70% towards safety, and 60% towards efficiency. This data suggests that a pattern exists in the prioritisation of innovation drivers when implementing new technology.

Figure 6: Illustration of main drivers for RT's specific programme functions implemented in Australia vs other countries of operation




Source: Author

*Data: Information from the above tables all accessed from various RT sites.*

From this above figure, it is clear that productivity is the main driver behind Australia's innovation programmes, followed very closely by safety and then efficiency. It is important to note that all although the innovation programmes that run internally at RT do not specifically focus on environmental factors, this does not mean RT is not focused on this issue. Innovation and R&D at RT also include a large focus on environmental concerns, but as was mentioned earlier, that focus is predominantly through collaboration initiatives with external partners (see Table 21 for reference of collaboration partners focused on environmental initiatives).

As mentioned earlier, in conjunction with understanding drivers of innovation, it is also useful to understand the nature of the innovation implemented. As can be seen in Table 20 above, RT employs a wide range of different technologies with their most commonly utilised technology being automation. Most of the functions performed by RT's innovation programmes appear to

change radically the current way of work, with 70% of programmes creating radical change and 30% creating incremental operational improvements. Firms that radically innovate are often considered to be trendsetters, drivers of change, and creators. This is a positive finding since radical innovations are considered most appropriate in creating the biggest impact and helping a firm remain competitive while ensuring continued long-term growth (Mitzkus, 2022).

#### 4.3.4.2 THE WHY BEHIND THE FIRM'S INNOVATION

RT believes that they have a pioneering spirit and their approach to innovation and technological development is all about developing and maintaining this (Brightmore, 2021). Pioneering automated innovation in mining has been part of who RT is for more than 144 years (Brightmore, 2021).

RT also link their commitment to developing innovative practices to the role it will play in assisting them overcome market challenges and falling commodity prices (Sommerville, 2018). In 2012, RT highlighted their desire to recover USD 5 billion over five years. This they planned to achieve through achieving operational savings and enhancing their mining efficiencies and productivity (Sommerville, 2018). This they have achieved through their prominent focus on automation, which has ensured operational savings as well as productivity and efficiency improvements were met. It also dramatically improved their environmental impact and worker safety (Sommerville, 2018).

RT refers to the success of their automation and technology drive using the following catch statement, "A decade of innovation leads to a lifetime of opportunity" (Rio Tinto, 2022a). This is a perfect way of describing the commitment RT has to the innovation process.

It would appear that RT is driven, first, to improve productivity that is then accompanied by improvements in safety and the environment. Their productivity focus does not mean that other important drivers like safety are not met but it does mean that RT understands that without ongoing productivity improvements, no other innovation drivers have any long-term sustainability. This initial *productivity lens* that seems to drive many of RT's innovation choices is well supported by its commitment to developing their automation capabilities.

### 4.3.5 FOCUS AREA FIVE: FIRM INVOLVEMENT IN DEVELOPING NETWORKS AND COLLABORATION

As was mentioned in this section during the AA within-case analysis, highly networked innovation systems enable businesses to pool knowledge and resources for innovation. Prioritizing collaboration, supporting SMMEs, and enhancing digital literacy of the workforce are crucial in developing such a system (Australian Government, 2016).

Table 21: RT's existing collaboration partners in 2022 [109]

| **Collaboration form** | **Collaboration intention** | **Impact area** |
|---|---|---|
| Business to business collaboration | Partnership with Mining Microbiome Analytics to enhance sustainable mining practices. | Environmental through sustainability |
| | Developed partnership strategies with Regeneration Enterprises, on needed ecological and technological inputs to ensure correct closure work. | Environmental |
| | RT partnered with Broken Hill Propriety Company Ltd (BHP) to develop tailings technology that could increase water recovery. | Environmental |
| | Through partnering with LinkedIn Learning, an online energy and climate change curriculum was launched for employees. | Environmental and human capital development |
| | Through a partnership with Shougang Group and Salzgitter Flachstahl, RT is working towards developing low-carbon solutions for the steel value chain. | Environmental |
| | RT continued its partnership with Scania to better its design for autonomous trucks. They intend on making them smaller and more agile. | Productivity through automation |
| | RT partnered with Volvo Group, to pilot Volvo's autonomous hauling solutions, and contribute to decarbonising operations. | Environmental |
| | RT Pioneer Portal is used as a platform to locate partners wanting to work on developing innovative solutions to various business challenges. In 2022, six challenges were launched, 200 submissions received, and 20 new partnerships | Business development |

[109] (Rio Tinto, 2012-2022); (Rio Tinto, 2022h)

| Collaboration form | Collaboration intention | Impact area |
|---|---|---|
| | formed. These partnerships were supported by R&D funds worth more than $40. This has been beneficial for reducing discovery and development cycles at RT. | |
| | Partnerships with Komatsu, Caterpillar, and Volvo progress options for electrified vehicles. | Environmental |
| | Codelco collaboration agreement intended for designing and constructing underground mines. | Business development through project expansion |
| Business to government collaboration | A public-private partnership with the National Alliance for Water Innovation is working on securing a reliable water supply, through researching the current technical barriers that exist for desalination. | Environmental |
| | Partnership with the Canadian government, to decarbonise their Qubec operations. This included an investment of C$737 million. | Environmental |
| | ELYSIS, is a partnership between RT and Alcoa to develop technology that can revolutionise the aluminium smelting process by eliminating greenhouse gasses. | Environmental |
| | Partnerships with the Chinese government and various state-owned entities to develop knowledge on topics such as climate change, innovation, training, procurement, and product supply. | Human capital development through developing knowledge capacity |
| Business to university collaboration | Future Tails Partnership is a collaboration between RT, BHP, and the University of Western Australia (WA) to develop knowledge and skill sin the industry. | Human capital development |
| Business to research centre collaboration | Partnerships with research centres and universities to improve the industry's current approach to rehabilitation and hopefully enhance the outcome of rehabilitation activities. | Environmental |
| | Recently set up a China Technology and Innovation Centre to learn from China's leading expertise in research, technology, and innovation. This aims to help solve some of RT's operational and business challenges. | Business development |

| Collaboration form | Collaboration intention | Impact area |
|---|---|---|
| | Partnership with the US Department of Energy to explore carbon storage potential. | Environmental |
| | Partnership with the Maersk Mc-Kinney Moller Centre to develop Zero Carbon Shipping. This is to support technology development that will assist in enabling the industry's low-carbon transition. | Environmental |
| | Innovation and Technology Centre established by RT. This aims to improve health and safety, support growth opportunities and increase productivity. | Productivity |

Source: Author

Table 21 indicates that RT is an active collaborator, with most of their collaboration activities focused first on environmental factors followed by human capital development, business development, and then productivity. Business to business collaboration is their highest activity area, followed by business to research institute, business to government, and then business to university. RT's large number of business to research collaboration partnerships active in 2022 as well as their collaboration focus on human capital development could be contributing positively to the firm's ability to absorb external knowledge. This is an important enabler for the easy adoption and adaption of new ideas and technology.

In addition to this extensive collaboration partnership list, RT also supports SMME development that is, in turn, an important contributor to the development of an innovation ecosystem.

Table 22: RT's 2022 SMME development[110]

| SMME investment | Includes a focus on technology development | Main impact area |
|---|---|---|
| Lumo Analytics: Focus on improving exploration drills with the introduction of laser technology | Yes | Exploration |
| Terra$CO_2$: Focus on lowering carbon dioxide emissions of cement and | Yes | Environmental |

[110] (Rio Tinto, 2012-2022).

| SMME investment | Includes a focus on technology development | Main impact area |
|---|---|---|
| concrete production | | |
| Aymium: Focus on reducing carbon dioxide in ilmenite smelting | Yes | Environmental |
| Electric Hydrogen: Focus on developing low-cost green hydrogen production to decarbonise iron and titanium smelting | Yes | Environmental |
| ElectraLith: Focus on developing electrically driven filtration process to extract lithium from brine | Yes | Efficiency |
| NanoOne: Focus on developing innovative manufacturing methods for batteries in electric vehicles and energy storage | Yes | Environmental |
| CarbonCapture Inc: Focus on developing direct air capture technology to remove carbon dioxide from the atmosphere | Yes | Environmental |

Source: Author

From Table 22 above, it is evident that RT supports a variety of SMMEs, all of which include an aspect of technological development. This is important since RT is not only developing the capability of local value chains but is also increasing the technological capacity of these small firms and contributing to their own innovation ecosystem.

To complement the development of this innovation ecosystem, RT has invested in developing the digital literacy of their workforce.

Table 23: RT's efforts to enhance digital literacy in the current and future workforce[111]

| Skills development initiative focus area | Initiative summary | Enabler for implementation of advanced technology in the workplace |
|---|---|---|
| Automation, digital future | RT's Centre of Mine Automation at the University of Sydney, has partnered with BlueChillie to develop a curriculum that will overcome the large skill gap that exists for the future workforce. This includes a A$10 million investment in a four-year national programme. This is focused on school learners and intends on developing their | Yes |

[111] (Rio Tinto, 2012-2022); (Rio Tinto, 2020); (Rio Tinto, 2019).

| Skills development initiative focus area | Initiative summary | Enabler for implementation of advanced technology in the workplace |
|---|---|---|
| | digital skills and automation and data analytics capabilities. | |
| Automation | RT have been involved in launching Australia's first nationally recognised qualifications in automation. This was developed through a partnership between RT and the Australian government. It is now being used to develop training programmes to assist in developing future skills. | Yes |
| STEM development programme | RT is involved in developing STEM skills for school students. They invested $10 million, in 2019, to fast-track STEM education in schools. | Yes |
| Automation, digital future | RT is committed to developing the next generation of workers. For this they have invested $2M into vocational education and training initiative focused on developing digital skills that will be needed as the mining industry becomes more automated. This will focus on areas such as robotics, IT, analytics and other technology-based tasks. [112] | Yes |
| Future Careers Development | RT has partnered with EdTech and invested A$2.8 into extending their digital careers programme to more students throughout Australia. This digital career programme will be offered for students and parents across Australia. | Yes |

Source: Author

As indicated in Table 23 above, RT has programs for both the development of the future and the current workforce. These programs are focused largely on developing automation capabilities; this is well suited to RT's drive of implementing automation to improve productivity. These efforts to enhance the digital literacy of the workforce are forward thinking and create a strategy to tackle the looming skills gap that will arise as the workforce becomes more automated. These programs offered by RT provide employees with a chance to

[112] (Turner, 2018).

futureproof their skill sets, and ensure that innovation and technology, with a particular focus on automation in this case, are central to each individual's professional development path.

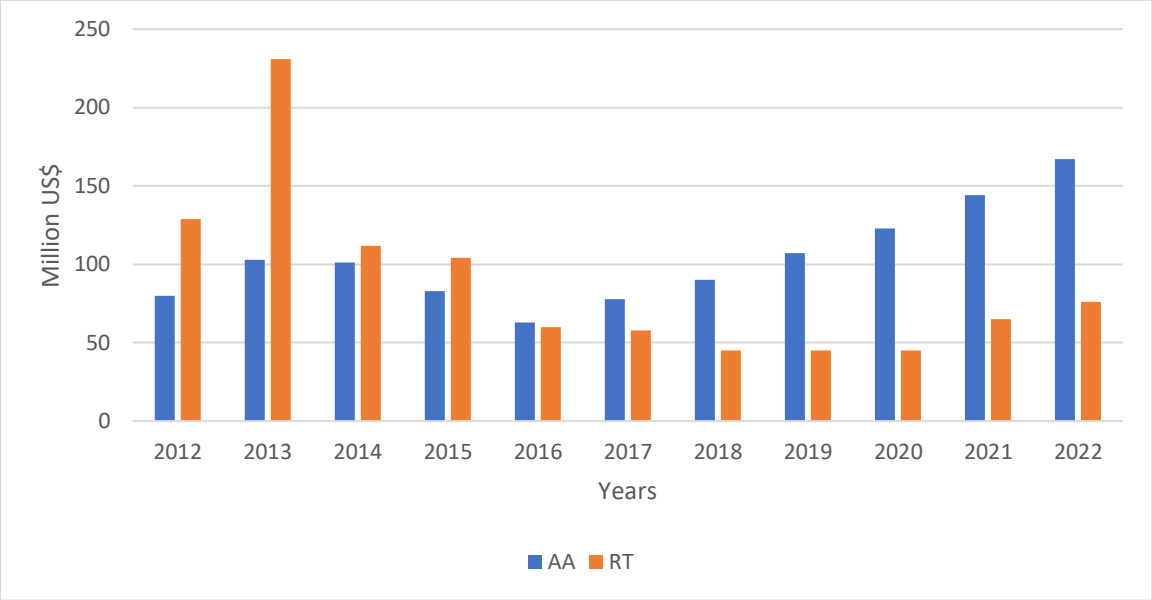
## 4.4 FIRM A AND B – CROSS-CASE ANALYSIS

Comparative case studies are valuable for showcasing contextual influences and the interplay between policy and success of interventions. They offer a nuanced understanding of change process dynamics and are particularly useful for tailoring approaches to enhance success. This specific comparison aims to identify areas where South African mining companies can adapt their strategies to improve their programs and potentially bridge the gap in productivity and automation levels with global leaders like RT (Cherim et al., 2020).

### 4.4.1 LEVEL OF FIRM COMMITMENT TO DEVELOPING TECHNOLOGICAL CAPACITY

Research conducted by McKinsey&Company (2019) pointed out that innovation has become a core driver of growth and performance. More than 70% of the senior executives, according to a survey they conducted, say that innovation will be at least one of the top three drivers of growth for their companies in the next few years. Other executives see innovation as the most important way for companies to accelerate the pace of change in the global business environment (Bigliardi et al., 2020). For these reasons, it is important for a company to develop consistently their activity level in the innovation system, promoting firm longevity and strategic success (Indeed, 2022). The research from McKinsey&Company (2019) is relevant as it reflects the story that the data in this research is inductively telling. The graphs and Table 24 below compare and contrast AA and RT's innovation activity to find similarities and differences between their approaches to innovation.

Figure 7: R&D expenditure comparison

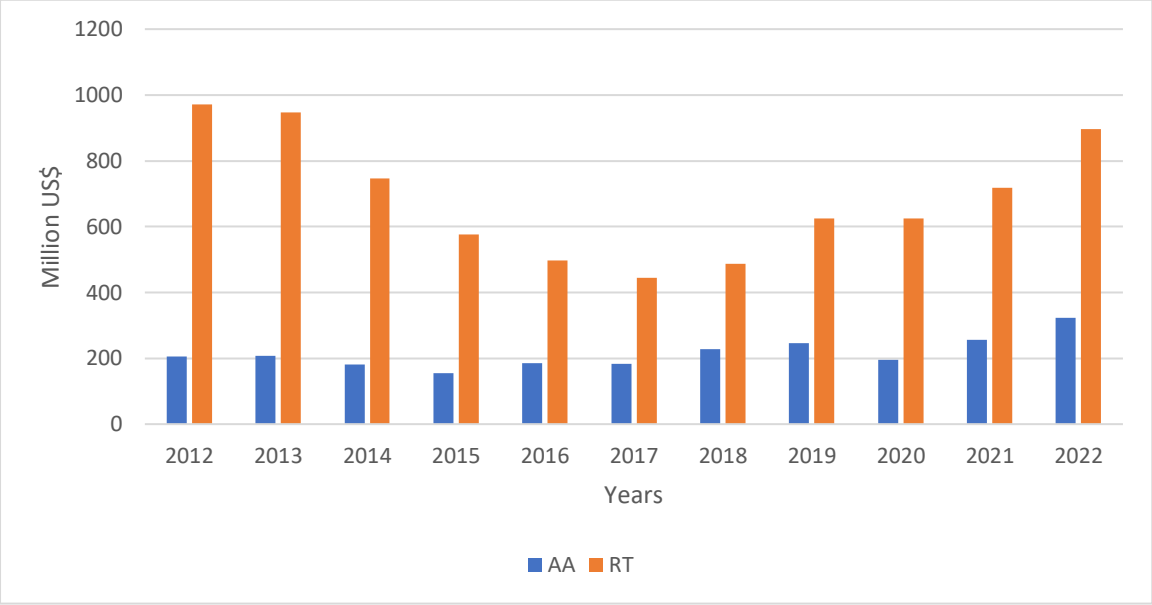



Source: Author

*Data: Information from the above tables all accessed from various AA and RT sites.*

This figure above represents firm R&D expenditure, illustrating that both firms spend significant amounts. The notable difference is that AA expenditure has increased over time, whereas RT expenditure has decreased. The patterns found in this study suggest that this could be due to a stronger innovation ecosystem present in RT's operating environment. This will be discussed further in Table 24 of similarities and differences below.

Figure 8: Exploration expenditure comparison

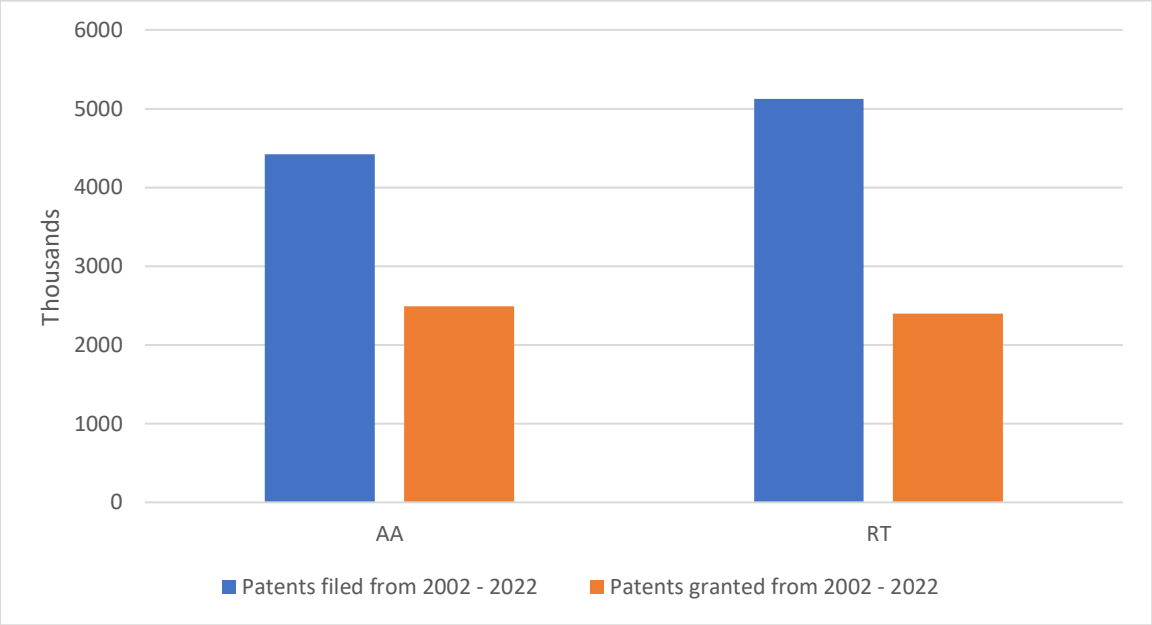



Source: Author

*Data: Information from the above tables all accessed from various AA and RT sites*

This figure above represents firm exploration expenditure, illustrating the similarity between AA and RT with regards to consistency of investment. However, regardless of the fact that both companies consistently invest, Figure 8 also highlights the significant difference in amounts invested by both companies each year. This will also be discussed further in Table 24 of similarities and differences below.

Figure 9: Patent activity comparison from 2002 - 2022

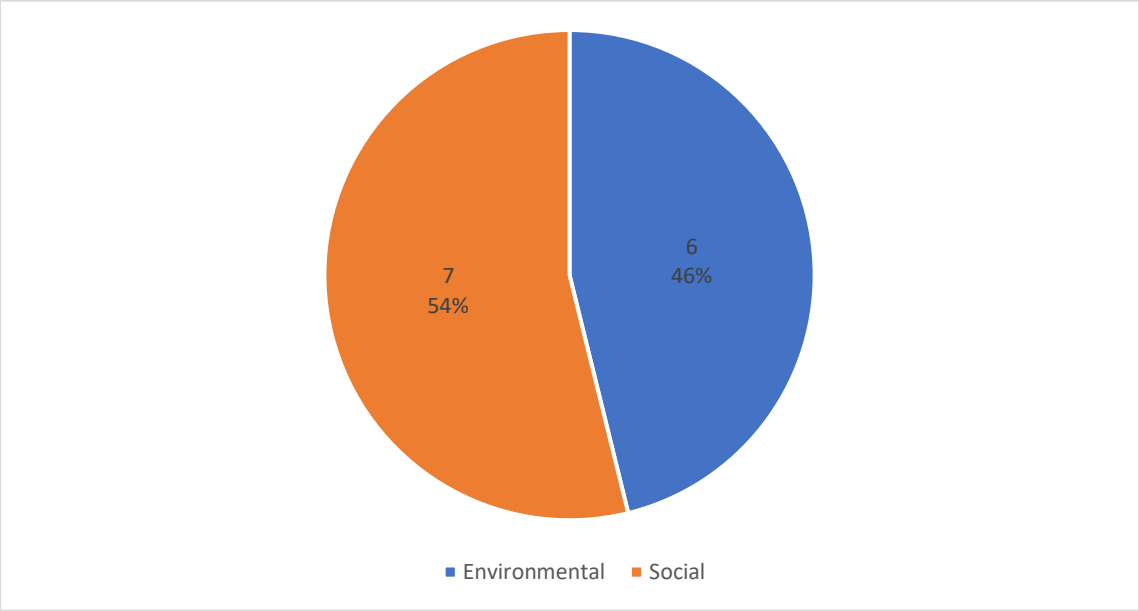



Source: Author

*Data: Information from the above tables all accessed from various AA and RT sites.*

This figure above represents patent activity of each firm, illustrating the similarity, once again, is the consistency in filing patents and the difference is the number of patents filled each year. This will be discussed further in Table 24 of similarities and differences below.

Figure 10: AA collaboration partner driver

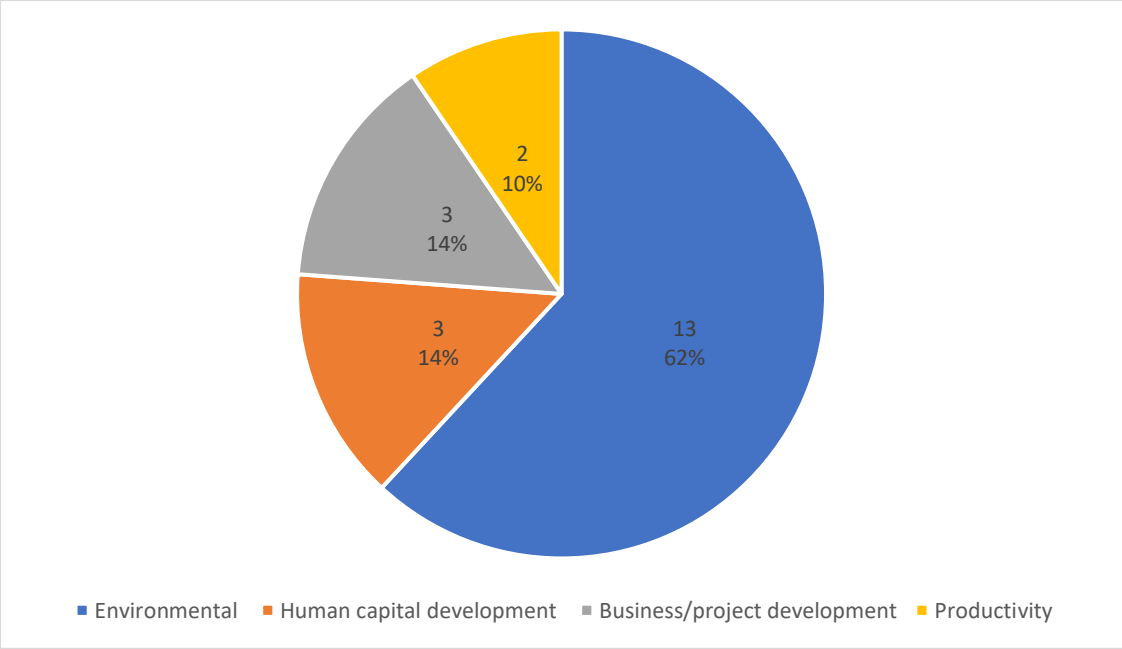



Source: Author

*Data: Information from the above tables all accessed from various AA sites.*

Figure 10 above, represents the drivers behind each of AA's collaboration partnerships, illustrating that AA is mostly driven to collaborate around environmental and social issues. In comparison to this, Figure 11 below indicates that RT has a more diverse approach to collaboration. This will be discussed further in Table 24 of similarities and differences below.

Figure 11: RT collaboration partner driver




Source: Author

*Data: Information from the above tables all accessed from various RT sites*.

Table 24: Similarities and differences of innovation system activity

| **Innovation system activity** | **Similarities** | **Differences** |
|---|---|---|
| R&D expenditure | Both firms spend significant amounts on R&D. | From 2012-2015, RT had much higher R&D expenditure amounts than AA did, but from 2016-2022 RT expenditure started to decline and AA's increased steadily.<br>This could be because of a difference in the strength of innovation ecosystems systems in which each firm operates. RT has many supporting entities around its operations that also conduct R&D and a long list of collaboration partners with which most of its environmental R&D initiatives are conducted. This would reduce the pressure for RT to conduct all their R&D in house. |
| Exploration expenditure | Both firms have invested in exploration consistently. | A major difference here is the amount invested. RT appears to be far more committed to exploration activities compared to AA.<br>Exploration is important if a firm is to remain competitive and sustainable. Extensive exploration activities are also often commonly linked to widespread technology development that matches the exploration activity. |
| Patent activity | Both AA and RT are active in developing patents. | RT has a higher number of patent applications compared to AA, but a lower percentage of successful applications.<br>This could indicate a more bullish approach to innovation, possibly suggesting that RT, in being more confident in and committed to their drive to achieve a fully innovative firm, is willing to pursue many different ideas (even if these ideas are not always successful).<br>AA could have more of a bearish approach in pursuing only the ideas that they are somewhat convinced would work (Greyb, 2022a). |

| Innovation system activity | Similarities | Differences |
|---|---|---|
| Collaboration partner development | Both firms are very active collaborators, understanding the importance of collaboration to successful innovation. | The firms differ slightly in the intensity of their collaborations. RT had 21 active collaboration partners in 2022, and AA had 13. They also differ in their collaboration focus areas. AA's collaboration partners are predominantly focused on the environment and social benefits. RT's collaborations also have an environmental focus, but with additional foci on human capital development, business development, and productivity. |
| SMME development | Both firms actively support SMME development. | The firms differ slightly in the type of SMMEs they commonly support. AA mostly supports SMME development in the agriculture and manufacturing sector, with a large focus on social upliftment.<br>RT supports SMMEs with a focus on creating impact in the areas of environment, exploration, and efficiency. RT's SMME development also has a large focus on technological development; this is not a priority for AA. |

Source: Author

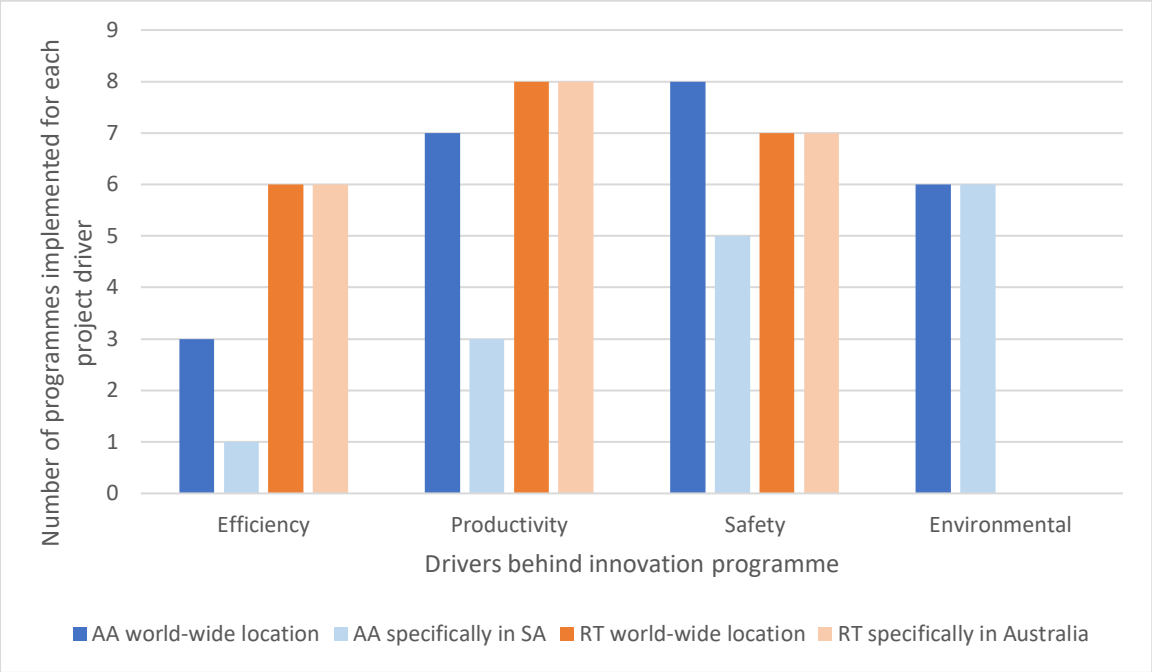
From the above graphs and Table 24, it is clear that both firms are very active in the innovation ecosystem, but with different priorities. AA has a stronger presence in R&D activity and RT is far more active in exploration. Limited exploration from AA is detrimental to firm sustainability. To catch up with the performance levels of global leaders, extensive exploration from firms in SA is necessary. Exploration should also be linked to ground-breaking technology that enables the search for minerals. This limited focus for AA could reduce their need to develop radical, transformative technologies and result in concentrating more on incremental technological improvements. Both firms are active in developing the innovation ecosystem; they both collaborate extensively and support SMME development. However, they once again appear to have different priorities in this area. AA collaboration is focused purely on environmental and social outcomes as well as on their SMME development programme, that also has social upliftment as a main priority, with little technological consideration. This

is different from RT that collaborates for a number of outcomes that include more aspects of the business. For example, their SMME development is quite predominantly focused on investing in firms that are developing their technological capacity. This is an important contribution to the innovation ecosystem in which RT operates. As mentioned above, this could be one of the reasons RT is no longer obliged to conduct so much in-house R&D. The data implies that through this ongoing investment into technologically oriented SMMEs, RT has created a national/regional innovation ecosystem and it is now gaining returns from this investment, in a lot of intangible ways.

### 4.4.2 MAIN FIRM DRIVER FOR INNOVATIVE CHANGE

Technological changes are motivated by different drivers of innovation. These drivers can include a focus on improving productivity and business expansion, a focus on reducing environmental impacts, a focus on safety improvements, or a focus created through pressure to meet certain requirements from customers and industry standards (Nguyen, 2009). An innovation driver will influence the type of technology pursued as well as the technological trajectory in which the firm operates (Li & Yu, 2018). The following graphs and Table 25 indicate the similarities and differences between AA's and RT's innovation drivers as well as the influence different country contexts may have on this driver. They illustrate the different approaches taken by both firms, highlighting SA's AA operations being predominantly focused on safety and environmental innovations; with limited attention on efficiency and productivity. In contrast to this, Australia's RT operations appear to be sufficiently focused on all innovation drivers, with the top area of focus being productivity innovations.

Figure 12: Drivers of innovation behind each innovation programme function




Source: Author

*Data: Information from the above tables all accessed from various AA and RT sites.*

Table 25: Similarities and differences of the firms' *why* behind its innovation drive

| **Discussion point for what drives firm innovation** | **AA** | **RT** | **Firm similarity or difference** |
|---|---|---|---|
| Innovation programs implemented across a variety of different drivers | Innovation programs are implemented across all major drivers. | Innovation programs implemented are across all major drivers with the exception of environmental, but it appears that this is no longer an in-house activity for RT and is well catered for through their innovation partners. | Firm similarity |
| Focus on interaction between country of operation and specific drivers | There is massive interaction. Only some of AA's innovation programs have been implemented in SA, with the exception of all AA's environmental programs operational in SA. SA has the least focus on efficiency and productivity as drivers, with their greatest focus being on safety and environmental drivers. | There is no interaction. All of RT's innovation programs have been implemented in Australia. | Firm difference |

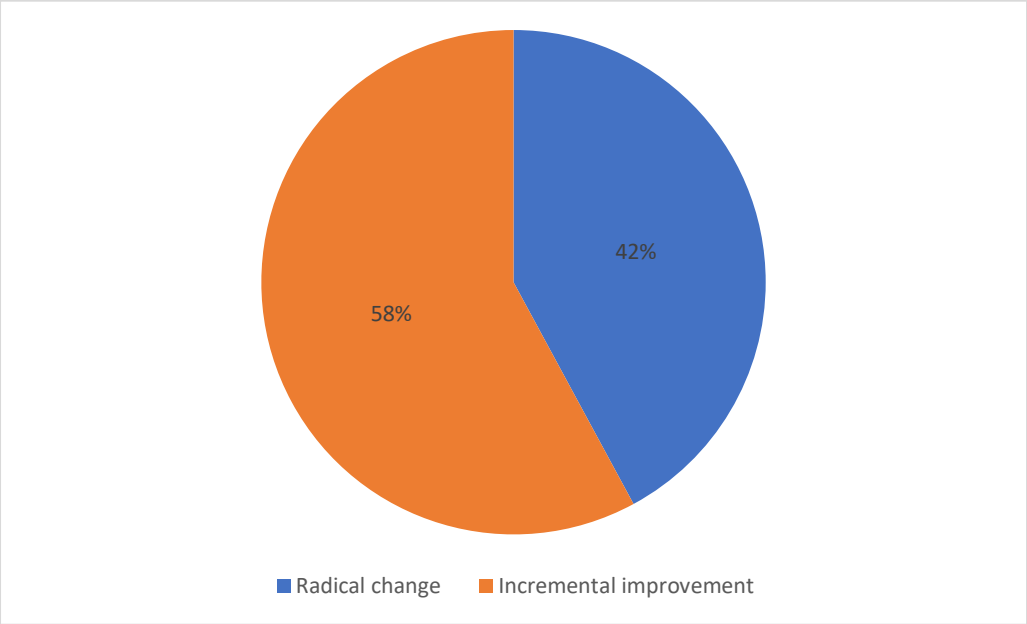
Source: Author

The above graph and Table 25, suggests that there is a large interaction between the why behind a firm implementing technology and the context in which it operates in. The table indicates that context in Australia does not prevent the implementation of any certain innovation programme, which means the "why" will be solely driven by organizational needs and not influenced by the demands of the contextual environment. This context does not dictate the type of innovation needed by the firm. All of RT's programs that are operational around the globe, are also all operational in Australia. It would appear that this is very different in SA. Not all of AA's programs are operational, with the exception of their environmental programs, in SA. Of all global productivity programs, only 43% have been implemented in SA. This would suggest that in this instance, context does play an important role in influencing they "why" behind a certain programme and subsequently determining the type of technological trajectory in which the firm operates.

### 4.4.3 NATURE OF TECHNOLOGICAL INVESTMENTS MADE BY FIRM

The technological resources and capabilities of a firm are essential in ensuring that it maintains its competitive success. Many firms have expanded their technology base by becoming active in many technological fields (Ceipek et al., 2019). They differ, though, in the level of this technological diversification. Some have a focused approach to their technological resources and development capabilities, whereas others choose to diversify across many fields (Ceipek et al., 2019). This choice regarding the type of technology the firm chooses to pursue will influence their technological adoption journey and the kind of impact created. Types of technological solutions, include, for example, artificial intelligence, automation, GPS technologies, workforce tracking and drones, just to mention a few (Cashman, 2022). Transformative/disruptive technology is more likely to cause radical changes to the current way of work. Technology that is not transformative will most likely create incremental firm improvements. The following graphs and Table 26 show how this technological diversification is similar or different between AA and RT. They also consider possible reasons for this.

Figure 13: Operational impact of AA's innovation programme functions

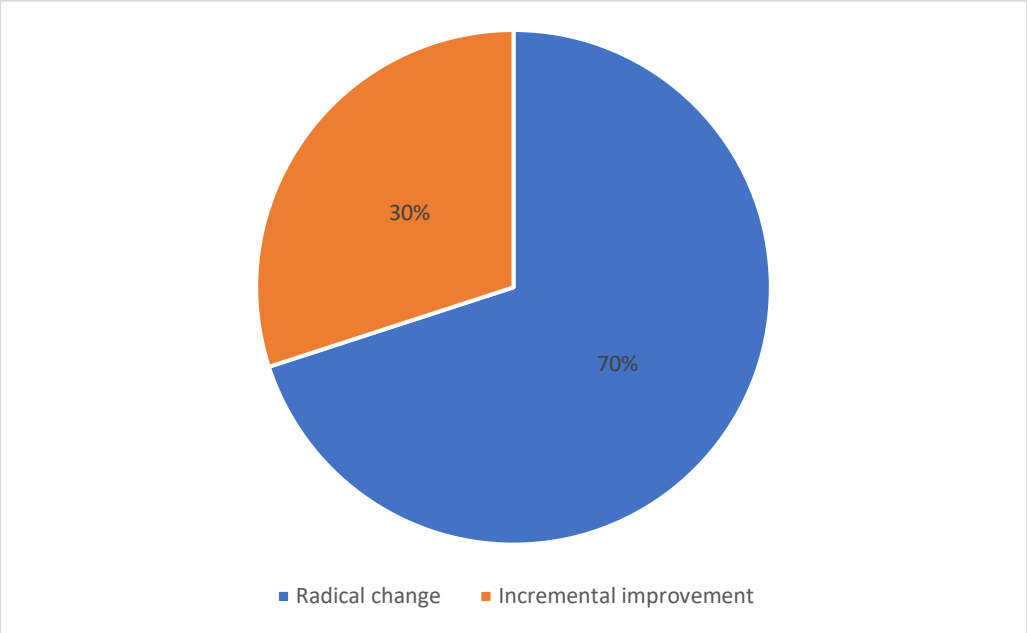



Source: Author

*Data: Information from the above tables all accessed from various AA sites.*

Figure 13 above and Figure 14 below illustrate the nature of innovation programs, either radical or incremental, carried out by AA and RT respectively. Radical innovations represent changes in technology that revolutionary and drastically transform the way work is currently done (Kasmire et al., 2012). In contrast, innovations that are incremental involve simple adjustments to current technology, processes or services and produce minor improvements (Chandy & Tellis, 2000; Hall 1996). These figures illustrate that AA appears to be more focused on implementing incremental programs compared to RT which has a greater number of radical programs.

Figure 14: Operational impact of RT's innovation programme functions




Source: Author

*Data: Information from the above tables all accessed from various RT sites.*

Table 26: Similarities and differences regarding the nature of the innovation pursued

| **Nature of innovation discussion point** | **AA** | **RT** | **Firm similarity or difference** |
|---|---|---|---|
| Focus on technological developments that result in incremental improvements or radical changes to the way of work | Although AA does have a number of disruptive/breakthrough type technologies in their portfolio, such as the introduction of their hydrogen trucks, most of AA's strategic goals are achieved through implementing incremental process improvements. | RT have focused a large portion of their innovation efforts on disruptive technology. The introduction of an autonomous train, for example, is not going to incrementally improve the production process. Instead, it is going to disrupt radically the usual way of operating. | Firm difference |
| Common type of technology implemented | AA has developments in a variety of different areas, including automation and AI. However, a concentrated focus was on process improvement technologies that do not use any type of 4IR/transformative technology. | RT has extensive developments in automation, smart mining, and artificial intelligence; all these technologies are transformative in nature. Most of their developments are in the automation field. | Firm difference |
| Circumstances required to implement automation as a strategic priority | AA will not automate for the sake of it. They pursue automation only when it can replace a mundane task. AA would move to | RT do not stipulate that any conditions need to be present to automate. RT focuses extensively on automation, under any | Firm difference |

| Nature of innovation discussion point | AA | RT | Firm similarity or difference |
|---|---|---|---|
| | fully autonomous operations only in exceptional circumstances. A decision like this would likely be influenced by operational factors that endanger the safety of the driver, extraordinary circumstances that may lead to operator exhaustion, severe weather conditions, or geographical remoteness. | circumstances, to increase productivity and improve worker safety while also reducing environmental degradation and costs. They believe that automation is the future of mining. | |
| Potential influence of context on the nature of the firm's innovations | High levels of unemployment in SA could influence AA's choice not to automate often, and to choose incremental improvements over radical changes to protect employment. | Low levels of unemployment in Australia and the critical need to reduce their dependence on labour could drive the uptake of automation and radical changes that move away from current labour-intensive methods. | Firm difference |

Source: Author

The graphs and Table 26 above illustrate the significant difference between the type of technology commonly implemented by the firm as well as the common type of impact these technologies create. As can be seen above, AA has implemented far more innovation programs that create incremental improvements, compared to RT that predominantly creates radical changes to the current way of work. This is supported by the fact that although AA does use a lot of automation in their operations, it is not a top priority, and they therefore also include a lot of process- improvement technologies. This is very different to RT who believe that the future of mining rides on a firm's ability to implement automation. This is linked to comparison area one that suggested that AA's limited exploration activity would influence their drive to pursue groundbreaking technology like RT clearly does. These different opinions on automation could be influenced by the context of the firm. RT's labour shortage crisis requires automation for long-term sustainability, whereas AA's contextual constraint of high unemployment and an expectation to provide employment would prevent this. This again suggests that a restrictive context can sometimes dictate the technological trajectory of a firm.

### 4.4.4 INFLUENCE OF COUNTRY CONTEXTUAL FACTORS ON FIRM PATH DEPENDENT TECHNOLOGICAL TRAJECTORY

The success of change initiatives in a firm, specifically the introduction of new technology, is affected by a number of contextual factors. These factors either enable or hamper the success of the technological development (Haldrup, 2018). Among others, these include the influence of power and politics, policy and legal frameworks, and socio-economic context. These influences affect the organisational capacity and technical skills of the organisation's workforce (Haldrup, 2018). Understanding the influence context has on a firm's innovation activity as well as the trajectory in which it operates, is useful for developing a firm's strategy related to technology adoption.

The heat map as well as Table 27 below show the influential role context plays. It also illustrates the possible strategic developments these influences could have created. In its use of different colours to convey meaning, a heat map is a useful data visualisation tool that clearly communicates inputs (Kenton et al., 2022). This heat map will use the following scale to attach meaning to each colour.

Figure 15: Heat map colour scale

Negative impact on technological development capability[113]

Negative impact on investment attractiveness

| | Low | Medium | High |
|---|---|---|---|
| Low | | | |
| Medium | | | |
| High | | | |

Source: Author

[113] Technological development capability is the ability of a firm to effectively utilise technology enabling a competitive edge (IGI Global, 2014).

Figure 2: Heat map colour key



No negative impact. This input is excellent for the industry.

No negative impact. This input is beneficial for the industry.

Medium negative impact. This input partly inhibits the industry.

Significant negative impact. This input is detrimental to the industry.

Severe negative impact. This input stunts industry growth.

Source: Author

Table 27: South African context influencing AA: Heat map diagram

| POLITICAL & LEGAL | ECONOMIC | SOCIAL | TECHNOLOGICAL | ENVIRONMENTAL |
|---|---|---|---|---|
| Uncertainty around the MRPDA | Dwindling FDI | Terrible history of Apartheid that still plagues the industry. | Declining country level R&D | Energy supply constraints |
| Controversy created because of various parts of the Mining Charter | Declining exploration budgets | High unemployment rate | Increasing country level R&D employment | Increase in the threshold for electricity, generated without licence (Electricity Regulation Act, 2004) |
| Ongoing policy changes, no stability | Generally limited tax incentives for the mining industry | Large portion of SA workforce with low skills levels | TEA rate is very low. | Poor performing logistics infrastructure |
| Land expropriation | Insufficient tax incentives for mining exploration | Protests and labour unrest | Non-conducive systems for the allowance of new patents and IP | Water supply to mines is a potential problem because of the deteriorating public water infrastructure. |
| | | Strife from labour unions | Currently, there are no insights into how to approach policy formation and funding necessary for the implementation of SA's new innovation plan. | The White Paper on National Rail Policy (2022) will enable access to Transnets freight rail to third-parties. This will hopefully assist with bottlenecks and bring down the cost of transportation. |
| | | Poor standard of education | | |
| | | Increase in the development of human capital | | |

Source: Author

*Data: Information from the above tables all accessed from various AA sites.*

Table 28: Australian context influencing RT - Heat map diagram

| POLITICAL & LEGAL | ECONOMIC | SOCIAL | TECHNOLOGICAL | ENVIRONMENTAL |
|---|---|---|---|---|
| Policy and regulatory stability | Increasing levels of FDI | Low unemployment rates | Significant R&D commitment | Port and rail infrastructure very well structured and managed |
| Influence of Resources 2030 Taskforce on policy development, to remain a world leader | Patent Tax incentive | Labour shortages | Strong patent activity | Innovation activity not only alive in mining operations, but also in their rail sector |
| Australia's AI Action Plan | Junior Mineral Exploration Tax Credit | Shortage in skilled labourers (worst skills crisis in a generation) | Significant university research funding | Australian companies committed to finding new innovative ways of conducting business to ensure the rails operate at highest levels of productivity |
| Government policy, geared towards fostering a growth enabling framework | R&DTI Tax Offsets | | Advancements of STEM fields | Regulatory certainty provided with announcement of regulated monopoly until 2040 |
| Policies all have proactive foreign investment regimes | | | Significant R&D employment | Reliable energy supply |
| | | | Large focus on AI as an important enabler for the technology Digital Economy Strategy | |

Source: Author

*Data: Information from the above tables all accessed from various RT sites*.

Table 29 below shows how the inputs in the above heat maps could have, at least potentially, influenced the strategic development and direction of the firm. It also assesses the similarities and differences of strategic development between AA and RT.

Table 29: Interaction between contextual environment and firm strategic direction

| PESTLE Factor | Possible influence on AA strategic direction | Possible influence on RT strategic direction | Similarity of difference in strategic direction |
|---|---|---|---|
| POLITICAL & LEGAL | Reduced external investment could affect the firm's ability for growth and expansion. | High investments into the country could produce a growth-oriented mindset for the firm. | Difference in strategic direction<br><br>AA: Possibly more focused on maintaining and incrementally improving current projects with limited focus on transformative strategic initiatives. |
| | This could cause less company exploration (particularly green field) given the uncertainty of | The firm's commitment to exploration and developing exploration technologies could be | |

| PESTLE Factor | Possible influence on AA strategic direction | Possible influence on RT strategic direction | Similarity of difference in strategic direction |
|---|---|---|---|
| | continuing operations in an unstable climate. | influenced by their operating environment. This environment has significantly high yearly exploration budgets and promotes exploration through tax incentives. | RT: Possibly more focused on increasing productivity margins of current projects as well as on exploration and transformative exploration technology needed to develop new projects. |
| ECONOMIC | The lack of incentives and the unfavorable economic environment could lead to reduced exploration commitment by the firm. | The economic growth mindset that appears to be present in Australia could create a higher strategic interest in developing new ways of work and finding new productivity-oriented technology. | |
| | Less exploration could mean reduced R&D investment into transformative technology that would be used for exploration. | RD&I tax offsets could promote firm R&D. This could motivate the firm to develop disruptive technology that radically changes operations thus enabling them to remain a world leader. | |
| | Less focus on explorative type R&D could, potentially, mean a shift in the focus of the firm's R&D to a more incremental type of technology. | | |
| SOCIAL | Safety, health, environmental and transformation objectives form a crucial part of the firm's strategic goals. The apparent limited focus on productivity could be driven by the intention to uphold these objectives. Productivity can sometimes be associated with a decline in social well-being. It appears that upholding the one means very limited attention on the other. | Dealing with labour and skill shortages would influence strategic priorities for Australian firms. This could lead, potentially, to increased involvement in STEM. It could mean prioritising automation so as to be less reliant on the human workforce. It could also mean prioritising remote working opportunities to cater for a wider audience of potential employees. | Difference in strategic direction<br><br>AA: Potentially more focused on managing social complexities of SA's environment. This could limit strategic focus on technological developments that would radically shift the current way of work.<br><br>RT: Potentially very focused on strategy that would reduce their dependence on labour. This would promote the large-scale development of transformative technology, radically shifting the current way of work. |
| | The poor education system and high levels of unemployment could lead to great firm responsibility to develop learning programmes as part of their strategic commitments. | | |

| PESTLE Factor | Possible influence on AA strategic direction | Possible influence on RT strategic direction | Similarity of difference in strategic direction |
|---|---|---|---|
| | The high unemployment issue that governs the social environment could influence the strategic focus of technology development. The firm may, potentially, prioritise the implementation of technology that will not cause significant job losses. | | |
| TECHNOLOGICAL | The limited technological activity and the under-developed innovation ecosystem may influence the firm's ability to drive innovation and radical technological change. | The innovation culture starts from the company's grassroots, making the development and implementation of new technology a norm that is somewhat expected of the firm. This environment could produce a culture that normalises technological development, putting an expectation on the firm to produce technology that will radically improve business. | Difference in strategic direction.<br><br>AA: Possible development of strategy that values the importance of technological development but, without the support of a strong innovation ecosystem, it is not central to every decision made by the firm. Potentially, this results in a more conservative, incremental approach.<br><br>RT: Possible development of strategy that considers technology to be part of every aspect of the firm. This could result in a bold, radical approach to how the firm views innovation. |
| | | An environment that welcomes technological development like Australia does, could have influenced the firm's choice to implement all their developments and file most of their patents in Australia. | |
| ENVIRONMENTAL | The energy crisis in SA could be creating a necessary strategic drive to invest in renewable energy projects. | Energy stability in the country puts no pressure on the firm to self-generate. However, the environmental and cost-saving benefits of renewable options have most probably still been a strategic driver for the firm. | Difference in strategic direction.<br><br>AA: Strategic focus, including technology development and investment priorities may, potentially, be focused on addressing environmental constraints, as a necessity to protect the longevity of operations.<br><br>RT: Although infrastructure development is beneficial to any firm, in the case of RT this would not be necessary to insure the survival of the |
| | Due to failing infrastructure, there may be a strategic priority to develop technology to make mining operations more self-sufficient, such as with water use. | | |

| PESTLE Factor | Possible influence on AA strategic direction | Possible influence on RT strategic direction | Similarity of difference in strategic direction |
|---|---|---|---|
| | | | firm. It would be a choice to enhance the operations. This could be considered after other strategic priorities have been addressed. |

Source: Author

The heat map and Table 29 above indicates the restrictive contextual influences affecting AA, versus the enabling environment in which RT operates. As can be seen from Table 29, these contextual differences have resulted in very different strategic development. Context is a factor that cannot be overlooked when one is considering an approach to technological innovation. However, this does not mean the context has to control every aspect of the technological trajectory. If a firm in a restrictive environment intends to catch up with global leaders, it appears that this will be unlikely to happen through incremental improvements since these most commonly keep the firm on its current technological trajectory. It appears that catching up to global leaders would need a change in this trajectory—a radical leapfrog shift to a new trajectory or paradigm—and once this shift has happened and the firm is on its way to catching up to global leaders, the incremental improvements will be more beneficial. A firm would need to develop solutions, alongside their difficult context, that will enable this radical change.

Despite the difficult context in which the South African mining industry operates, and despite the conventional assumption that innovation success usually happens in the advanced countries, research by Perez (2014) suggested that in the last thirty years society has seen significant changes, with an increasing number of innovations originating in the developing countries. Perez (2014) argued that these changes are the result of a radical paradigm towards the information technology revolution and away from mass production.

### 4.4.5 FIRM CULTURE REGARDING TECHNOLOGICAL DEVELOPMENT

Introducing new technologies can be a complex process for companies that is often accompanied by much workforce resistance (Aliahmadi et al., 2011). Employee acceptance of technological change is commonly influenced by individuals' perception of how this new technology will affect their job stability (Davis & Lippert, 2006; Sharma, 2013). It is useful for a firm to prioritise understanding how individuals respond to the introduction of new

technologies to promote the formation of an enabling environment for the adoption of new technology (Lo et al., 2018). User acceptance is a necessary factor to consider in technology adoption, implementation, and usage since it is commonly linked to the success of the technology (Davis & Lippert, 2006). However, despite this, Table 30 below suggests differences regarding the intention behind culture development in each firm, which influences the type of impact each cultural development activity is creating. This pattern seems to affect the successfulness of developing an innovation culture in all aspects of business life.

Table 30: Similarities and differences regarding firm innovation culture

| **Culture and innovation alignment point** | **AA** | **RT** | **Outcome between firms** |
|---|---|---|---|
| Is innovation included as part of *who we are*? | The firm's notion of *who we are* does not explicitly mention innovation. It does, however, mention key activities that would implicitly suggest the need for innovation, such as the development of future smart mining projects. | The firm's notion of *who we are* explicitly mentions innovation. They highlight that all their operations include "data centres, R&D labs which all prioritise artificial intelligence." There is also mention of their exploration activities (which would inherently include the need for innovation to produce good exploration technologies). | Cultural difference |
| Is there alignment between the firm's purpose and its development of an innovation culture? | The firm's purpose is to "re-imagine mining to improve people's lives", which they believe will be achieved through embracing technologies of the smart future. AA has a clear link between their purpose and innovation. | RT's purpose is to produce products that are crucial to human development, and this is enabled through their commitment to Development & Technology. RT has a clear link between their purpose and innovation. | Cultural similarity |
| Is there alignment between firm strategy and the development of an innovation culture? | The firm's strategy does support the development of an innovation culture. One of three tiers of AA's strategy is focused solely on innovation. This tier focuses on technology and digitalisation to achieve | RT's low carbon strategy has three important steps with each containing an element of innovation. These are: first, decarbonising operations through renewables and | Cultural similarity |

| Culture and innovation alignment point | AA | RT | Outcome between firms |
|---|---|---|---|
| | sustainability in mining practices. | electrification; second, accelerating their exploration activity for commodities that will enable the shift to renewable energy and achieving net zero; and third, increasing investment into R&D to enhance the development of products that will assist their customers in decarbonising more quickly. All these strategic actions inherently involve a link to innovation. | |
| Is there alignment between firm values and the development of an innovation culture? | AA has six values, two of which are linked to innovation. Both collaboration and innovation, as values, would assist in creating an innovative culture in the firm. | RT's values are care, courage, and curiosity. Courage promotes not being afraid to try new things and curiosity invites diverse ideas, continual learning, and collaboration. Both are in line with developing an innovation culture. Care is necessary to compliment both courage and curiosity, as it ensures that individual well-being is still prioritised along the journey of developing an innovation culture. | Cultural similarity |
| Influence of firm patent activity on innovation culture? | The higher percentage of successful patent applications (discussed above) could influence the type of innovative culture the firm develops, thus creating a more conservative approach to innovation. This could lead to thinking within existing boundaries and thinking in line with technology that is more incremental. | The firm with the lower success rate could indicate a culture that promotes disruptive thinking. This could produce innovations that are less conservative, and more explorative in nature. Disruptive thinking could be more futuristic and in line with ideas that are radical. | Cultural difference |

| Culture and innovation alignment point | AA | RT | Outcome between firms |
|---|---|---|---|
| | This may also result in fewer breakthrough ideas because of the conservative nature of the culture. | | |
| Are activities prioritised to develop an innovation culture? | AA's people focus on their strategy is to ensure the creation a working environment that is inclusive, supportive and encourages people to think with an innovation mindset.<br>One of the ways that this culture development is actively managed is through their employee engagement survey. AA utilise this to assess how extensively their values are felt amongst their employees, and to understand areas that could be improved. | RT is committed to building an inclusive, people-centred culture, one that is willing to drive and embrace the necessity of change.<br><br>Senior management at RT acknowledges that an evolving culture is a time-consuming process but is something that they support. They also commit to their assistance to tackling challenges that arise as the culture changes.[114]<br><br>RT works at being seen to be synonymous with innovation, ensuring that talented students from leading universities seek them out for employment. However, their culture development is not only outwardly focused but also seeks to develop current employees. Through the use of their Pioneering Pitch programme and Pioneering Portal, RT is supporting growth and positive change within their organisation. | Cultural similarity in that both firms prioritise cultural development.<br><br>But there appears to be a cultural difference regarding the senior level management involvement in this process.<br><br>An additional cultural difference has to do with the type of initiative implemented. The survey utilised by AA is less interactive, less stimulating, and will produce fewer innovative thinkers. It is mostly a measurement tool, whereas the two programmes at RT will drive the development of innovative thinkers. |

Source: Author

[114] (Rio Tinto, 2022g)

Table 30 above indicates that both firms actively drive the development of an innovation culture. They both include innovation in various business development aspects such as purpose, values, and strategy formation. They also both have initiatives in place to promote a good working culture connected to innovation. The one noticeable difference appears to be the intention of the cultural development initiatives run by each firm. It seems as if AA's employee engagement survey would result, mostly, in achieving alignment between employees and senior management, whereas RT's Pioneering Pitch programme and Pioneering Portal focus on developing a certain type of innovative thinker. Perhaps the former is more focused on how innovation fits into the present, whereas the latter is concerned with how innovation will influence the future.

The information from the within-case analyses combined with the cross-case analysis allowed the identification of patterns and relationships in order to formulate propositions. Following the layout from the work of Cruz et al. (2016) and Yan and Gray (1994), who combine the findings from their research to formulate various propositions, the following theoretical predictions have been derived in the form of propositions.

**Proposition one:** R&D activity and efforts to build an innovation ecosystem, with the intention of catching up to global leaders, will be effective and sustainable only with extensive commitment to exploration.

**Proposition two:** A restrictive contextual environment will influence the type of technological trajectory in which a firm operates.

**Proposition three:** A catch up with global leaders is unlikely to happen through incremental improvements. Incremental improvements will keep the firm in its current technological trajectory. A catch up will require a radical leapfrog shift to a new trajectory.

## 4.5 CONCLUSION

This chapter conducted a within-case analysis for AA and RT, followed by a cross-case analysis. The within-case analyses included detailed description case study write-ups. The descriptions were structured around five focus areas. These areas included the context of the firm and analysed how innovation fits into the identity of the firm. The third focus area involved tracking firm activity in the innovation system over time. This was followed by focus area four, an analysis of the type and nature of technological innovation pursued by the firm. Focus area five investigated the firm's involvement in developing networks and collaborations. The cross-

case analysis utilised a set of categories to compare and contrast similarities and differences in relationships and behaviours between the cases. The chapter concluded by combining all the information from the within-case and cross-case analysis to form three theoretical predictions in the form of propositions.

# CHAPTER 5: INTERVIEW-BASED QUALITATIVE ANALYSIS FINDINGS

## 5.1 INTRODUCTION

As mentioned in the chapter 3, this qualitative analysis consisting of a series of semi-structured interviews, was aimed at inductively developing theory that could better explain the complex phenomena in this study. These semi-structured interviews were used to complement the findings of the comparative case study analysis that was conducted between AA and RT in the previous chapter. Using a grounded approach and thematic content analysis, certain relationships around technological development and the influential role of contextual factors are analysed. This chapter includes the formation of a data structure that illustrates the emergent themes in this study. This is accompanied by Table 31, consisting of supporting evidence that contains all representative extracts from participant interviews that form the basis of the data structure. This chapter also includes a grounded model that represents a synthesis that connects the emergent analytical concepts. The grounded model is then followed by the findings.

## 5.2 THE DATA STRUCTURE

This study focused on the possible rejuvenation of the mining industry via technological advancements. It involved an investigation of a number of complex phenomena. Figure 17 illustrates the emergent data structure. The text in the boxes on the left show the first-order categories (created from similarly grouped informant terms). The concepts in the middle column of boxes show the combination of these first-order concepts into second-order analytical/theoretical themes. The boxes on the right show the over-arching dimensions that developed from the analysis process. Table 31, below Figure 17, contains additional supporting evidence, linked to it. It contains the representative extracts from the participant interviews as well as all the first order categories, second order themes, and aggregate dimensions. All the representative extracts from the interviews that are presented in column three are presented verbatim, with light editing in the interests of grammatical integrity (see Corley et al., 2012).

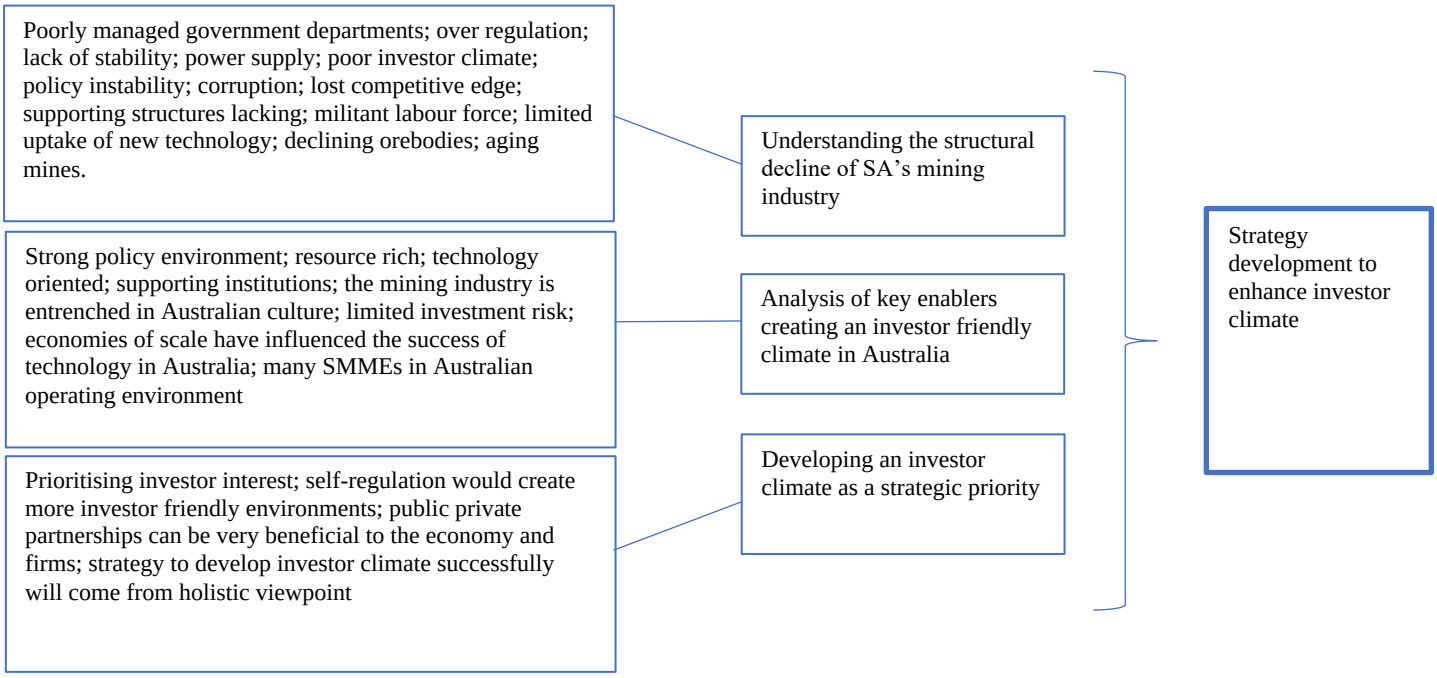
Figure 17 displays the original emerging data structure, which includes first-order categories and their connections to second-order themes and overarching dimensions. However, it presents a relatively stationary depiction. To comprehend the dynamic nature of the situation, further analyses were conducted on the primary themes, resulting in the grounded model illustrated in Figure 18. This model, in a sense, is a depiction of Figure 17 in motion.

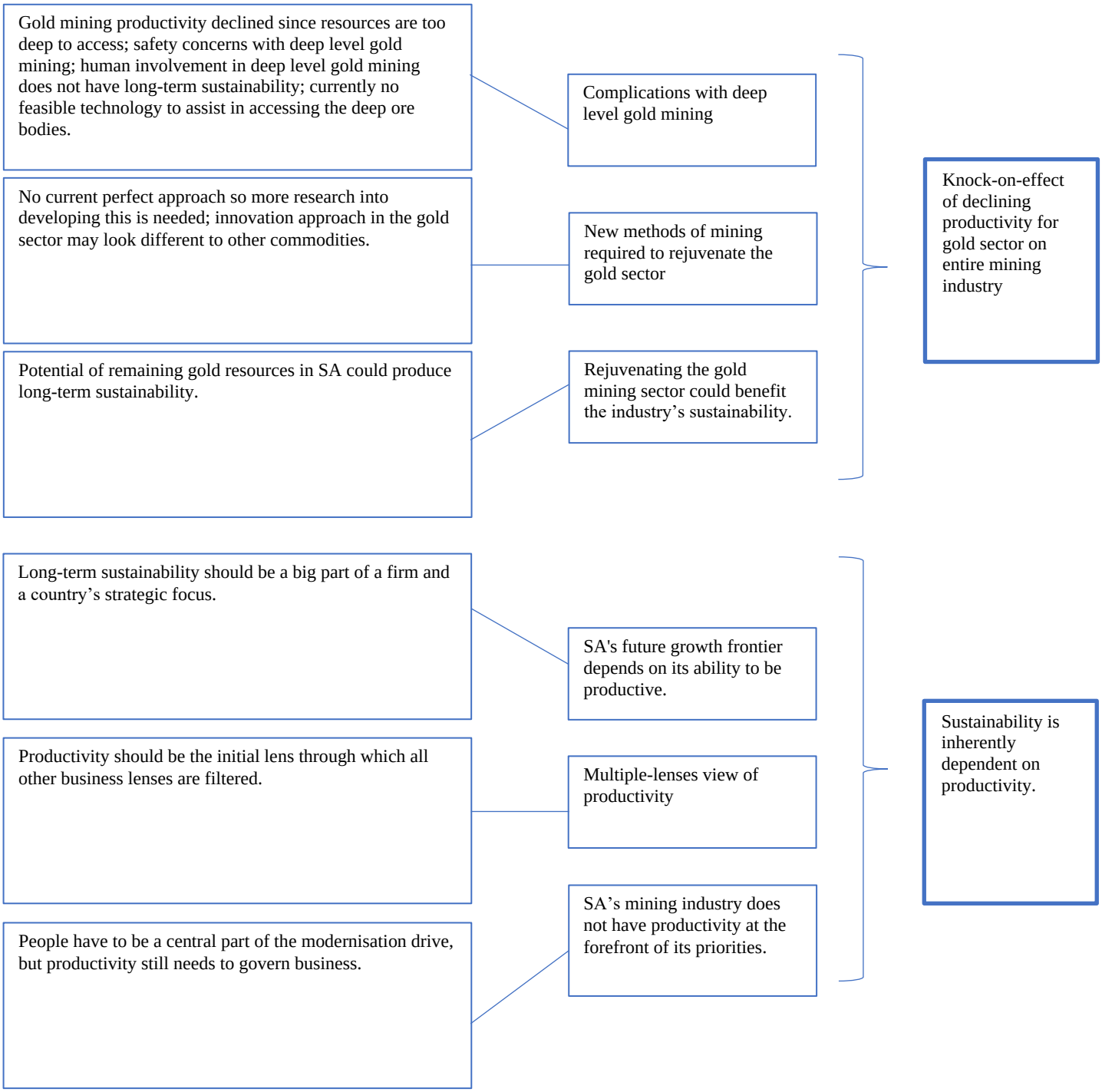
## 5.3 THE GROUNDED MODEL

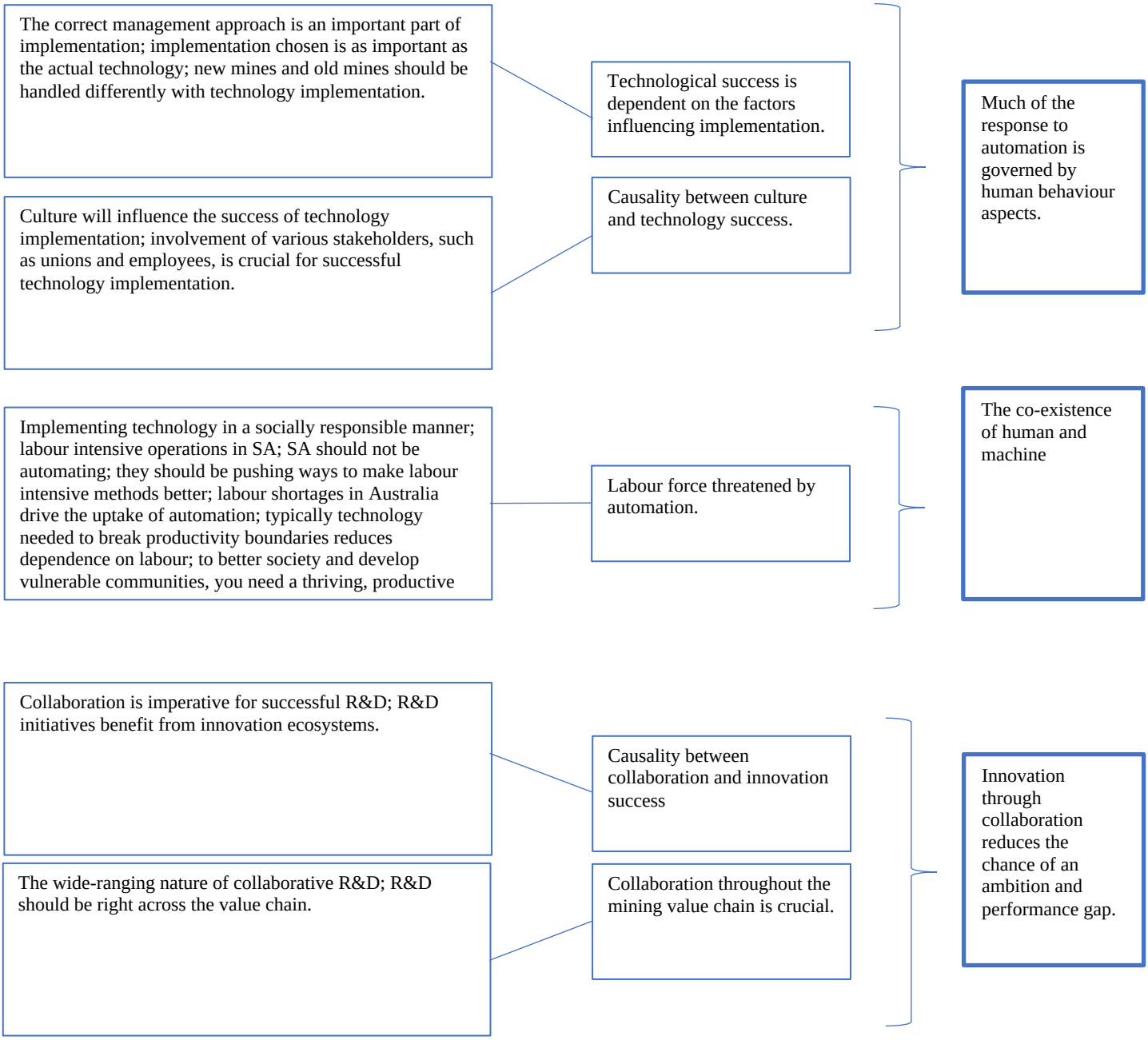
The grounded model (Figure 18) represents a synthesis that establishes connections between various analytical concepts. In this depiction, the intricate dynamics of the complex relationships are clearly captured. The focus in Figure 18 is placed on the more informative theme level, rather than the more detailed and specific dimensional level. It will become clear that the tensions depicted in the overarching dimensions ultimately stem from deeper issues and processes that are better understood through these themes. This approach to presenting the findings is a demonstration of the strong correlation between method, data, and grounded theory. Figure 17 offers the bridge between this method and the data. Figure 18, in turn, provides the vital bridge between the data and the emergent grounded theory. For these reasons, the following findings narrative is based on Figure 18.

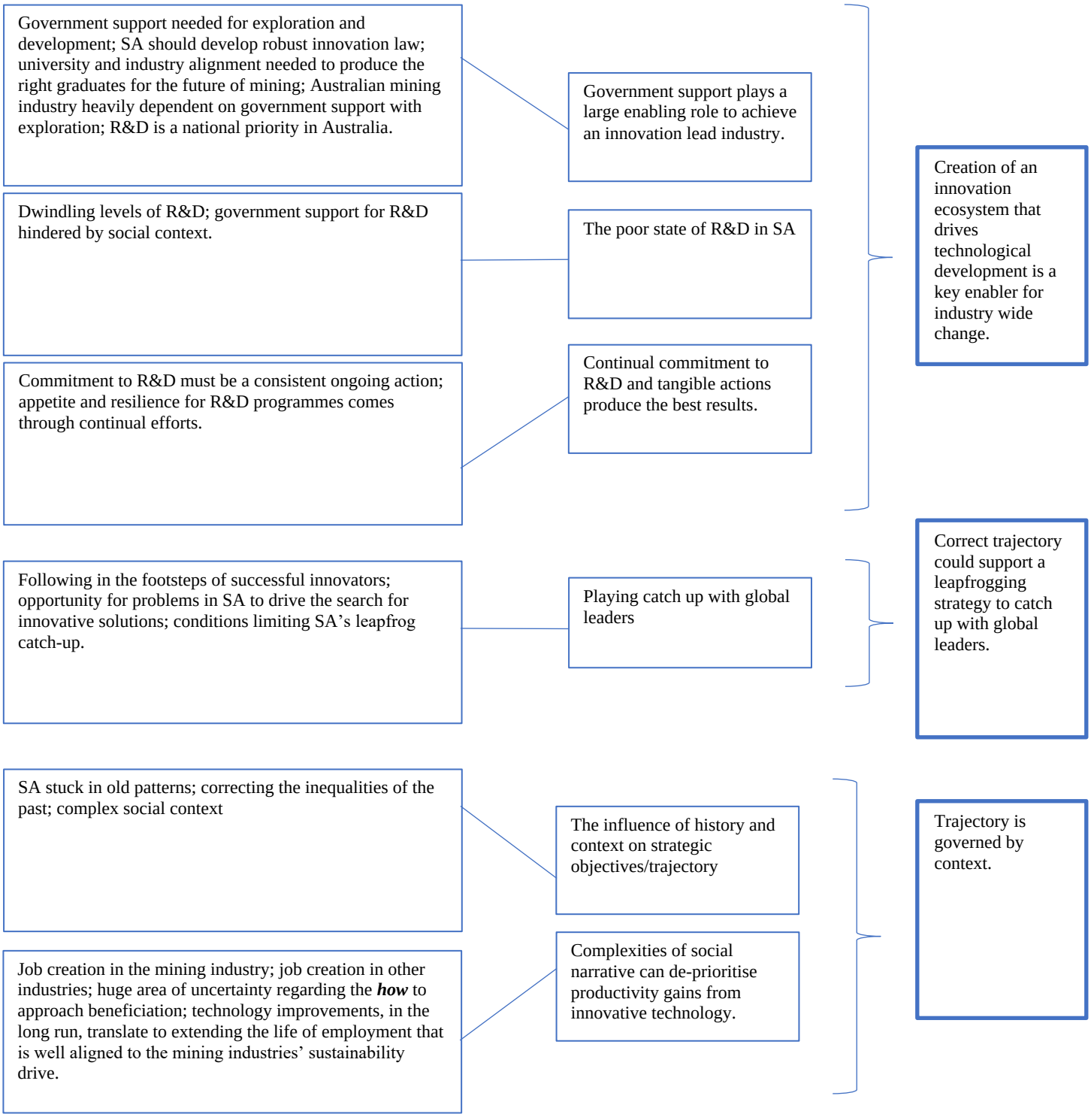
Following the previous work of Mantere et al. (2012), Nag et al. (2007) and Nag and Gioia (2012) the steps in the above paragraph were conducted in a way that maintained the necessary scholarly rigour. An overview of these steps, which have also been elaborated on in Chapter 3 - the Methodology chapter, include the use of the grounded approach to thematic analysis which was represented in a data structure and supported with a table of representative quotes as well as a grounded model. Using these well-established approaches from the above papers, allowed me to progress through the data collection, analysis, interpretation and representation in a way that maintained trustworthiness throughout the paper (Guba & Lincoln, 1985).

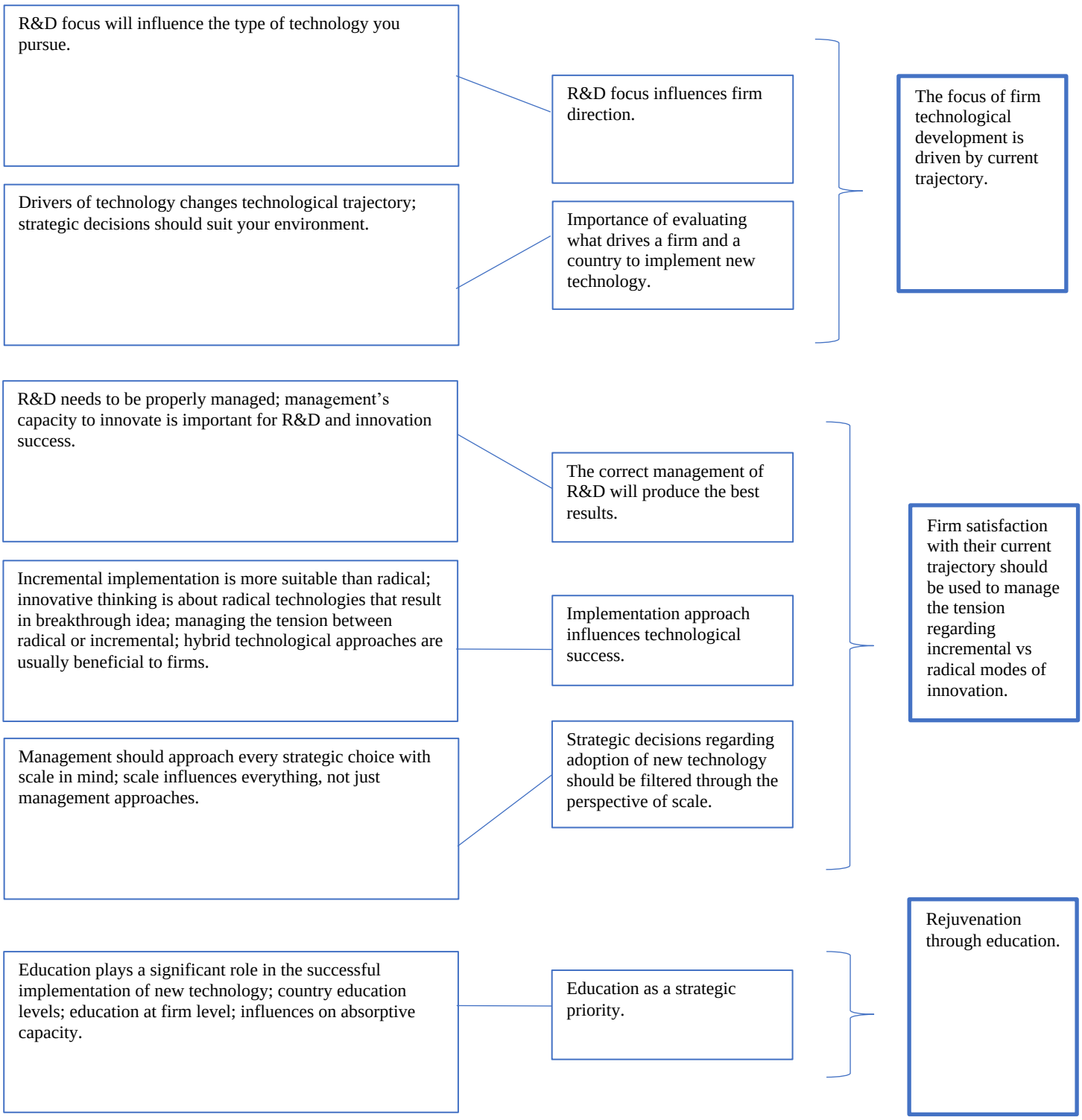
Figure 17: Data Structure

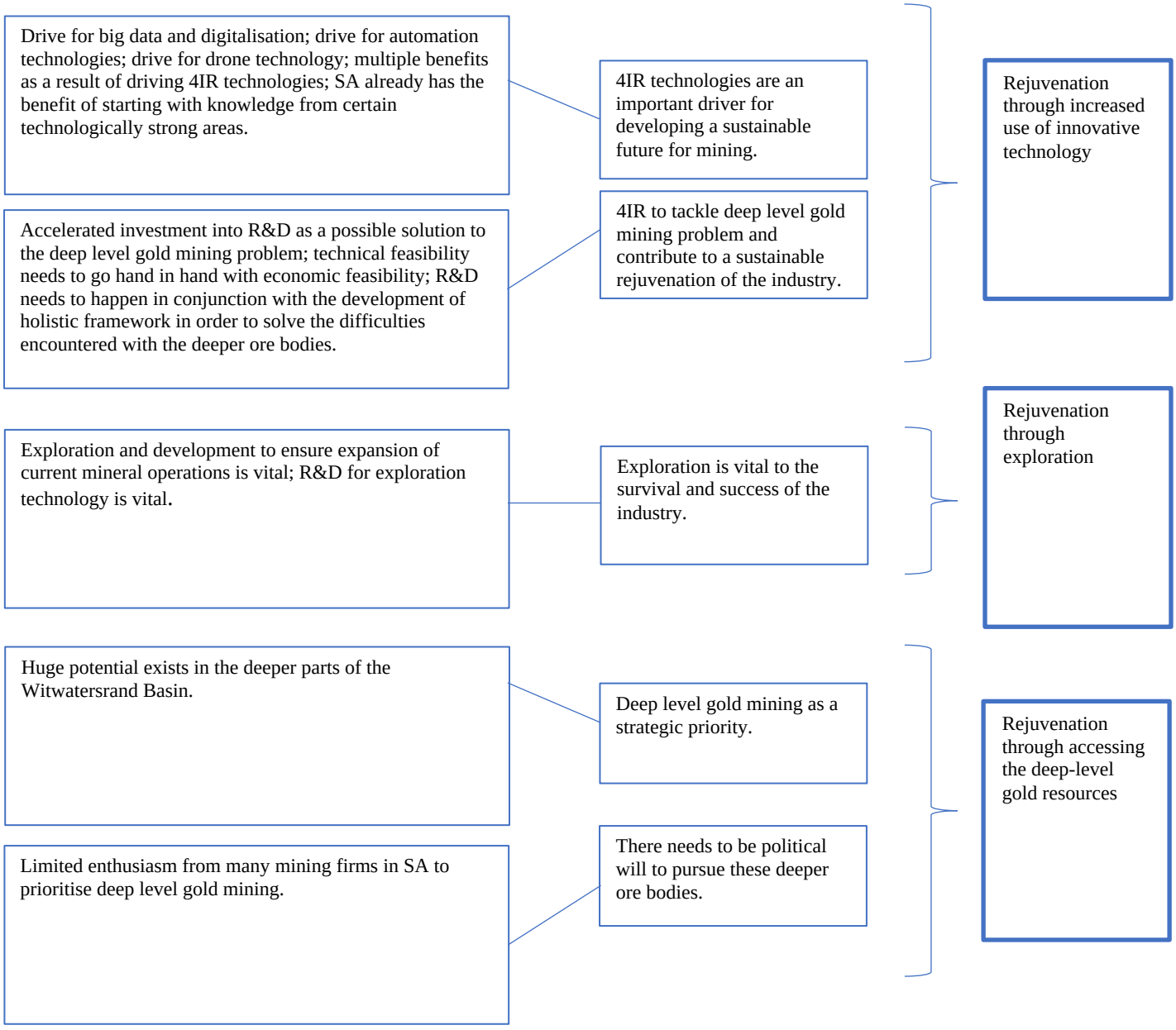



Gold mining productivity declined since resources are too deep to access; safety concerns with deep level gold mining; human involvement in deep level gold mining does not have long-term sustainability; currently no feasible technology to assist in accessing the deep ore bodies.
No current perfect approach so more research into developing this is needed; innovation approach in the gold sector may look different to other commodities.
Potential of remaining gold resources in SA could produce long-term sustainability.
Complications with deep level gold mining
New methods of mining required to rejuvenate the gold sector
Rejuvenating the gold mining sector could benefit the industry's sustainability.
Knock-on-effect of declining productivity for gold sector on entire mining industry
Long-term sustainability should be a big part of a firm and a country's strategic focus.
Productivity should be the initial lens through which all other business lenses are filtered.
People have to be a central part of the modernisation drive, but productivity still needs to govern business.
SA's future growth frontier depends on its ability to be productive.
Multiple-lenses view of productivity
SA's mining industry does not have productivity at the forefront of its priorities.
Sustainability is inherently dependent on productivity.


The correct management approach is an important part of implementation; implementation chosen is as important as the actual technology; new mines and old mines should be handled differently with technology implementation.
Technological success is dependent on the factors influencing implementation.
Culture will influence the success of technology implementation; involvement of various stakeholders, such as unions and employees, is crucial for successful technology implementation.
Causality between culture and technology success.
Much of the response to automation is governed by human behaviour aspects.
Implementing technology in a socially responsible manner; labour intensive operations in SA; SA should not be automating; they should be pushing ways to make labour intensive methods better; labour shortages in Australia drive the uptake of automation; typically technology needed to break productivity boundaries reduces dependence on labour; to better society and develop vulnerable communities, you need a thriving, productive
Labour force threatened by automation.
The co-existence of human and machine
Collaboration is imperative for successful R&D; R&D initiatives benefit from innovation ecosystems.
Causality between collaboration and innovation success
The wide-ranging nature of collaborative R&D; R&D should be right across the value chain.
Collaboration throughout the mining value chain is crucial.
Innovation through collaboration reduces the chance of an ambition and performance gap.


Government support needed for exploration and development; SA should develop robust innovation law; university and industry alignment needed to produce the right graduates for the future of mining; Australian mining industry heavily dependent on government support with exploration; R&D is a national priority in Australia.
Dwindling levels of R&D; government support for R&D hindered by social context.
Commitment to R&D must be a consistent ongoing action; appetite and resilience for R&D programmes comes through continual efforts.
Government support plays a large enabling role to achieve an innovation lead industry.
The poor state of R&D in SA
Continual commitment to R&D and tangible actions produce the best results.
Creation of an innovation ecosystem that drives technological development is a key enabler for industry wide change.
Following in the footsteps of successful innovators; opportunity for problems in SA to drive the search for innovative solutions; conditions limiting SA's leapfrog catch-up.
Playing catch up with global leaders
Correct trajectory could support a leapfrogging strategy to catch up with global leaders.
SA stuck in old patterns; correcting the inequalities of the past; complex social context
Job creation in the mining industry; job creation in other industries; huge area of uncertainty regarding the ***how*** to approach beneficiation; technology improvements, in the long run, translate to extending the life of employment that is well aligned to the mining industries' sustainability drive.
The influence of history and context on strategic objectives/trajectory
Complexities of social narrative can de-prioritise productivity gains from innovative technology.
Trajectory is governed by context.


R&D focus will influence the type of technology you pursue.
Drivers of technology changes technological trajectory; strategic decisions should suit your environment.
R&D focus influences firm direction.
Importance of evaluating what drives a firm and a country to implement new technology.
The focus of firm technological development is driven by current trajectory.
R&D needs to be properly managed; management's capacity to innovate is important for R&D and innovation success.
Incremental implementation is more suitable than radical; innovative thinking is about radical technologies that result in breakthrough idea; managing the tension between radical or incremental; hybrid technological approaches are usually beneficial to firms.
Management should approach every strategic choice with scale in mind; scale influences everything, not just management approaches.
The correct management of R&D will produce the best results.
Implementation approach influences technological success.
Strategic decisions regarding adoption of new technology should be filtered through the perspective of scale.
Firm satisfaction with their current trajectory should be used to manage the tension regarding incremental vs radical modes of innovation.
Education plays a significant role in the successful implementation of new technology; country education levels; education at firm level; influences on absorptive capacity.
Education as a strategic priority.
Rejuvenation through education.




Source: Author

Table 31: Dimensions, Themes, Categories, and Quotes

| **Aggregate Dimensions (Selective Codes)** | **Second-Order Themes (Axial Codes)**<br><br>**First-Order Categories (Open Codes)** | **Representative Quotes** |
|---|---|---|
| **Strategy development to enhance investor climate** | **1. Understanding the structural decline of SA's mining industry** | |
| | A. Poorly managed government departments | **A1.** Administrative issues in SA. **A2.** SA mining department is largely incompetent. MPRDA is drafted well (clear and concise), but the implementation of it is terrible as the process is far too long and requires too much fighting. **A3.** The DMRE is appalling; they need to improve their service to attract investors. |
| | B. Over regulation | **B1.** One of the areas that need change to be more efficient, is the South African government's regulations on how you should invest, like social labour plans in mining. **B2**. Too much regulation. ESG should be more self-regulated and less government regulated; this might produce bigger benefits, because it will no longer be about ticking the box now. **B3**. If there were fewer regulatory demands on mines, like gold mines, they may not be forced with the automate or close option. **B4**. The way the MPDRA is drafted, legislatively, the onus is on the mining companies to comply and so it becomes a tick box exercise. When you perform activities as a tick box exercise, they are limiting. |
| | C. Lack of stability | **C1.** SA needs stability in their regulatory environment. **C2**. Investing into R&D usually only shows returns within 10–15-year cycles, so an investor needs to know that the legislation is stable and won't change multiple times from when they make their investment. **C3.** Provide certainty for investors that the framework won't change. **C4.** Long-term investments require a certain amount of certainty that we don't have. |
| | D. Power supply | **D1**. SA has been saying that we can't guarantee you power, but you aren't allowed to generate your own. They are stopping any type of solution to a business problem. How does a company proceed? **D2.** Expansion through the value chain requires reliability of power supply. **D3.** A huge productivity challenge in SA is the |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| | | reliability and supply of various inputs, like electricity. **D4.** Eskom is a major issue against operating in a predictable manner. **D5.** Eskom is a big contributor to the increasingly expensive operations in SA. |
| | E. Poor investor climate | **E1.** I think the cycle is harsh – difficult context equals declining investment, but declining investment also means worsening context. I think it's best to say that the dwindling investment is coupled with incompetence, lack of education, lack of serious qualifications, poor administration of power stations, roads, dams, airports, all contributing to the decline. To fix this decline both sides of the equation need to be addressed. **E2.** You can't expect investors to have to use their own money to build plants that can generate their own power. **E3**. The SA environment (power, water, policy issues) makes it difficult for an investor to know where the country is going to be in 10 years. **E4**. The un-willingness to invest in these long-term tech initiatives is made worse by the uncertain regulatory factors. **E5.** South African government hasn't done anything to change poor image. They should have an international campaign to lift the image as much as possible. **E6.** One of the things that scare investors off are labour strikes and unrest. Changing government policies also scare investors off. This has a lot to do with the long-term nature of a mining investment. The Mining Charter, for example, is constantly changing – the third one just came out and they are probably planning the 4th already. We need to provide certainty for investors that the framework won't change. **E7.** Low levels of investment in the mining sector, the drop in FDI, is such a big deal. It affects all aspects of the industry and inhibits growth and long-term success. The mining industry is heavily reliant on FDI. You are not going to get all the capital you need internally, you will have to rely on other sources. **E8.** There are definite causal links between uncertainty and lack of investment into the industry. |
| | F. Policy instability | **F1.** SA mining policy doesn't support the industry like Australia's does. **F2.** Government policies are not very favourable for SA mining. **F3.** Many SA policies around ownership are very difficult. Little comfort around security of tenure & ownership of assets**. F4.** Infrastructure changes and policy developments needed to give people more freedom, with their own power generation for example, that will reduce uncertainty and decrease risk. **F5.** Policy changes needed for long-term |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| | | certainty. **F6.** The BEE situation, which is morally correct, is improperly applied, and hasn't been clearly enough thought through. **F7.** Government should also look at labour law and make it less onerous for employers. **F8.** Government policies create a lot of stifling, blocking and red tape. **F9.** This poor international image is because of the political system, policies, and their historical profile. **F10.** BEE policy in mining shouldn't be taken away, but they need some kind of political solution to manage it better. **F11.** BEE policy has good intentions but is not done properly. **F12.** It's not that the BEE transformation principle is a problem, it's the way that it is enforced. **F13.** New policies need to address these past injustices. |
| | G. Corruption | **G1**. The government has high levels of corruption, so they can't really push money at innovation. **G2.** Bureaucracy and corruption in institutions have made SA mining industry very difficult. **G3.** Government can make mistakes which they need to then fix. **G4.** SA does try and drive the mining industry, but fear of corruption and department difficulties hamper it. **G5.** Not policies hindering FDI, but corruption. People are concerned that what they invest will not be spent in the right way. **G6.** The number one contributor to reduced investment is far less about policy and far more about corruption. People are concerned that what they invest will not be spent in the right way. Corruption in the government has created this image that investment will be squandered on personal gains. This hinders money coming into the country. **G7.** It's the corruption in the broader Macroeconomics that hinder investment. **G8.** Not sure how to handle the question about job losses, but one thing I can say is the corruption should be reduced and this would make the problem less. The gold deposits produce so much wealth, but none of it is shared back to the community. |
| | H. Lost competitive edge | **H1**. Lost competitiveness because costs have gone up, efficiencies gone down, productivity has gone down. This means we are less efficient than other countries. **H2.** Challenges with labour and capital productivity. Partly due to lack of new investment into the mining sector, and partly due to geology. **H3**. These challenges effect commercial viability of products. Products elsewhere in the world become more attractive. **H4.** Labour costs gone up so much and performance you are getting |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| | | out of labour has dropped significantly. **H5**. Such stringent health and safety laws, and freedom of RDOs to declare their areas unsafe and have down time with their teams has increased inefficiency. **H6.** Economic issues for SA's decline, include declining ore grades, ore bodies getting deeper, escalating costs, particularly labour costs and electricity costs. **H7.** Productivity levels in SA quite low. The very labour-intensive methods effect this low productivity level. **H8.** SA haven't invested enough to keep up with the rest of the world in terms of efficiency. **H9.** We are unable to close these efficiency and competitive gaps because we don't prioritise the type of technology needed for massive productivity gains. |
| | I. Supporting structures lacking | **I1.** Infrastructure for mining is critical for success. **I2.** Logistics problems can be one of the biggest issues for mining companies to deal with. **I3**. Transnet problems causing massive financial losses to the industry. |
| | J. Militant labour force | **J1.** Very militant labour, and labour law very much in favour of the labourer. **J2.** Labour is becoming very expensive, and constantly demanding higher pay. |
| | K. Limited uptake of new technology | **K1.** Very low level of skills and lacking education in SA has prevented the uptake of new technology and caused a decline in the industry. **K2.** SA is not positioned to continue doing well because of all our constraints but also because of our lack of technology investment. If this is not addressed the deterioration of the industry will create terrible socio-economic knock-on effects. |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| | L. Declining ore bodies | **L1**. Declining industry is due to a lack of investment in finding new resources. **L2.** Declining ore bodies that previously sustained the industry have been mined out – contributing to the SA decline. **L3.** Not enough exploration and new development. **L4.** Deeper ore bodies getting expensive to mine. **L5.** The technology which could create more efficiency ultimately spirals into needing to attract more investment and doing more exploration. **L6.** All high-grade ores, close to the surface have largely been exploited. **L7.** Other regions, improvement in their mining sector is continual. Whereas, in SA our resources have just become more remote and more difficult to access, and there is not enough investment into funding new resources. **L8.** Challenges with labour and capital productivity. Partly due to lack of new investment into the mining sector, and partly due to geology. **L9.** More exploration would mean we find more good ore bodies. **L10.** One of the main reasons SA is lagging behind other countries is because we don't do enough exploration. **L11.** An issue with many of existing tech projects in other industries that the mining industry is looking to adopt, is that you need a decent amount of funding to test which technologies can be suitable where. |
| | M. Aging mines in SA | **M1.** Age of mine might inhibit ability to implement new tech. **M2.** Difficult to implement new tech with old infrastructure. **M3.** Another problem with an old mine, you can't have a fancy new tech in one place because all of the other infrastructure before and after that one new tech, won't support it. You will need new tech along the whole way. **M4.** Many underground mines don't have the infrastructure for new technology. **M5.** New technology for new mining methods difficult because of the existing infrastructure. **M6.** No physics that prevents R&D from discovering a way to go deeper, it's a commercial question about whether this can be done effectively or not? **M7.** One massive issue with automating is the existing infrastructure. **M8.** Retrofitting a mine can be quite complicated due to the existing infrastructure. |
| | **2. Analysis of key enablers creating an investor friendly climate in Australia** | |
| | A. Strong policy environment | **A1.** Australian government policies benefit international companies developing in |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| | | Australia. **A2.** Mining policies & acts in Australia are regularly updated by a government that knows the worth of the mining industry in Australia. **A3.** Mining acts in Australia are constantly updated. **A4.** Australian mining Tax is of the most favourable in the world. **A5**. Australia's R&D is highly tax efficient. **A6.** Australian tax regime is also attractive. |
| | B. Resource rich | **B1**. Australia is great because, first and foremost, it has the deposits, it has the bounty that is pretty hard to find anywhere else on the globe. **B2.** Australia is flourishing because of all the rich minerals they have. |
| | C. Technology oriented | **C1**. Australian approaches to mining, most particularly their approaches to technology are world class. **C2.** Australian mines are definitely so economical because of their technology improvements, this being a big contributor to the success of the industry. **C3.** Technology has been a big driver for Australian mining. **C4.** Technology has played a big role in the success of the Australian mining industry. It has greatly increased productivity levels. |
| | D. Supporting institutions | **D1.** Australia is a great mining destination because of the strong institutions that are there to support the mining industry**. D2.** The establishment of strong institutions which have been kept in good working order contribute to the reason why Australian is such a great mining destination. **D3.** The Australian mining industry success has a lot to do with the enabling environment. **D4.** The whole Australian environment is very conducive to mining investments. The environment is robust. There are structures in place to help you to get your license. **D5.** Australia is flourishing because of the great education system the country has. |
| | E. The mining industry is entrenched in Australian culture | **E1.** Mining is in Australian culture. Most people in Australia know that the mining law is doing them some good. **E2.** Australia has a long history of mining and funding mining so people in Australia, right down to the grassroots investors understand mining, which means the industry has a good sort of capital market to support and to provide the money for mining. **E3.** Australia has a culture that is more willing to embrace new technology than most of the African countries. |
| | F. Limited investment risk | **F1.** Australia has a good sovereign risk profile in terms of robust laws and remedies at courts. This attracts investment. **F2.** Investment profiles are incredibly important |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| | | and Australia has a good one. **F3.** Australia is very low on the world scale for corruption. **F4.** Australia has strong financial markets. |
| | G. Economies of scale have influenced the success of technology in AUS | **G1**. Australia has maxed out technology in terms of economies of scale. **G2.** Big contributing factor for the success of the Australian mining industry was understanding economies of scale. This is important for SA to understand that they can achieve too. **G3.** Technology allows you to treat bigger tonnages, so scale becomes important. |
| | H. Many SMMEs in Australian operating environment | **H1.** Most of Australia's big companies followed a single person start-up company thinking approach, using innovative ideas. **H2.** Smaller companies in Australia are the ones who innovate. **H3.** These big corporates require greenfield projects to meet shareholder requirements, because of their large overheads. This is difficult to sustain compared to smaller companies. **H4.** Another difficulty in the South African mining industry, since long ago into its history, is that it has been dominated by large companies. Australia also has big companies, but they have many small companies also. **H5.** SA needs more support for small companies in the market and not just big mega companies. **H6.** Australia has got a very strong history of supporting small companies. BHP was once a small company. **H7.** South Africa is dominated by big corporate companies, whereas Australia has a smaller more vibrant company market. **H8.** Smaller companies in the market are very agile, whereas big companies are not. **H9.** Small companies in SA are very embracive of technology. Big companies have a lot of red tape to get through before implementing technology and so they don't get as much done. **H10.** Small and big companies are very different and is a good example of how South Africa and Australia have developed such different paths. **H11.** The development of small vibrant companies in the South African mining sector hasn't happened enough along the development path. **H12.** Company culture is easier to manage in small companies. **H13.** Small companies are more willing to embrace technological change. Usually if they can see something will improve the business, they are willing to embrace it quite quickly. |
| | **3. Developing investor climate as a strategic priority** | |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| | A. Prioritising investor interest | **A1.** Investors often invest in big mining firms and not juniors. **A2.** Investors often want reliability and predictability, not necessarily massive growth. **A4.** Good for company management to focus on ESG, but this will not be the thing that attracts more investment into a company. **A4.** ESG focus is a fundamental variable for big capital markets. **A5.** Correlation between clean, healthy equipment (Good ESG) and company performance. **A6.** Generally speaking, companies that have good ESG performance, have that performance because they spend time thinking about the risks within their business, and that flows through to other areas of business as well. **A7.** And in many cases, firms that have good ESG performance are also utilising more modern technology, because they recognise that modern technology tends to have lower carbon emissions, is more energy efficient, has better productivity, and is healthier and safer. **A8.** There is a correlation, I think between the use of more modern, safer, healthier, cleaner equipment and performance. **A9.** The South African government doesn't seem to see that if they truly want to uplift our nation and fix the constraints in SA, they need to attract more investment. |
| | B. Self-regulation would create more investor friendly environments. | **B1.** Instead of creating new ESG vehicles, rather give companies the flexibility to self-regulate their ESG initiatives. **B2.** There is too much ESG regulation. ESG should be more self-regulated and less government regulated. This might produce bigger benefits, because it will no longer be about ticking the box. |
| | C. Public private partnerships can be very beneficial to the economy and firms. | **C1.** Public private partnerships have to be fair, it can't be the private sector funding the deficiencies of the public sector. **C2.** Public, private partnerships are great if you properly define what those partnerships look like (not private funding government). **C3.** Public, private partnerships have to jointly run projects with joint responsibilities, liabilities and benefits. **C4.** I think that privatising a lot of our infrastructure will help enormously with attracting investment. **C5.** Private sector should be allowed to own service providers, it shouldn't be run solely by one company **C6.** Transnet shouldn't own the whole value chain. |
| | D. Strategy to successfully develop investor climate will come from holistic viewpoint. | **D1.** New technology will work only if you look at the picture holistically. **D2.** Regulatory issues need to be tackled holistically. **D3.** You need to look at everything holistically. **D4.** More investment into R&D and innovation can help overcome the |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| | | technical issue of mining the difficult to reach ore bodies, but it obviously won't influence government or labour skills and militancy or the fact that big mining areas have been exhausted. **D5.** There needs to be a holistic effort from multiple parties. **D6.** To rejuvenate South African mining, technology will help, but you need more than that. It needs to be a holistic rejuvenation. **D7.** Such a large amount of inter-relatedness between problems in the resources industry, this is why everything needs a holistic approach. **D8.** Technology could, as a factor amongst other forces, help rejuvenate the mining industry. **D9.** Policy changes will be effective only if they are made in conjunction with other things. **D10.** Public, private sector collaborations can't be in isolation, they need to take place with other policy changes. **D11.** You can't develop technology in isolation because this will cause a multitude of socio-economic issues. **D12.** One company, one capitalist, one free market economy is not going to solve this machine vs man problem on its own. It will need to be a coordinated approach with government and state. **D13.** Can't just be the company solving the machine vs human problem, because even though a company must care about its social license, it is still fundamentally there to make a profit and also most of businesses' actions happen within a framework, and they can't necessarily change this whole framework. **D14.** A collective approach is everything. **D15.** The problems faced by the declining resources industry are just like the problems of poverty and environmental degradation – they are interconnected with market forces like capital, innovation, corruption, and bureaucracy. It needs a holistic problem-solving strategy. **D16.** SA has bigger issues then just their technology profile, they need a variety of factors to work together with the technology. |
| **Knock-on-effect of declining productivity for gold commodity on entire industry** | **4. Complications with deep level gold mining** | |
| | A. Gold mining productivity declined since resources are too deep to access | **A1.** Decline in gold has had a massive impact on the entire industry. **A2.** Despite having the largest resources in the world, the gold is too deep to access. **A3.** Getting more expensive to maintain and to mine as you go deeper. **A4.** Operating at deep |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| | | levels to access the gold, makes it more difficult to compete effectively. **A5.** The problem with going deeper is that the cost of mining just keeps rising. |
| | B. Safety concerns with deep level gold mining | **B1**. If mining firms in SA believe that they can go deeper safely with the current workforce, then they should be pushing to do it safely (this will save both lives and livelihoods). To just walk away from deeper mining is just too easy. **B2.** If you close the mine because of safety issues, then so many more lose their lives due to no food. **B3.** Australia isn't using manpower to operate underground in narrow vein stopes like South Africa which makes South Africa's technology adoption more complicated. **B4.** Deep level gold mining is difficult due to safety and the increasing cost the deeper you go. |
| | C. Human involvement in deep level gold mining does not have long-term sustainability | **C1.** Many mines around the world already operate very remotely with very little human intervention so it is possible for our deep gold mines. Human interaction at great depths will definitely be limited though. **C2.** SA has already been operating, with people, deeper than most countries. So, you've already got a head start on everyone, because you actually know how to do it pretty effectively. But we already know that there's a human limit to that. **C3.** Machines for deep level mining may make everything very efficient, such as higher returns so part of this profit can be used to create employment for lost workers. |
| | D. Currently no feasible technology that we need to assist in accessing the deep ore bodies | **D1.** Currently, the industry has never been able to automate or come up with tech to get so deep in gold mines. **D2.** We have limited innovative ways to access deep resources and this is a big problem. **D3.** In SA, there have been many strides towards mechanisation, but the automated type of technology needed to go deeper, we don't have. **D4.** More technology will help reduce the difficulties with ore bodies in difficult to reach places, but there will always be ceilings that you can't breach. Current ceilings may be breached in the future, but currently we don't have the technology to breach them. **D5.** The many technical challenges that come with operating technology at depths have prevented further research into this area, if we continue actively pursuing this search, we could find the right solution. **D6.** South Africa should be prioritising the search for as many technical ways as possible to access the remaining deep resources. |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| | **5. New methods of mining required to rejuvenate the gold sector** | |
| | A. No current perfect approach – more research into developing this is needed | **A1.** Physical challenges, such as depth; difficult geology; narrow reefs; ventilation problems; heat problems and visibility problems inhibit the success of current labour-intensive methods, but also reduce the viability of current technology so we need more research into new advanced methods of accessing these deeper ore bodies. **A2.** Difficult to apply new technology to the geology of the South African ore bodies. Particularly in gold and platinum mines so we need a more innovative solution. **A3.** Is it perhaps that we aren't tailoring the tech we have well enough to our specific problems, to form a new method of mining? **A4.** I know with the deep mines in SA, it's getting to the point where it's, it's just getting too hard to send humans down, it's getting to the point where you've got to basically come up with a brand-new mining mode. But on the other hand, you've got this social contract and social licence, where you've got to employ people. **A5**. In order to achieve productivity that is sustainable, the sector requires a great deal of research to review mine planning, design. |
| | B. Innovation approach in the gold sector may look different to other commodities | **B1.** Maybe it's good enough to be mechanising or modernising in the platinum or the coal sector, but perhaps because of the depths of many of SA's gold mines, it needs full on automation to remove the people right out of these depths. **B2.** Different commodities should have varying levels of tech and varying levels of implementation. **B3.** Auxiliary automation still with humans at the center could be an option for other commodities and fully autonomous with robots underground can be for gold. **B4.** Perhaps we should tailor a "hybrid approach" that might involve mainly gold being automated to reduce those costs, access deeper resources and increase safety; and the other commodities following a more incremental approach to improving and becoming more efficient. |
| | **6. Rejuvenating the gold mining sector could benefit the industry's sustainability** | |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| | A. Potential of remaining gold resources in SA could produce long-term sustainability | **A1.** Perhaps gold is the main reason for the drastic decline and not necessarily the industry as a whole. Accessing the remaining gold could reverse this problem. **A2.** Without gold productivity increasing then we won't be one of the leaders again. **A3.** Many of the remaining gold mines still have substantial mineral resources that could support the industry for many years into the future, and additionally play a material role in the inland revenue of SA and the development of local economies. |
| **Sustainability is inherently dependant on productivity** | **7. SA's future growth frontier depends on its ability to be productive** | |
| | A. Long-term sustainability should be a big part of a firm and a country's strategic focus | **A1.** Only looking at short-term gains is suicidal and not at all sustainable. Only focusing on the now, means absolutely no future. **A2.** Mining industry is not self-sustainable, ore bodies have a limited life span, finding new ore bodies or developing technology to extend the life of current ore bodies is sustainable thinking. **A3.** Mining industry is not self-sustainable: ore bodies have a limited life span, and without extensive use of innovative technology this limited lifespan cannot be increased. **A4.** SA is not as well explored as Australia is, there is a lot of opportunity for future growth. **A5.** SA is more under explored than Australia, more future opportunity for another big boom and a new growth frontier. **A6** Increasing the length of the life of mine through advanced technologies to increase productivity should be massive sustainability focus. **A7**. You may come up with a technological model that works for deep-level gold mining and can remove people from harm and increase productivity, but you're actually not helping the society because you're not employing the people, or as many people as previously employed within the mine. And that's where I think the mining industry in SA has to jump over that hurdle. This hurdle should not only think about the jobs of now, but also think about the sustainability of the future of the mine. **A8.** Without productivity, all sustainability efforts would eventually become null and void. **A9.** In the long run, productivity increases would be one of the number one contributing factors to stability and sustainability in job retention. **A10**. Without extensive use of innovative technology to ensure productivity, mining has a limited lifespan that cannot be increased. |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| | **8. Multiple lenses view of productivity** | |
| | A. Productivity should be the initial lens through which all other business lenses are filtered | **A1.** Companies should achieve productivity, and then ensure that they are sustainable while doing this. **A2.** A company must understand that they need to be productive if they are truly going to develop their human capacity and the community. **A3**. Important to understand that productivity and worker safety are not mutually exclusive. You can prioritise technological developments that ensure a productive work environment and then make sure that all of these are promoting worker safety. **A4.** Lots that can be done, and is already being done around safety and technology, and this is great, but surely there could be a way that this technology for safety can somehow have a dual purpose, of safety and productivity gains? **A5.** If productivity and efficiency are not prioritised, workers soon won't have any jobs. Shouldn't they go hand in hand – maintaining a strong focus on safety, but not just disregarding productivity. **A6.** Important that companies protect their social license to operate, whilst they are making decisions to prioritise technology that increases productivity. |
| | **9. South African mining industry does not have productivity at the forefront of its priorities** | |
| | A. People have to be a central part of the modernisation drive, but productivity still needs to govern business | **A1**. Our context perhaps dampens productivity because it is ideologically frowned upon. **A2.** Everything that will benefit the human element of the workforce happens through productivity, even the generation of human knowledge happens through productivity. **A5.** Recently there has been an increase in funding for R&D but mainly for worker safety/fatality purposes. This is incredibly important, but if there seems to be limited focus into increasing efficiency and productivity. **A6.** As you grow the mines, you employ more people. They will be more productive, but they'll have a different skill set. Technology will equal productivity growth, which will allow mines to find a new way of obtaining their social license. **A6.** Should think about cost, linked to productivity, being a driver of mining, and consider how innovation/technology can be implemented to reduce cost – I don't think SA focuses on this as much as it could. |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| **Much of automation/4IR response is governed by human behaviour aspects** | **10. Technological success is dependent on the factors influencing implementation** | |
| | A. Correct management approach is an important part of implementation | **A1.** Technology will need new management systems. **A2.** Success of implementing new technology is dependent on management's capacity to innovate or to use the new technologies and innovations. **A3.** Change management is necessary when you are implementing tech. **A4.** Change management is crucial at all levels of management, not just lower levels. **A5.** Drivers of change at senior level are very important – they set the level of what kind of technological culture is to be embraced. **A6.** Mid to senior operational level should develop a culture that rewards responsible risk taking, even if this is not successful. This method makes sure change is implemented. **A7.** New ways of managing systems and people are just as important as the actual technological innovation. **A8.** The more familiar people are with something, the more willing they are to try it. **A9.** If someone is forced to do something that they don't understand they will push back against this, this needs to be approached correctly by management. **A10.** You can't halt your whole production to adopt new technologies – you would have to develop some kind of system where you implement one while still using the other to make sure production doesn't stop – this will be a tricky management task. **A11.** With the rapid nature of changing modern technology, mine managers need to learn to dance on a moving rug. **A12.** Management should learn how different people react to different types of situations. **A13.** When managing your implementation of technology, the social license needs to be the centre of everything you do. **A14.** You could have the best technology but if you don't manage and train your people, the technology will just be sitting there. |
| | B. Implementation chosen is as important as the actual technology | **B1**. Technology can be amazing, but the implementation approach followed is crucial. **B2.** Implementation needs to be right at each stage of the value chain. **B3.** Excellent technology can be incorrectly applied. **B4.** Not just about implementation |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
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| | | of technology, but also integration. **B5.** The implementation of the technology is very important. |
| | C. New mines and old mines should be handled differently with technology implementation | **C1.** New mines should start off all autonomous. **C2.** Should use hybrid approaches to implementing new tech into old mines. New mines can more easily build in radical changes. **C3.** Designing a new mine around automation might work, but not in an old mine. **C4.** New mines at start-up have flexibility about what they do in relation to new tech - but old mines don't have this flexibility. **C5.** New mines can easily deploy new tech. **C6.** New mines can quite easily swap to autonomous. **C7.** Not just about implementation of technology, but also integration. **C8.** The only time it would be radical is if it is a whole new mining operation with a completely new design. |
| | **11. Causality between culture and technology success** | |
| | A. Culture will influence the success of technology implementation | **A1.** Successful implementation of technology is very dependent on the organisation's culture and the willingness of the labour force to adopt it. **A2.** Company culture is incredibly important for the success of new technologies. **A3.** Culture is driven at several levels. **A4.** Employee buy-in is necessary for new technology. **A5.** Often get a lot of resistance in the middle level; this is where building a culture that rewards risk taking can be useful. **A6.** Reduce labour resistance by creating culture around mining processes and mining industry. **A7.** Culture change must be considered at all three different levels, and really driven. **A8.** A culture that is willing to embrace technology is driven by education and communication. |
| | B. Involvement of various stakeholders, such as unions and employees, is crucial for successful technology implementation | **B1.** Bringing unions along with you is so important for the success of new technology. **B2.** Employee involvement in choosing the right technology will make the implementation easier. **B3.** In SA's case the digitisation will be slower, more gradual process that's thought out and planned in consultation with the labour force. **B4.** Labour unions in Australia have in some sense actually driven the increased uptake of technology, because they have made labour so expensive. **B5.** To manage the tensions between needing technology, but protecting the social interest should be |

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| | | dealt with by creating a mutual understanding with the unions. **B6.** Communication with the community about technology is important. |
| **The co-existence of human and machine** | **12. Labour force threatened by automation** | |
| | A. Implementing technology in a socially responsible manner | **A1.** Implementing technology in a socially responsible manner can be achieved through ensuring education and awareness. **A2.** Should use scale to manage the tension between needing technology and implementing it in a socially responsible manner. |
| | B. Labour intensive operations in SA | **B1.** SA is built on manual labour, that is where the focus should stay. Employ double the people to get more productive (even if it is at a slightly lower profit number). **B2.** Big difference for the ease of technology adoption in Australia compared to SA, is the lack of thousands of men depending on the mine to generate employment for them. **B4.** Automation is great for safety, since fewer people are underground, and productivity, but the job losses it causes is an issue in developing countries. **B5.** Job losses is a contextual constraint that will hold a country back from automation adoption. **B6.** Big problem around the fact that you can't just remove people and put technology in. **B7.** The industry/country should follow a diversified approach about how to create jobs. **B8.** Without new technology, the mines will close, if the mines close there will be an even bigger unemployment problem then if some workers lost their jobs due to technology. **B9.** You will need fewer people once technology is fully implemented, creating resistance. **B10.** Imperative to think about SA's context before anything else. This means we need to think of the unemployment problem before we think about getting smart automation. **B11.** SA hasn't moved away from their labour-intensive methods of the past. **B12.** Local community won't allow an operation with no employment. **B13.** Our cheap and abundant labour force means we have had no need to drive technology, where other countries like Australia who have a labour shortage and expensive labour structures had a need to constantly drive technology. **B14.** Another reason that there will be resistance from SA labour intensive workforce is because of the number of livelihoods that are dependent on the mining industry. This will cause a lot of social unrest. **B15**. SA's mining industry was built on a labour-intensive framework that |

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| | | included practices that were not okay. Working conditions, safety and worker payment are all examples of this, and they have underpinned things for a long time. **B16.** In the absence of these harsh labour conditions, SA has never been able to catch up. **B17.** South African gold mining needs to move away from labour intensive mining methods, but I think they are well aware of this, and I think that they are trying to move away from this. **B18.** SA never progressed their mining methods over time. |
| | C. SA should not be automating, they should be pushing ways to make labour intensive methods better | **C1.** I actually think that unions and government don't understand that we should actually be pushing labour intensive mining, simply to create jobs. **C2.** Other countries with labour shortages and little unemployment want to automate, that shouldn't be the focus for SA. **C3.** Perhaps the South African context makes it a different situation and maybe automation isn't the answer. **C4.** SA's high unemployment affects their ability to automate. **C5.** SA should drive digitisation and focus on safety areas for labour force. **C6.** Personally, I don't think that the objective of technology, specifically in South African operations, should necessarily be around replacing people. **C7.** The reality is we are sitting in a country with 35% unemployment, should our real drive be trying to automate and replace lots of people, I'm not 100% sure that is the right solution right now. **C8.** We are not going to have a complete shift away from labour intensive methods. **C9.** All three forms, labour, mechanised mining, and automation will all progress together. These different forms should coexist in SA. |
| | D. Labuor shortages in Australia drive the uptake of automation | **D1.** Australia can't be labour intensive as they have labour shortages, so machines and automation are good. SA should be the complete opposite. **D2.** Australia's context is a better place to automate because their operating models are less labour intensive. And the labour force tends to be on a level of education and expectation that lends itself to embracing technology. |
| | E. Typically, the technology needed to break current productivity boundaries reduces dependence on labour | **E1.** Technology and automation have played a big role in the success of the Australian mining industry. It has greatly increased their ability to be productive. **E2.** Automation lowers your costs and allows you to access more difficult to reach lower grade resources and still make a profit. The productivity is higher by doing it |

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| | | that way. **E3.** In Australia, we are finding that our operating costs are lower, and productivity is higher, because the machines are running at the same level all the time. And therefore, we are having fewer breakdowns and safer environments. Fewer people, fewer breakdowns, less fatality, more productivity. So, the technology is great, and it's reducing our reliance on labour. **E4.** Because of the depths of many of SA's gold mines, it needs full-on automation to remove the people right out of such depths. |
| | F. To better society and develop vulnerable communities, you need a thriving, productive economy | **F1.** Declining productivity and stagnated growth will inherently affect the well-being of the workforce. **F2.** Understandably, implementing certain types of smart technology and automation required for certain commodities might reduce dependence on labour, but these productivity gains will flow back into the growing economy and create an environment that can reabsorb lost jobs. |
| **Innovation through collaboration reduces the chance of an ambition and performance gap** | **13. Causality between collaboration and innovation success** | |
| | A. Collaboration is imperative for successful R&D | **A1.** Co-partnerships and collaborations are key to getting more money out of R&D. **A2.** It is a company's responsibility to do R&D and get lots of partners doing it with them. **A3.** Important to look outside of the industry you are in for new innovations. **A4.** Easier to get R&D funding from a group of players and not just one specific person. **A5.** R&D should be done both in-house, outsourced, and through partnerships. **A6.** Mining industry can piggyback on some of those technologies from other industries and modify them for our use. **A7.** Research initiatives are sometimes duplicated that were done in the past, because of poor communication and transparency in the industry. **A8.** I don't think the quality of the research is influenced by whether it is conducted in house or if it is outsourced. |
| | B. R&D initiatives benefit from innovation ecosystems | **B1.** Get a circle of R&D going, an innovation ecosystem is so important. **B2.** Public funded R&D must be done at different institutions for different parts of the mining value chain. These institutions together should build an environment that supports |

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| | | innovation. **B3.** Other places in the world generally overcome challenges better than we do in SA. We don't have an environment that supports problem solving and innovative thinking like other countries do. |
| | **14. Collaboration throughout the mining value chain is crucial** | |
| | A. The wide-ranging nature of collaborative R&D | **A1.** R&D that is vital is R&D that is across the board; collaboration eases this process. **A2.** Fundamental research is important, because you don't know what is going to work in a particular area. **A3.** Targeted research and general research are both very necessary. **A4.** It is not just fundamental research that is important, but applied research as well. **A5.** Cross industry innovation is particularly useful in the exploration industry. **A6.** It is important to look outside of the industry you are in for new innovations. **A7.** Technology development needs to be very diverse because of the different needs of all the commodities. |
| | B. R&D should be right across the value chain | **B1.** You need a full chain of R&D. You need fundamental, key middle portion (applied R&D), and then the implementation of that, which comes back to the end user. **B2.** Middle link in SA R&D chain is fickle and doesn't bring the R&D and the actual application of the R&D together. **B3.** Creating more effective R&D value chains between big and small companies in the mining industry is important. **B4.** Important to have a translator or intermediary in between big and small organisations, conducting R&D. **B5.** Good R&D programmes think carefully about what should be in-housed, what outsourced. These together form a comprehensive innovation strategy. **B6.** The whole mining value chain needs to embrace 4th industrial revolution technologies. **B7.** Mining firms in Australia are innovatively focused at each stage of mining. **B8.** SA public funded R&D can sometime be too concentrated in one part of the mining value chain. |
| **Creation of an innovation ecosystem, that drives technological development, is a key** | **15. Government support plays a large enabling role to achieve an innovation lead industry** | |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
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| **enabler for industry wide change** | | |
| | A. Government support needed for exploration and development | **A1.** Many of our Australian discoveries are from government grant money for exploration projects. **A2.** Cannot expect exploration companies to go out and do base level geologic mapping, because that's not their job; they need support from the government. **A3.** Exploration findings must be properly stored in a data base, may not be useful for you but may be useful in the future. This will build exploration knowledge for others. **A4**. SA government policies don't fund innovative exploration ideas, like the Australian government does. **A5.** Incentives for exploration in SA don't need to be financial incentives they can be the absence of red tape. **A6.** Attracting more investment in exploration would require the government to streamline their processes for licensing and permitting and getting prospecting rights and all the issues and the red tape that is around that. **A7.** General research environment in SA is lacking. Government needs to make sure that universities are the leading centres of research. **A8.** In Australia, the government and universities work together to promote R&D initiatives, not always the case in SA. **A9.** R&D success has a lot to do with funding availability. **A10.** SA should have better remuneration for people working in university research centres to promote more people working in R&D. |
| | B. SA should develop robust innovation law | **B1**. All laws should empower businesses to be more innovative. **B2.** Government should empower innovation through legislation, tax concessions and government grants. |
| | C. University and industry alignment is needed to produce suitable graduates for the future of mining | **C1.** Advanced programmes at the university for mining graduates is necessary. **C2.** A key aspect to any, any long-term research initiative is the combination of university, industry, and end users. **C3.** Needs of the industry and outputs of the universities can be better aligned. **C4.** No coordination between universities and industry regarding the type of research needed. There is no central coordinating mechanism. **C5.** SA has experienced a knowledge drain problem where highly educated people move to other countries. **C6.** SA government should donate more to university research funding. |

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| | D. Australian mining industry is heavily dependent on government support for exploration | **D1.** Exploration policy makes the exploration process easier which results in more Australians doing it. **D2.** In most states in Australia, if you've got an innovative exploration idea, you can get the government to co-fund half of a drilling program. |
| | E. R&D is a national priority in Australia | **E1.** R&D in Australia is a national priority because of the importance of minerals to the Australian economy. R&D is absolutely vital. **E4.** The Australian government also give a lot of R&D and exploration tax breaks. This is something which SA should consider as a strategic priority. **E5.** There is a proactive strategy in Australia, where the government actually provides some sort of incentives to the mining industry to embark on technology and R&D. |
| | **16. The poor state of R&D in SA** | |
| | A. Dwindling levels of R&D | **A1.** Difficulty with R&D investments in the length you wait before a return, often a 10-year cycle. This long waiting period also means policy should change a lot in SA during this time. **A2.** Attention on the middle link between the university research and the outputs the industry is looking for has been lacking in SA and is very important to ensure successful R&D. Wits' Digi mine is a good example. **A3.** Funding for the middle R&D link had dried up, it is slowly being implemented again now, but was a fundamental gap lost. **A4.** SA should promote R&D by showing the short-term benefits of it; this will decrease resistance to it. **A5.** The lack or return from R&D can create hesitancy, and companies often prefer someone else to develop it and if it works then they will use it. **A6**. In order for the private sector to feel comfortable enough to throw lots of money into R&D, they need to know that there is political stability and unchanging laws for long enough time periods that their investment is stable. SA doesn't have this. **A7.** This lack of investment extends further than just the industry itself, and moves into sectors directly linked to the industry, such as the R&D sector. The unwillingness and reluctance of individuals to invest into long-term R&D and tech initiatives is made far worse by the uncertain regulatory factors that exist in SA. **A8.** Past operations have worked well and there hasn't been a strong business imperative to develop new technology. The consequence of this is a lack of investment into R&D and tech development, which means today we don't have the right tech that we need because there was no incentive to invest in new tech. |

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| | B. Government support of R&D is hindered by social context | **B1.** Government should spend money on R&D because it is a driver of economic growth, but should they be spending more in light of our social context? I really don't know it's a very complex question. **B2.** A government in a country with many social problems has many more problems to deal with than investing in innovation. |
| | **17. Continual commitment to R&D and tangible actions produce the best results** | |
| | A. Commitment to R&D must be a consistent, ongoing action | **A1.** You have to continually invest in R&D throughout the whole cycle to really know what is out there and get any good technological development. **A2.** You must see R&D as something that constantly changes, and so constantly needs development. **A3.** A lot of short-term R&D strategies don't yield fruit, so the longer you are involved in them the higher the likelihood of one of them providing a solution. **A4.** Australia is reaping rewards from billions of dollars of exports from money which they have spent on R&D over the decades. They have had a consistent and long-term commitment to R&D. **A5.** Often by the time the investment starts, you already need the answer tomorrow, so it's too late. This is why you need to be constantly investing. **A6.** R&D investment won't solve problems immediately, but often it needs long-term, on-going work. **A7.** There must be a certain mind-set that constantly looks at the appropriateness of new technologies, innovation, and management advances all the time, at every scale of the business. **A8.** Why is it that even though SA committed to R&D, they are still behind Australia? The difference is that you can be committed and still not take the right action. |
| | B. Appetite and resilience for R&D programmes comes through continual efforts | **C1.** Australia has the ability to invest in risky activities, which is the nature of innovation. This is because over the years they have constantly developed a big appetite and resilience for those kinds of programs. **C3.** Government incentives to pursue innovation create a culture that praises risk taking. |
| **Correct trajectory could support a leapfrogging strategy** | **18. Playing catch up with global leaders** | |

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| **to catch up with global leaders** | | |
| | A. Following in the footsteps of successful innovators | **A1.** No one really wants to embrace technology first. They want someone else to blow up first and then look at the problems and then adopt it. It's a big rush called the first to be second. **A2.** As a country, we need to look where the world is going, and move in the same direction. |
| | B. Opportunity for problems in SA to drive the search for innovative solutions | **B1.** SA contextual problems could spur on technology if viewed correctly: depth, technical barriers, physical barriers are drivers of technological change or innovation. **B2.** Physical and political constraints can actually drive SA to be more innovative. **B3.** SA, if approaching problems in the correct mind-set, may actually be more willing to be innovative than other places as a way to tackle their problems. |
| | C. Conditions limiting SA's leapfrog catch-up | **C1**. In the absence of harsh labour conditions, SA has never been able to catch up. **C2.** There appears to be a limited will in SA to actively search for the type of technology that will enable rejuvenation of the deeper gold resources in the Wits basin. Nobody wants to spend money to be the guinea pigs seeing if the technology will even work at such great depths. |
| **Trajectory is governed by context** | **19. The influence of history and context on strategic objectives/trajectory** | |
| | A. SA is stuck in old patterns | **A1.** SA has been using conventional ways of mining for years; they are stuck in this pattern. **A2.** Historically people just don't want to embrace technology, they just don't want to change. **A3.** Not easy to change methods of the past. **A4.** Not only workers, also management that doesn't want to change. **A5.** Some resistance to change is based on valid reasons, some is just because we have done it like this forever, so we don't want to change. **A6.** Opposed to change because it has been this way for so long. **A7.** The issue is around education, familiarity, and familiarisation with the technology benefits. Because I think that as people recognise that there are benefits to be derived from the use of technology, they demand it themselves, they won't be resistant to change. **A8.** SA has a very poor culture of adapting and wanting to employ new or look at new technology. **A9.** We have to try and get onto |

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| | | the automation trend, even at depth. If we don't and we keep labour intensive methods that deep, we will be uneconomical, thus having an even greater effect on the social inequalities that exist. **A10.** The problem basically stems from path dependency; SA was very happy with using labour, Australia was always short of labour. So, SA was never incentivised to innovate but Australia was. Now the cheap labour model can't work as the ore bodies are getting too deep, so SA now needs innovative technology, and they don't have it. |
| | B. Correcting the inequalities of the past | **B1**. SA has a big strategic focus to train the previously disadvantaged. **B2.** SA needs a big portion of its focus on addressing issues of the past. **B3.** Imperative to redress the historical inequalities. **B4.** SA has to deal with legacy issues of the past of building this industry on cheap labour, but that is a government issue not a company issue. **B5.** History will influence your current decision making. **B6.** Mining methods brought in need to regulate and address social injustices of the past. **B7.** Land redistribution can be detrimental to the industry, it needs to be done equitably. **B8.** SA is where it is today based on its past; the past influences its present. **B9.** A lot of terrible aspects from the Apartheid era are still coming out. **B10.** The South African mining industry was built on a labour-intensive framework that included practices that were not okay. Working conditions, safety and worker payment are all examples of this, and they have underpinned things for a long time. |
| | C. Complex social context | **C1.** You can't overlook our social problems when contemplating the kind of investment SA should be making into R&D. **C2.** Old mining policy did not address the social imperatives in SA. New mining policy needs to have its primary focus on the social context of SA, not on introducing new technology. **C3.** SA mining was built on labour because it was cheap, but that world doesn't exist anymore. **C4.** The challenge with introducing technology, will be the social license to operate. **C5.** You can't open a mine and not employ the local people. **C6.** We are physically constrained by our social problems. This is the reality we have to deal with; we can't approach things like other first world countries do. **C7.** Leaders of companies should appoint proper community managers who are tasked with community engagement. Proper social performance teams should be a priority. **C8.** Automation causing many job losses is something all developing countries face. This is a |

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| | | contextual constraint that can't be ignored; a solution needs to be developed for it. |
| | **20. Complexities of social narrative can de-prioritise productivity gains from innovative technology** | |
| | A. Job creation in the mining industry | **A1.** The mining industry should focus a lot of attention on upskilling programmes. Adequate training will ensure that employees are able to transition into new jobs. **A2.** Management should be planning ahead to absorb for job losses. They should have good redundancy policies in place. **A3.** To deal with job losses, there should be significant digital upskilling efforts. |
| | B. Job creation in other industries | **B1**. Suppliers must be involved in setting up servicing stations for local people to be employed, it must not only be up to the mining firms to absorb lost jobs. **B2.** You must create jobs in the service industry. **B3.** In addition to upskilling in the industry, the mines also need to be educating people in totally new skills, not for the mining industry. Employees can then look for employment opportunities in other industries. **B4.** The mining industry should train people up and create new jobs to absorb lost jobs; a good avenue to do this in is the green energy field, as the industry moves towards decarbonisation. |
| | C. Huge area of uncertainty regarding the ***how*** to approach beneficiation | **C1.** Real challenge lies in how to upskill people to do the new and better jobs that will come from technology. **C2.** Jobs from the future mine are for highly skilled and semi-skilled people not low skilled people. **C3.** People with low skills are not going to be able to do the new jobs. **C4.** A literate person is much easier to upskill or reskill to fill a new position; low levels of education are a big problem for upskilling the South African workforce. **C5.** The upskilling plan that is followed will be dependent on the type of technology that is being introduced. **C6.** You will always need people, even technology will need people; the problem is that the technology may not need the same people as before. **C7.** The difficulty with the idea of technology creating growth and new jobs, is that you will need a certain level of skill and education to do that job. **C8.** The balance between putting in new machines and protecting jobs is a very difficult one that I don't know how to solve. |

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| | D. Technology improvements, in the long-run, translate to extending the life of employment which is well aligned to the mining industries' sustainability drive | **D1.** Tech won't take 1000 jobs of current workers. The tech that does come out will just mean not replacing old labourers (natural attrition). Also, productivity gains mean accessing new ore bodies which will in any case extend the life of employment. |
| **The focus of firm technological development is driven by current trajectory** | **21. R&D focus influences firm direction** | |
| | A. R&D focus will influence the type of technology you pursue | **B1**. Health and safety have been the focus of the industry for 20-30 years. **B2.** Many mine health and safety technologies brought in recently. **B3.** Mechanising and automating at depth need to happen to take people out of the risk areas. **B4.** Must understand the current challenges in SA, when choosing new technology. **B5.** Recently there has been an increase in funding for R&D in SA but mainly for worker safety and fatality purposes **B6.** The focus of the R&D your company pursues will largely determine the direction the firm moves in. **B7.** Where is our mining industry focusing its efforts with innovation? The right focus is very important to obtain the desired outcome. **B8.** Critical to decide where SA should be focusing their investments in mining technology. **B9.** Different firm evolutionary paths are influenced by the type of investment made. **B10.** The focus of the R&D your company pursues will largely determine the direction the firm moves in. **B12.** R&D is definitely important as long as it is focused on technology that is implementable in our type of environment. |
| | **22. Importance of evaluating what drives a firm and a country to implement new technology** | |
| | A. Driver of technology changes technological trajectory | **A1.** One of the drivers for why we want technology is because it simplifies our lives and makes working safer. **A2.** Climate change related issues ae being tackled with new technology. **A3.** Innovation and price drive the search for a mineral. **A4.** If you |

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| | | cannot control someone's safety, you shouldn't carry on mining. **A5.** Innovation drives the cost of production. **A6.** Must consider your driver of why you are putting in more technology. **A7.** Must understand the current challenges in SA, when choosing the new technology. **A8.** Need to always be looking for how things can change, this pursuit of change should drive adoption of technology. **A9.** People-free mining activities drives automation in Australia. **A10.** Big technology driver in Australia is improving productivity. **A11.** A developing country would need to have people as its focus and take this into account for all decisions. **A12.** Every strategic choice should go through the filters: How can I extend the life of mine? How can I make it more profitable? How can I make it safer? **A13.** Australia has worked to run every single penny out of operating costs that they possibly can with a huge focus on productivity and efficiency. |
| | B. Strategic decisions should suit your environment | **D1.** Your technology development must accommodate and be suited to the environment you are operating in. **D2.** Companies should all have well thought out technology roadmaps that are well fitted to their environment. |
| **Firm satisfaction with their current trajectory should be used to manage the tension regarding incremental vs radical modes of innovation** | **23. The correct management of R&D will produce the best results** | |
| | A. R&D needs to be properly managed | **A1.** If you don't manage R&D and focus it well, it is a wasted expense. **A2.** Unfortunately, we have way too many examples of R&D being mismanaged and not focused well enough on their business needs. **A3.** Is the question of management more about managing what technology to invest into, with a suitable approach be it either incremental/radical/or hybrid to match the technology, and then managing the social interaction with this new tech that is needed for the sustainability of the industry? |

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| | B. Management's capacity to innovate is important for R&D and innovation success | **B1.** The usefulness of new technologies in deep level mines will depend on management's capacity to innovate and use new technologies. **B3.** This is like the threshold level of technological understanding and capability that needs to be in the management team, for them to be able to take it forward. |
| | **24. Implementation approach influences technological success** | |
| | A. Incremental implementation is more suitable than radical | **A1.** Sceptical about one breakthrough technology, rather small improvements. **A2.** Introduce small amounts of technology to make little improvements. **A3.** Existing infrastructure won't allow for radical change. **A4.** New technology would certainly help SA become more efficient again but, because of existing infrastructure, radically changing everything would be difficult. **A5.** Technology should be implemented incrementally with a good strategy. **A6.** Because the cost of failure is so high, innovation is a step change, but technological creep is actually what you really want. **A7.** It's in human nature to do things more incrementally. **A8.** Practically, the incremental option could be useful especially in the mining industry. **A9.** We normally lag behind technology. So, the incremental approach could be an advantage. |
| | B. Innovative thinking is about radical technologies that result in breakthrough ideas | **B1.** People think too small with innovation and technology. I believe that we will see people get to underwater goldmines in the next 15 years. **B2.** Knowledge gained through experimenting and trying new things needs a radical thinker. **B3.** Minerals make such a high contribution to GDP, so your R&D should be focused on massive operational improvements & technological breakthroughs to sustain this GDP contribution. **B4.** People always think of R&D on a small scale, but if we can put people on the moon why can't we think of bigger innovations for the gold mining sector, like building an underground city that simulates real life and workers live there for three weeks and then one week on land. **B5.** I think if you look back to the massive strides we have made in mining technology since the 80s and the great work that has come out of R&D since then, there is great hope for its impact in the future. **B6.** At one point in time, SA was the world leader at developing the ground- |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| | | breaking technology that was coming out of R&D. **B7.** New technology is looking at working in underwater and great depth places. **B8.** The underground mine in Sweden where there are no people, is also possible in SA. **B9.** I see a day when you will be able to mine the reefs in Johannesburg using sub aqueous underwater machinery without people. **B10.** You know, for me, innovation is not an incremental change. Innovation is something that is step change, it's a big change. **B11.** Technology should be radical if it is to make any difference. **B12.** Incremental takes too much time thinking about how something should be done, it should be radical if you want real change. **B13.** If you really want to make a change, you want to have huge leads, then you have to go radical. **B14.** Innovations from other industries can be useful to provide step changes to the mining industry, which is what is needed for a turn around. **B15.** When something requires a big change, and it has a massive stretch goal component then no amount of incremental change is going to get you where you want to be. Instead, you need to fundamentally rethink how this is going to work. It is this real re-imagining of what we are doing that drives real radical innovation and not just a step forward. **B16.** For growth, your aspirational goals shouldn't be about how do we just make small improvements and take a few steps forward, it should instead should really be about how we shift our entire operating model. |
| | C. Managing the tension between radical or incremental | **C1.** The radical vs incremental choice should be influenced by whether the current operating model is working or not. **C2.** The choice should be influenced by the specific commodity and wants of the company. **C3.** Radical or incremental is influenced by scale: are you innovating because you are desperate or empowered? |
| | D. Hybrid technological approaches are usually beneficial to firms | **D1.** SA technological path will be more of a hybrid one. **D2.** Even within one operation you can have different technology profiles. **D3.** You will need to use hybrid approaches in operations. **D4.** Should use hybrid approaches to implementing new technology into old mines. **D5.** Adoption of technology should be both radical and incremental. **D7.** Good to start incrementally to improve things and train your workforce while doing this and then when the work force is ready and the technology is cost effective, then you go as radical as you can. **D8.** The best would |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| | | be implementing different solutions in between both incremental and radical. **D9.** If you are too slow, you miss out on opportunities. If you are too fast, people become scared. This balance needs to be properly managed. |
| | **25. Strategic decisions regarding the adoption of new technology should be filtered through the perspective of scale** | |
| | A. Management should approach every strategic choice with scale in mind | **A1.** The concept of scale is important when managing the social aspect of implementing technology. **A2.** All those things are related to the scale of your business. And how a particular business handles it, depends on the scale at which it operates. **A3.** Big companies can afford more regulatory aspects, like a technology officer and an ESG officer so they should all be encouraged to have it; small companies can't afford this. **A4.** Can't have the same legislation imposed on small-scale and large-scale operators with regard to their technology adoption: scale is everything. **A5.** Realising that the scale you're operating it means you've got to think through your problems, and what the solutions are, because they are different at different scales. **A6.** Radical or incremental is influenced by scale: are you innovating because you are desperate or empowered. **A7.** Should use scale to manage the tension between needing technology and implementing it in a socially responsible manner. |
| | B. Scale influences everything, not just management approaches | **B1**. Small businesses just need help innovating. They need legislation that insists on innovation and doesn't bog you down with regulatory issues. **B2.** Scale is critical to understanding legislation, innovation, and technology, absolutely, critically important. |
| **Rejuvenation through education** | **26. Education as a strategic priority** | |
| | A. Significant role education plays in the success of implementing new technology | **A1.** Education is key for the successful implementation and application of technology. **A2.** Education is more important than R&D in mining. **A3.** Educating and retraining the workforce help reduce job losses as a result of new technology. **A4.** The capacity of the tool maker will greatly influence if the innovator can bring |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| | | his dreams to life. **A5.** Low levels of technology implemented are largely influenced by a lack of skills, lack of ability to operate technology efficiently, and the cost of technology. |
| | B. Country educational levels | **B1**. Germany is one of the biggest innovators in the world, because they also educate the tool makers not just the PhDs who invent the ideas. **B2.** I think in terms of new technology, it's difficult to absorb as I think there are very low skill levels, which stems from the low level of education in this country. In order to conduct the process of changing technology, SA needs to put more into educating our people. **B3.** Maybe there are enough degree qualified people coming through, but there's certainly not enough on the lower technical levels. I don't think there's nearly adequate focus on developing sufficient skills there. **B4.** SA has not spent enough on educating people to decent standards; this hampers the country. Government has to come to the party in areas like education. They have to make better education systems for all, that produce well educated individuals that can be trained and moulded for different jobs. |
| | C. Education at firm level | **C1.** Firm's using new innovative ways of educating people is crucial. **C2.** Employees have to be educated and skilled enough to be involved in beneficiation, into artisan like jobs so like making the new technology for the mines. Beneficiation will be challenging if they have limited education. **C3.** Ensuring an educated workforce should be a strategic priority. **C4.** Very important to educate employees about technology. **C5.** Education is such a critical part of upskilling employees. **C6.** Education and upskilling of basic skills need to be a critical part of training and development at mines. **C10.** Employees should be trained using technologies that are in line with the needs of the mine of the future. VR and immersive technologies are a good way of teaching employees' skills. From a neuro-physical perspective this method will be more effective, as your brain absorbs more. **C11.** VAR environments will teach you more than paper without putting you at great risk. This was a step-change from paper-based learning. **C13.** Australian employees are more skilled, therefore, more productive, when compared to SA. There is a link between skill level and productivity. **C14.** Mines should have a graduate training programme |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| | | and an artisan training programme. **C15.** You could have the best technology but if you don't properly manage and train employees, the technology will just be sitting there. |
| | D. Influences on absorptive capacity | **D1.** A person's attitude and drive to work comes back to their social environment and peer group. This variable is dependent on far more than just their absorptive capacity. **D2.** Training and education can definitely help with absorptive capacity, but it's not everything. **D3.** Even people in the workforce who are not educated but with adequate training will be able to embrace some form of technology, because they have the right attitude and motivation to learn. **D4.** Make sure your workforce has sufficient education and training coupled with a good support structure which will influence their behaviour and positively affect absorptive capacity. |
| **Rejuvenation through increased use of innovative technology** | **27. 4IR technologies are an important driver for developing a sustainable future for the mining industry** | |
| | A. Drive for big data and digitalisation | **A1**. Using new tech should revolve around digitalisation, data, and efficiency. **A2**. Big data and real-time information will allow better monitoring of underground activities; this gives an opportunity to optimise activities and processes. **A3**. Digitalisation and real-time data monitoring for efficiencies, and productivity, are the biggest levers the industry has to pull. **A4.** Big data and digitalisation are key to the future of mining. **A5.** Digitisation focuses on safety, allowing more people to work underground enabling the extension of the life of the mine. **A6**. One example of how digitalisation and real-time monitoring created jobs was through its creation of a huge amount of data that requires a whole team to manage it. **A7**. Electronic monitoring and data collection has led to a new round of innovation. |
| | B. Drive for automation technologies | **B1.** Autonomous vehicles and robotics operate 24 hours a day and you don't need people there, so excellent for productivity**. B2.** Automation is a key driver for 4IR technologies and the future growth of mines. **B3.** 4IR technologies such as autonomous operations will enhance safety and productivity and will make a big difference in the mining sector for SA and Australia. |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| | C. Drive for drone technology | **C1.** Drones underground ae useful to keep people out of unsafe areas. **C2.** Drones are coming into play with many possible safety uses for mines. **C3.** Massive scope for drone technologies that are exceptionally useful to the mining industry. |
| | D. Many benefits as a result of driving 4IR technologies | **D1**. Technology will make operations more efficient, and allow you to make more money, this means that the economy will grow and give more people jobs. **D2.** New 4IR technology will make working environments safer and protect lives and health of people. **D3.** New 4IR technology will create massive gains in operational productivity. |
| | E. SA already has a benefit of starting with knowledge from certain technological strong areas so this can be used as a vantage point to build on future technological developments | **C1.** I don't think that SA is lagging behind with technology. For example, SA, has a lot of underground support mechanisms and remote mining. In my opinion, SA is at the forefront of a lot of exciting research. **C2.** There are certain niche areas in SA that are extremely advanced with regard to technology. |
| | **28. 4IR to tackle deep level gold mining problem and contribute to a sustainable rejuvenation of the industry** | |
| | A. Accelerated investment into R&D as a possible solution to the deep level gold mining problem | **A1.** The more invested in R&D the more chance you have of overcoming problems faced at depth. **A2.** New innovative technologies will allow the deep level gold and platinum mines to go on. **A3.** No physics that prevents R&D from discovering a way to go deeper; it's a commercial question about whether this can be done effectively or not? **A4.** If we are going to go deeper, we need to extend our R&D knowledge base. **A5.** An increase in technology and R&D will most definitely help to access these deeper ore bodies. **A6.** Physical constraints shouldn't be a cause for concern, with enough R&D, evolution of machinery and technology can be tailored to suit the current structure of our mines. **A7.** We have so much knowledge and so much computing power available, more now than when they sent Apollo into space, so through innovation we could definitely find a way to go deeper. **A8.** Automating at depth is possible through the following two arms. 1) Educating our people and 2) Providing the technology. Those two go hand in hand. **A9.** Building a tribe of people, who don't have to think the same, but want the same outcome and are |

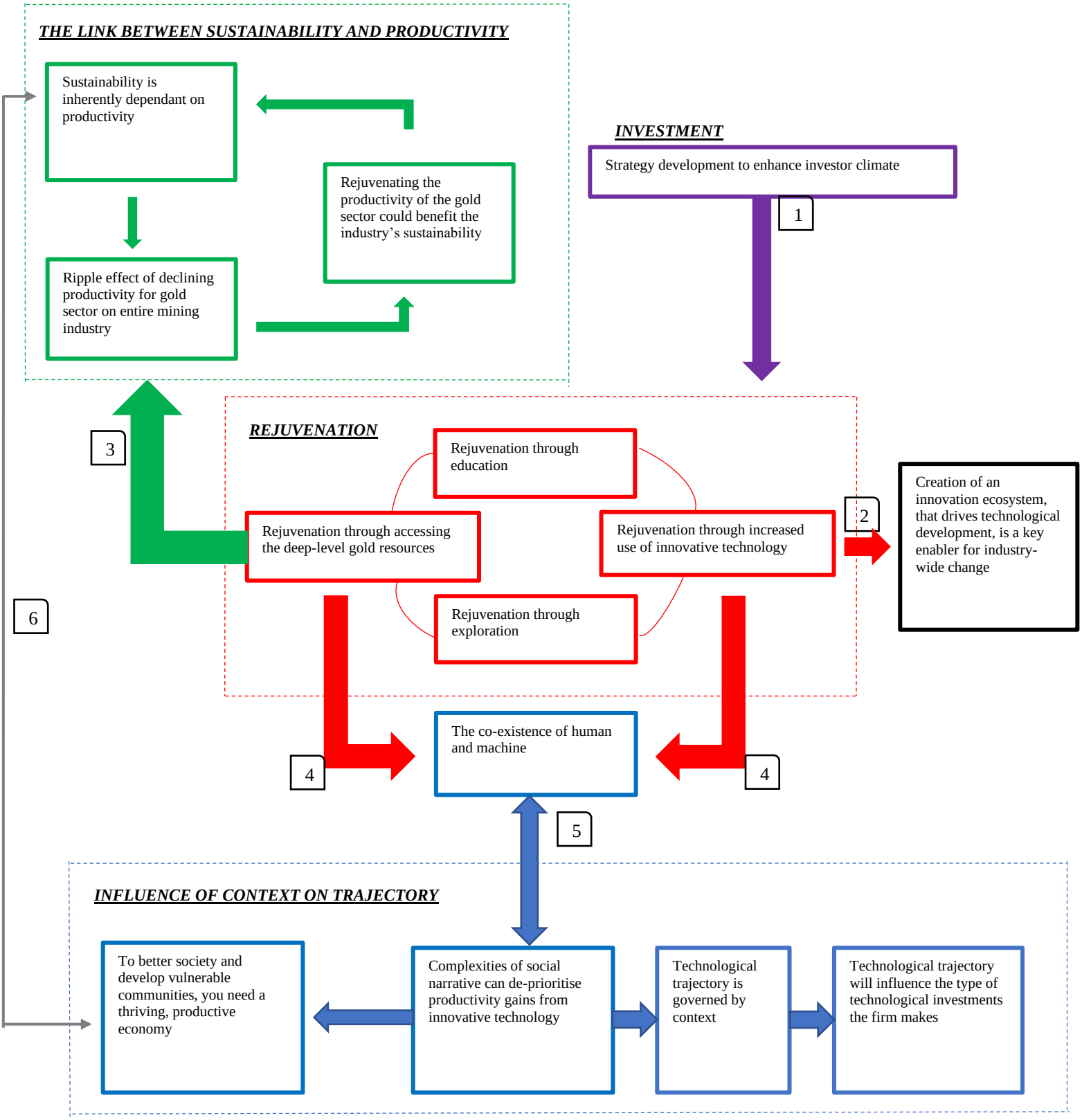
| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| | | equally as driven as you, will help you get through the process of achieving the end goal, even when things are difficult. |
| | B. Technical feasibility needs to go hand in hand with economic feasibility. | **B1**. We are on a learning curve; we can reach that kind of technology to get to deeper level ore bodies. But it can't just be technically feasible, it needs to be economically feasible also. **B2.** The reason we haven't been able to go that deep is an economical thing. The risk reward return is not great enough. **B3.** I think that the technology to mine deeper exists, but we are a small market to manufacture for in comparison to world markets. **B4.** It is largely about miniaturising, you know, making the equipment smaller. And perhaps also a bit more tough in terms of the deep-mine environment. But the technology exists. I think it's maybe more an economics kind of thing. |
| | C. R&D needs to happen in conjunction with the development of a holistic framework in order to solve the difficulties encountered with the deeper ore bodies. | **C1.** R&D is always great, but the gold mining industry is facing problems of efficiency that R&D may not solve. **C2.** So, in a nutshell, I think that the deep level mining can be done (technically with more R&D) but I don't think we have the appetite to do it, especially not from a shareholder's point of view. The accelerated R&D would need to fit into a framework of multiple stakeholders coming together to make this industry flourish. |
| **Rejuvenation through exploration** | **29. Exploration is vital to the survival and success of the industry** | |
| | A. Exploration and development to ensure expansion of current mineral operations is vital | **A1**. An interesting area of development to look at is something like the rare earths, you might have a look at scandium. **A2.** If exploration declines in any way, it impacts the entire mining industry. **A3.** No investment into finding new resources is detrimental for survival. **A4.** Mining countries need exploration. **A5.** Not enough exploration and new development. **A6.** More exploration means we would find more good ore bodies. **A7**. One of the main reasons SA is lagging behind other countries is because we don't do enough exploration. |
| | B. R&D for exploration technology is vital | **B1.** Australian R&D doesn't only invest a lot into extraction technology, but also huge amounts into exploration technology. **B2.** Investment into exploration also has quite a huge technology component. Because the sharper our technological tools, the higher the probability that we will find some of the resources we're looking for. **B3.** |

| Aggregate Dimensions (Selective Codes) | Second-Order Themes (Axial Codes)<br><br>First-Order Categories (Open Codes) | Representative Quotes |
|---|---|---|
| | | The scope for exploration technology is so wide, including autonomous drilling, robotics devices to explore, exploration of non-conventional areas like the sea and space. The more you invest, the further you will be able to explore. |
| **Rejuvenation through accessing the deep-level gold resources** | **30. Deep level gold mining as a strategic priority** | |
| | A. Huge potential that exists in the deeper parts of the Witwatersrand Basin | **A1.** I believe that the magnitude of the Wits basin could really be the thing that underpins the rebound of the South African mining industry. **A2.** South African reefs are truly magnificent. It truly would be a shame to leave all that gold there. **A3.** Accessing the deep is such a huge economic development opportunity for SA. **A4.** With regard to going deeper, I don't think there's anything that we can't engineer in the air. But I'm absolutely certain that, you know, if the gold price went to $10,000 an ounce someone would find a way. |
| | **31. There needs to be political will to pursue these deeper ore bodies** | |
| | A. Limited enthusiasm from many mining firms in SA to prioritise deep level gold mining | **A1.** The question about rejuvenation though, is there really the will to redress and make a sustainable future? **A2.** SA commitment to developing technology for deep level mining has been successful in the past but has died down. We have to want to focus on this area for success in the future. |

Source: Author

## Figure 18: Grounded Model

Figure 18 presents a cohesive synthesis capturing the intricate dynamics and complex relationships among various analytical concepts. This figure serves as a vital bridge between the data and the emergent grounded theory, offering a comprehensive representation of the findings.



Source: Author

As mentioned earlier, in Figure 18, the grounded model represents a synthesis that connects the emergent analytical concepts. By focusing on the theme level in Figure 18, it allows for a more informative perspective than focusing on the more granular dimensional level. The findings explanation below is based on Figure 18. The six areas explained as key findings have significant overlap; this is not because of a lack of careful distillation of emerging themes, but, rather, it indicates the complex and intertwined nature of the phenomena under study.

### 5.4 INVESTMENT

The most prevalent theme from the interview data was the major concern with the declining levels of investment into the SA mining industry (see purple box 1 in Figure 18). The mention of the industry being in decline largely because of dwindling investment, was perhaps the most common informant comment. As one informant noted,

> Low levels of investment in the mining sector, the drop in FDI, is such a big deal. It affects all aspects of the industry and inhibits growth and long-term success. The mining industry is heavily reliant on FDI. You are not going to get all the capital you need internally; you will have to rely on other sources (Table 31, 1E7).

Most of the informants, regardless of their position in the mining value chain, suggested that this drastic decline in investment is because of a variety of contextual factors that shape investor climate negatively. At the forefront of these constraints, informants highlighted the very restrictive and negative influence SA's socio-economic and political environments have on the industry. These environments include political and policy instability; corruption; poorly managed government departments; over regulation and social unrest. The data suggests that these challenges contribute to the uncertainty of the industry's long-term viability, prevent the formation of a clear path forward for recovery, and result in investors becoming increasingly wary of the risks associated with investing in SA. A mining firm CEO gave his opinion on the causes of investment decline.

> One of the things that scare investors off are labour strikes and unrest. Changing government policies also scare investors off. This has a lot to do with the long-term nature of a mining investment. The Mining Charter, for example, is constantly changing; the third one just came out and they are

> probably planning the 4th already. We need to provide certainty for investors that the framework won't change. (Table 31, 1E6)

Another informant, although acknowledging the influential role policy plays, suggested, rather, that the decline in investment is vastly attributable to the corrupt image of the South African government. He mentioned that,

> the number one contributor to reduced investment is far less about policy and far more about corruption. People are concerned that what they invest will not be spent in the right way. Corruption in the government has created this image that investment will be squandered on personal gains. This hinders money coming into the country. (Table 31, 1G6)

This informant and a few others suggested that developing the investor climate in SA should be a country priority and a strategic objective through which all other decisions are filtered. One senior executive discussed his concerns about SA's limited drive to develop in saying,

> The South African government haven't done anything to change [its] poor image. They should have an international campaign to lift the image as much as possible. (Table 31, 1E5)

This is an important message to communicate since, based on these sources, it seems as if no efforts to rejuvenate the industry will be successful or sustainable without consistent investment into the country.

A smaller portion of interview participants, particularly those with geological and engineering backgrounds, acknowledged the contextual constraints discussed above, but suggested, too, that another whole layer of investor risk exists because of SA's complicated mining geology. They pointed out that the aging mines coupled with the difficult geological structure, particularly in the gold sector, prevent the uptake of new innovative technology that, in many cases, is needed to ensure productivity and promote the development of a competitive edge. These limits to technological productivity improvements were pointed out by two informants.

> SA has challenges with labour and capital productivity. This is partly due to lack of new investment into the mining sector, and partly due to geology. (Table 31, 1H2)

> These challenges effect commercial viability of products and then products elsewhere in the world become more attractive. All of this has resulted in lost

> competitiveness; because costs have gone up, efficiencies gone down, productivity has gone down, and we are less efficient than other countries. (Table 31, 1H1)

Although this subset of respondents all agreed on SA's geological potential, they shared the same concern that without a drastic change in mining methods, productivity from this potential cannot be guaranteed. Along with the concern that aging mines and difficult geology would limit the uptake of new technology and productivity gains, many informants linked this to their concerns about labour unrest and militant unions with their resistance to adopting the technology needed to access SA's potential.

The interviews highlighted how lack of investment is detrimental to the industry for a variety of reasons. One of the prominent reasons mentioned was that reduced investment results in SA operating out of declining ore bodies. There is very limited brownfield and greenfield exploration, and thus no growth and development of new ore bodies. In response to a question about why other regions seem to progress through their contextual constraints more easily than SA, a few informants linked this to SA's poor levels of exploration.

> [In] other regions, improvement in their mining sector is continual. Whereas, in SA our resources have just become more remote and more difficult to access, and there is not enough investment into finding new resources. (Table 31, 1L7)
>
> Declining ore bodies that previously sustained the industry have been mined out, contributing to the South African decline. (Table 31, 1L2)
>
> There is just not enough exploration and new development. (Table 31, 1L3)
>
> The technology which could create more efficiency ultimately spirals into needing to attract more investment and doing more exploration. (Table 31, 1L5)

Informants also mentioned the multiplier effect of this decline in investment. They touched on how a decline in mining investment often causes a decline in surrounding industries and value chains. This poor investment scenario creates a number of negative impacts, such as reduced job creation, slower economic growth in the region and limited expansion of current and new operations. It also affects the industry's ability to attract investment into long-term R&D

initiatives that are necessary for developing new technologies that suit South African mines. One informant mentioned the effect limited investment has on the ability to innovate.

> This lack of investment extends further than just the industry itself, and moves into sectors directly linked to the industry, such as the R&D sector. The unwillingness and reluctance of individuals to invest into long-term R&D and tech initiatives is made far worse by the uncertain regulatory factors that exist in SA. (Table 31, 16A7)

The last prominent investment theme was its link to the socio-economic context of the country. When asked about the reasons for the structural decline in the South African mining industry, an informant alluded to the existence of a vicious cycle between contextual constraints and dwindling investment. He explained that the worsening of the contextual factors causes a decline in investment, and equally, a decline in investment causes the contextual factors to become worse.

> I think the cycle is harsh; difficult context equals declining investment but declining investment also means worsening context. I think it's best to say that the dwindling investment is coupled with incompetence, lack of education, lack of serious qualifications, poor administration of power stations, roads, dams, airports, all contributing to the decline. To fix this decline both sides of the equation need to be addressed. (Table 31, 1E1)

It is important to note that fixing contextual constraints in SA will be difficult without significant investment, and receiving significant investment will be difficult without fixing these constraints. It is for this reason that investment has been placed as a stand-alone concept in the grounded model. It flows directly into the red block relating to all suggested themes of rejuvenation since none of these rejuvenation options would be possible without investment. Attracting investment should be a lens through which each country or firm strategic objective is viewed. Additionally, it should have a holistic view of all of the influential factors in SA, ensuring that each one is considered. When asked about the conflict between prioritising investment over the development of our country, one informant suggested the idea that these two concepts are actually intertwined.

> The South African government doesn't seem to see that if they truly want to uplift our nation and fix the constraints in SA, they need to attract more investment. (Table 31, 3A9)

SA is at a crossroads, and it is imperative that it prioritises improving its investor climate. According to respondents, in order to succeed in this rejuvenation endeavour, a holistic strategy must be developed. Respondents seem to suggest common factors to consider in this strategy. These include factors such as taxation benefits, exploration incentives, economic policy development, and addressing social needs as well as infrastructure development. The data suggests that without these facets working in unison, the country cannot hope to achieve the desired level of investor confidence. It is only when SA has taken the necessary steps to create an investor climate that fosters sustainable economic growth will it then be able to open the doors to new investment opportunities and build a brighter future for itself.

## 5.5 REJUVENATION

The next commonly discussed theme was that of rejuvenating the industry. Rejuvenation in the grounded model is represented by the red box, and includes four separate, but still inter-connected, rejuvenation concepts. These four concepts are: 1) rejuvenation through exploration 2) rejuvenation through education 3) rejuvenation through increased use of innovative technology and 4) rejuvenation through accessing the deep-level gold resources. These were the most frequently mentioned suggestions from informants on what should be included in SA's rejuvenation strategy.

All the interview data highlighted the fact that rejuvenating SA's mining industry is crucial for the country's economic growth and development. Rejuvenating the industry could lead to increased investment, job creation, export revenue, and infrastructural development, among other benefits. The government has been implementing various measures to initiate rejuvenation, such as promoting local beneficiation, improving infrastructure, and reducing regulatory red tape. However, the state of the industry and the findings found in this study suggest that these measures are not sufficient. The data suggests that a rejuvenation strategy, followed by government, should be better grounded in very specific "rejuvenation themes." This will ensure that all rejuvenation interventions are well aligned with and well suited to each other and the needs of the country.

### 5.5.1 REJUVENATION THROUGH EXPLORATION

In discussions on rejuvenation, the informants were asked to indicate the order of importance of factors that had the greatest inhibiting effect on rejuvenation. The first most commonly

mentioned was the poor level of exploration conducted in the South African mining industry. Informants highlighted that no type of rejuvenation activity would have any long-term sustainability if it was implemented into a pool of declining ore bodies. A geologist said,

> One of the main reasons SA is lagging behind other countries is because we don't do enough exploration. (Table 31, 1L10; Table 31, 29A7)

The informants noted that developing a culture of exploration in SA would need to be largely driven and influenced by government's commitment to funding and promoting exploration. This should be a serious consideration to include in any rejuvenation strategy. One informant mentioned,

> The Australian government also give a lot of R&D and exploration tax breaks. This is something which SA should consider as a strategic priority. (Table 31, 15E4)

### 5.5.2 REJUVENATION THROUGH EDUCATION

The second most commonly mentioned factor was the lack of good education. According to respondents this issue starts with the poor education system in SA. The data suggests that developing education at country level should be the first education priority since it will influence the success of any firm-related education initiative that is implemented. This was explained by one informant,

> SA has not spent enough on educating people to decent standards, this hampers the country. Government has to come to the party in areas like education – they have to make better education systems for all, that produce well educated individuals that can be trained and moulded for different jobs. (Table 31, 26B4)

The respondents pointed out that it is also important that the development of the education system caters for all levels of skill and does not merely focus on higher degrees. One informant expressed his concern that existing efforts to promote educational development in SA are not well rounded and could prevent the development of necessary skills. He explained,

> Germany is an example of a country that is one of the biggest innovators in the world, because they also educate the tool makers not just the PhD candidates who invent the ideas. (Table 31, 26B1)
>
> Maybe there's enough degree qualified people coming through, but there's

> certainly on the lower technical levels, I don't think there's nearly adequate focus on developing sufficient skills there. (Table 31, 26B3)

The interviews pointed out a link that exists between education level and the ability to learn new skills, particularly those related to the use of new technology. Employees with higher levels of education may possess a greater understanding of new technologies that can lead to increased productivity and efficiency in the workplace. In contrast to this, a limited education and low level of skill is restrictive since it prevents the absorption of benefits from new technologies. One informant mentioned the important role education plays in the successful adoption of new technology.

> I think in terms of new technology, it's difficult to absorb as I think there are very low skill levels, which stems from the low level of education in this country. In order to conduct the process of changing technology, SA needs to put more into educating our people. (Table 31, 26B2)

Education does not influence only technology absorption; it also influences how well employees are able to transition from one sector to another. With higher levels of education, individuals are better equipped with the necessary skills and knowledge to adjust to different industries, allowing them to be more resilient when faced with changes in the job market. Investing in employee education can provide long-term benefits for firms by enhancing their overall competitiveness. One senior executive mentioned the important link that exists between successful beneficiation and education level. He said,

> Employees have to be educated and skilled enough to be involved in beneficiation, into artisan like jobs so like making the new technology for the mines. Beneficiation will be challenging if they have limited education. (Table 31, 26C2)

Although the development of the education system is largely a responsibility of the government, the findings of this study suggested that prioritising educational development should also be a priority for the firm. Many informants suggested that mining firms should pay attention to the type of learning and development they offer employees. They highlighted that it should include digital skills, thus providing employees with the opportunity to futureproof their skill sets. They highlighted that it should also include immersive learning technologies. This is considered to be one of the most successful ways to absorb information and deal efficiently with the lack of

education in the workforce. The interviews pointed out the vast opportunities that exist for skills development in the green economy; they highlighted this as a promising avenue for potential absorption of jobs lost in the mining value chain. This potential in the green economy includes labourers needed for setting up solar and wind farms, hydrogen manufacturers, etc. To promote long-term sustainability of any initiative, education and upskilling and reskilling of basic skills should be a critical part of training and development at mines.

### 5.5.3 REJUVENATION THROUGH INCREASED USE OF INNOVATIVE TECHNOLOGY

As is clear in the above paragraphs, a lot of potential exists for rejuvenation of the industry through the increased use of innovative technology. Informants highlighted that without advanced technology it would be difficult to improve efficiency, productivity, and safety. One informant mentioned that SA is no longer as efficient or productive as many other mining countries, and has therefore, lost its competitive edge. He pointed out that, unless it considered the use of more innovative technology, this productivity and efficiency problem would prevent SA from ever returning to the status of a "mining world leader."

> SA has lost [its] competitiveness because costs have gone up, efficiencies gone down, productivity has gone down meaning we are less efficient than other countries. (Table 31, 1H1)
>
> We are unable to close these efficiency and competitive gaps because we don't prioritise the type of technology needed for massive productivity gains. (Table 31, 1H9)

Another informant linked this limited will to pursue technological advancements in South African operations to the current poor levels of exploration, in explaining that there is limited will to pursue bullish exploration ventures as the technology required for success is lacking.

> Investment into exploration, also has quite a huge technology component. Because the sharper our technological tools, the higher the probability that we will find some of the resources we're looking for. (Table 31, 29B2)

The research indicated that to promote the success of technological initiatives, through R&D, the R&D needs to include a mix of applied (targeted) and fundamental (general) research. Although applied research is usually more practical since it helps to develop a solution to a

specific problem, some informants indicated that fundamental research is just as important because it develops existing knowledge pools.

> It is not just fundamental research that is important, but applied research as well. (Table 31, 14A4)
>
> Fundamental research is important, because you don't know what is going to work in a particular area. (Table 31, 14A2)

This combination will ensure broad spectrum research that provides a chance for all options to be considered and a higher probability of success. Many informants suggested that to adapt an innovation driven culture that is eager to embrace all types of new technology, one should become comfortable conducting applied as well as fundamental research. An aspect of this wide-ranging research should include cross-industry innovation. There is great value in surveying the current available technologies in other sectors and considering how they can fit into the mining industry to overcome mining related problems. The interviews suggested that the industry can play a role in developing this open-minded approach to innovation, and this they should do by donating R&D funding to the universities to be used in different faculties, targeting a wide variety of areas across the whole mining value chain.

Innovation/technology management was additionally a common theme that emerged in respondent responses. Of particular interest was the potential influence the type of implementation (i.e. the choice to implement incrementally or radically) could have on technological success. As well as if the choice to implement incrementally or radically is influenced by the type of context in which the firm is operating. Informants were asked these to questions separately. Most of the informants agreed to the first part of the question and felt that the implementation approach would likely influence technological success. They suggested that it is often the implementation of the technology that is the riskiest part and is something that should not be overlooked by managers as a simple decision.

The second part of the question regarding the influence of context on the chosen implementation approach, received mixed responses. Some interview participants felt that context cannot be overlooked, and for this reason the method chosen to implement technology should be one that considers any contextual constraints of the country. Informants mentioned examples such as needing to consider the aging mines with old infrastructure that would need an incremental approach. They also mentioned the very labour intense mining methods SA has and the

impossibility of radically implementing any type of technology without facing substantial worker and union resistance. These informants were of the view that the context should govern how the technology is implemented.

Opposed to the above viewpoint, another group of participants reported that the question of management should rather be about managing what the actual needs of the industry are first and then addressing the social context. This would entail, first, deciding on what type of technology and implementation method is needed to address the needs of the industry adequately. Then, second, once the correct technology and implementation approach is selected, address how the interaction between the technology and the social context can best be managed. For one informant,

> Is the question of management more about managing what technology to invest into, with a suitable approach be it either incremental/radical/or hybrid to match the technology, and then managing the social interaction with this new tech that is needed for the sustainability of the industry? (Table 31, 23A3)

This second group of informants generally felt that firm management should not look at contextual factors as a stumbling block dictating how to approach technological innovation, but rather as an excuse to become more innovative in their way of doing business. The first group of participants appeared to be more despondent and less positive regarding our ability to overcome contextual constraints, compared to the second group who came across as far more positive in attitude.

Some informants highlighted the possibility that SA has actually embraced the idea of technology more than we give it credit for. They raised this on the basis that a lot of technological adoption has happened in certain commodities and to fulfil certain industry needs. They suggested that the issue is with SA's limited attempt to tailor the technology we use well enough to all of our specific problems, subsequently enabling a more wide-ranging adoption of technology. One informant pointed out that technology should not be something that is an optional addition to an operation, but should be, rather, an integral part of every business aspect. He suggested that it should get to a point where it is engrained into what the business is. Discussing the importance of technology being an integral part of every business aspect, and not small additions, led to the discussion that SA seems to prioritise technological developments to please certain drivers, but not all. One informant explained his view that if a

country is generally focused on developing technology for environmental causes, for instance, and not for cost reduction purposes, then the technology portfolio of the industry will not be well engrained into every aspect of business, thus limiting its effectiveness.

This same informant raised an important point regarding the need to diversify technological approaches across different commodities. He pointed out that although this might be considered as "obvious" knowledge, it is often overlooked. He suggested that a limited view could greatly influence the possible range of technologies and implementation methods that are pursued. This informant mentioned that a successful adoption of technology in the coal sector for example, may look very different to the gold sector and the industry needs to be flexible in that regard, understanding that their priority is developing and implementing technology in a way that will prioritise the long-term sustainability of the industry.

> Maybe it's good enough to be mechanising or modernising in the platinum or the coal sector, but perhaps because of the depths of many of SA's gold mines, it needs full on automation to remove the people right out of these depths. (Table 31, 5B1)

The interview data suggests strongly that for SA to regain competitiveness, it needs to focus on both internal innovation and external collaboration. Organisations are not able to develop an innovation strategy in isolation. To effectively facilitate change within the industry, miners should contemplate collaborating through alliances or joint ventures with technology providers and other companies that are already making efforts to utilise organisational intelligence. They suggested that the stakeholders who come together, share ideas and innovate together will create a culture of knowledge sharing and a culture that prioritises and supports technological advancements at all stages of the mining value chain. The responses have indicated that collaborative organisations, through pooling their talent, ideas and insights, enhance the probability of identifying innovative breakthroughs that can benefit all participants in the industry. The existence of a strong ecosystem is also beneficial for promoting local development of technology that is designed for and well suited to the South African industry. As the automation trend becomes more prevalent in companies, few mine workers will be required. Although this is a useful trend for safety improvements, it can also be detrimental to communities. This is especially the case for countries like SA where the mining sector is such an important employment contributor. In the future mining companies should contemplate

alternative means of generating employment, such as utilising their purchasing power to distribute mineral resources and offer social advantages to a wider community ecosystem.

Overall, the interviews highlighted that an innovation ecosystem is vital to every part of business innovation. In the short term, it can aid mining companies in mitigating and managing risks and developing more effective relationships with both the community and government. For mining services companies, it can facilitate in the production of new products and services and enhance their value in the industry. Additionally, in the longer term, it has the potential to address widespread issues such as corporate environmental performance, social responsibility and sustainability. The informants emphasised the need for mining companies to prepare for potential divergent future scenarios, where collaboration will be a crucial factor. They also stressed the importance of transitioning from a mind-set focused on current business practices to one that embraces future success.

The importance of the innovation ecosystem is represented in the grounded model through the use of arrow two. This arrow that moves from the need for innovative technology as a rejuvenation theme (red box), to the need for a collaborative approach to innovation (black box) serves to highlight that any innovative technology activity pursued by a company should have collaboration at its core.

### 5.5.4 REJUVENATION THROUGH ACCESSING DEEP-LEVEL GOLD RESOURCES

The above discussion leads us to the next important theme that is rejuvenating the industry through further exploring and accessing some of the deep-level gold resources that exist in the Witwatersrand Basin in SA using much needed, but yet to be developed, technology. Almost all interviewees mentioned the huge impact the declining gold sector has had on the entire industry. They highlighted that because of the magnitude of the shallow gold reefs which were mined out many years ago, the industry boomed, and when this started to decline, the whole industry felt it. A portion of informants (group A, for this discussion) were not in favour of trying to rejuvenate the current gold mines or attempt to pursue any deeper resources. They felt that the declining productivity, difficult geology, and safety concerns were too great and too complex for the industry to consider as a viable option. On the contrary, however, another portion of informants (group B, for this discussion) pointed out that a big aspect of rejuvenation could come potentially from reviving this particular sector. One informant, a geologist, shared

his view on this in saying,

> Perhaps gold is the main reason for the drastic decline and not necessarily the industry as a whole. Accessing the remaining gold could reverse this problem. (Table 31, 6A1)

His opinion is supported by the vastness of the remaining South African gold resources. It is well known that the Witwatersrand Basin still hosts the largest gold resource in the world. He went on to explain that

> South African reefs are truly magnificent. It truly would be a shame to leave all that gold there. (Table 31, 30A2)

This same group of participants, group B, also acknowledged the safety, productivity, and economic constraints of accessing these deeper resources, as did group A. The difference was that group B believed that these challenges were exacerbated by current labour-intensive mining methods, which could potentially be overcome with the right technological development. Generally, they felt that these physical constraints could be seen rather as drivers of innovation and new technological developments.

Labour intensive mining methods do not only affect the potential for accessing deeper resources, they also contribute to the declining productivity of gold mines that are currently operational. The MCSA reported recently that if mining production levels and output remain at their current level, there will only 39 years left of accessible gold reserves remaining in SA. The issue is that labour intensive methods cannot effectively increase productivity levels of current operations and they are incapable of accessing deeper resources that have the potential of creating long-term sustainability for the industry. This group of informants reported that the only chance for true rejuvenation of the gold sector would be with an extensive use of innovative technology, possibly including automation and robotics.

The idea of increasing the use of technology to access deeper ore bodies was met with some resistance from group A. Mostly, they reported that because of the lack of any existing technology that is able to travel to such depths, overcome the complicated geology, and withstand the harsh mining environment, this is not a plausible option. These informants were generally of the view that even if someone were to develop a technology that could access these deeper resources it would not necessarily be economical. However, this opinion was met with

an overwhelmingly positive outlook by most of the informants from group B, who suggested that with increased R&D, developing the correct technology could be possible, and that even the concern of an uneconomical constraint could be overcome.

Group B suggested that with will power, increased effort in R&D, and the right market influences (such as commodity prices) suitable technological development is possible. Many of these informants felt that the technology did not exist because SA, in the past, did not have a reason to develop it and this reduced any time and effort dedicated to this task, but that now with the right motive it should not be overlooked. The informants shared similar opinions that in the 80s and 90s when gold was booming, SA was mining the shallower and easy to reach reefs and did not require all this technology. One informant reported,

> Past operations have worked well and there hasn't been a strong business imperative to develop new technology. The consequence of this is a lack of investment into R&D and tech development, which means today we don't have the right tech that we need because there was no incentive to invest in new tech. (Table 31, 16A8)

Many informants in group B did acknowledge the concern about technology being uneconomical and limiting its chance of success. However, they pointed out that an economic constraint is not something that is fixed. As mentioned above, it will change with the changing markets such as commodity prices as well as supply and demand. The smarter and more efficient the technological breakthrough is, the more it will influence the economics and drive down the cost of mining. Another consideration mentioned by an informant was the influence of scale on the development of technology. He suggested that as SA participates in developing various technological advancements, they will achieve economies of scale and this influences the success of the technology they implement.

> A big contributing factor for the success of the Australian mining industry was understanding economies of scale. This is important for SA to understand that they can achieve this also. (Table 31, 2G2)

Some group B informants mentioned that many mines around the world already operate very remotely with very little human intervention (although not as deep as SA has the capacity to do) so, for this reason they believe that if this the technology could become scalable at depth then it is possible for use in SA's deep gold mines. However, they did note that human

interaction at great depths will be limited. Although group B was in favour of utilising innovative technology to access the deep, they still pointed out the huge tension that exists between balancing the needs of the mine and the needs of society. One informant expressed the difficulty to achieve this in saying,

> I know with the deep mines in SA, it's getting to the point where it's, it's just getting too hard to send humans down, it's getting to the point where you've got to basically come up with a brand-new mining mode, preferably involving more technology. But on the other hand, you've got this social contract and social licence, where you've got to employ people. (Table 31, 5A4)

Group B suggested ways to address the human and machine challenge, whereas group A mentioned this, along with the technological constraint, as a reason why it is not suitable. Group A informants were of the view that even if you could find the right technology to access the deep you would not be doing any good for society since you would not be employing as many people.

> You may come up with a technological model that works for deep-level gold mining and can remove people from harm and increase productivity, but you're actually not helping the society because you're not employing the people, or as many people as previously employed within the mine. And that's where I think the mining industry in SA has got to jump over that hurdle. This hurdle should not only think about the jobs of now, but also think about the sustainability of the future of the mine. (Table 31, 7A7)

Although the informants from group B linked the access of deep-level ore bodies to long-term sustainability of the industry and benefits to communities, they did take into account the potential immediate effect it would have on job losses, and they acknowledged the general lack of direction on how to handle this. Some informants suggested that if contextual issues, such as corruption, were better dealt with it could promote wealth sharing from the deeper gold resources, and limit the impact felt as a result of immediate job losses. They pointed out that this scenario would benefit the community much more than an unproductive mine that barely contributes to the development of the economy or the community.

> Not sure how to handle the question about job losses, but one thing I can say is the corruption should be reduced and this would make the problem less.

> The gold deposits produce so much wealth, but none of it is shared back to the community. (Table 31, 1G8)

Group B informants suggested that prioritising deep-level gold mining was the long-term solution to helping society. They suggested that if the wealth from accessing these excellent ore bodies was properly managed, it could be a way to enhance the sustainability of the industry and protect the interests of society.

> The mining industry is not self-sustainable: ore bodies have a limited life span, finding new ore bodies or developing technology to extend the life of current ore bodies is sustainable thinking. Without extensive use of innovative technology this limited lifespan cannot not be increased. (Table 31, 7A2)
>
> Many of the remaining gold mines still have substantial mineral resources that could support the industry for many years into the future, and additionally play a material role in the inland revenue of SA and the rejuvenation of the local economies. (Table 31, 6A3)

This entire discussion regarding the rejuvenation of the gold sector as a way of increasing productivity and sustainability of the industry is represented by arrow three in the grounded model. This arrow moves towards a green box with its discussion of the idea that sustainability and productivity are inherently linked.

## 5.6 A LINK BETWEEN SUSTAINABILITY AND PRODUCTIVITY

There appears to be a link between the declining productivity of the gold sector and the success of the rest of the industry. As discussed above, some of the interview data suggested that if we were able to rejuvenate the productivity of the gold sector, there is a chance that we could significantly influence the sustainability of the entire industry.

This relationship highlights the important role productivity plays in the success of the mining industry. It suggests that SA's long-term sustainability is highly dependent on its ability to be more productive. Some informants raised the important idea that productivity drives all aspects of a successful business. That does not mean to say that productivity is all that determines the success of the business but, rather, that any other business success is only short-term if there is

no productivity existing with this other success to carry the business into the future. One informant mentioned,

> Only looking at short-term gains is suicidal and not at all sustainable. Only focusing on the now, means absolutely no future. (Table 31, 7A1)

The informants highlighted the important fact that the mining industry is not self-sustainable as ore bodies have a limited life span. They pointed out that innovative technologies could assist in finding new ore bodies. As well as on improving constraints of current operations, thereby increasing the productivity for these orebodies, which would contribute to sustainability. Many informants alluded to the idea that increasing the life of a mine through productivity gains, from advanced technologies, should be a massive sustainability focus. "Now that is sustainable thinking", was a common phrase mentioned in relation to the idea of prioritising the development of productivity focused technologies. One informant suggested,

> Without extensive use of innovative technology to ensure productivity, mining has a limited lifespan that cannot be increased. (Table 31, 7A10)

As mentioned above in point 5.5.1 (rejuvenation through exploration) the South African mining industry has massive exploration potential. Some informants pointed out that SA, in comparison to Australia, is not as well explored. This means that there is still vast potential for exploration success and enhanced sustainability. One informant said,

> SA is more under explored then Australia, more future opportunity for another big boom and a new growth frontier. (Table 31, 7A5)

The interviews suggested that to promote business sustainability, productivity needs to be a priority. This suggestion does not overlook the importance of all business stakeholders. Rather, it focuses on how a certain decision will impact the long-term interests of a stakeholder. It is actually a suggestion that prioritises the sustainability and long-term development that is in the best interests of every stakeholder. Development efforts that cannot be sustained are somewhat futile, and it cannot be sustained if it is not productive. An informant offered his viewpoint,

> A company must understand that they need to be productive if they are truly going to develop their human capacity and the community. (Table 31, 8A2)

It is also important to note that productivity and employee/community upliftment are not mutually exclusive. One can prioritise technological developments that ensure a productive

work environment while making sure that benefits from this productivity are circulated back into the community and employees.

> It is important that companies protect their social license to operate, while they are making decisions to prioritise technology to increase productivity. (Table 31, 8A6)

Unfortunately, some interview participants suggested that in some cases productivity and employee/community upliftment are indeed mutually exclusive. These informants felt that the South African mining industry, in many cases, does not have productivity at the forefront of its priorities. They linked this to the possibility that our context perhaps dampens productivity because it is ideologically frowned upon. The respondents pointed out that people have to be an important part of the modernisation drive, but productivity still needs to govern business. One informant mentioned that it is important to remember that

> [e]verything that will benefit the human element of the workforce, in any case, happens through productivity, even the generation of human knowledge happens through productivity. (Table 31, 9A2)

As a mine grows through productivity gains, it will be able to maintain current and promote future employment. It will contribute more to the economy and support up and down stream businesses which in turn will promote employment through beneficiation. It could also invest in new forms of energy infrastructure, thus creating employment in these sectors too. The technology development that is needed can increase local content, preferential procurement, and contribute to SMME development in the country. If correctly managed, the increased wealth from productivity growth would allow mines to find a new way of fulfilling their social license to operate. This could include community wealth sharing structures which would ensure that the community and the vulnerable benefit from this productivity growth.

Overall, this theme from the interview data highlighted that in the long run, prioritising productivity through an increased use of innovative technology would be an important contributing factor to stability and sustainability in job security. As opposed to the alternative scenario, where productivity growth is deprioritised under the auspices of worker/community protection that will, in any case, end up negatively impacting both the worker and the community if the mine is no longer competitive and no longer sustainable.

However, there are two important concerns to note related to the idea of job security that the informants did not overlook. First, this is the changing skill set that will be required by employees as the mine becomes more productive with the introduction of new technology. Second, even though productivity gains, through the implementation of new technology, are linked to long-term sustainability there is still the concern regarding the number of immediate jobs that potentially could be lost. Many informants admitted to not having the answer about how to effectively manage this tension. In response to the difficulty of this point, one informant did reiterate the importance of long-term sustainability in saying,

> However, only looking at short-term gains is suicidal and not at all sustainable. Only focusing on the now, means absolutely no future. (Table 31, 7A1)

This theme around the need for advanced technological innovation to rejuvenate the industry leads to the discussion regarding the ability of human and machine to co-exist. This relationship is represented in the grounded model by arrow four.

## 5.7 THE CO-EXISTENCE BETWEEN HUMAN AND MACHINE

The tension that exists between the human workforce and the introduction of advanced technology such as automation, is a topic of concern in many countries and industries around the world; it is not specific to SA's mining industry. The difference, however, in the case of a developing country like SA, compared to a developed country like Australia, is the difficult socio-economic environment.

This environment, particularly the mining industry, employs vast numbers of lower paid workers who are dependent on their employment. The respondents highlighted that these employees often have limited skill sets that prevent them from easily absorbing new technologies or transitioning to other industries if their employment in the mining industry is lost. This very labour-intensive environment described in SA's mining operations has resulted in a labour force that is largely threatened by the introduction of automation thus creating a contextual constraint for the implementation of advanced technology. One senior executive gave his opinion on this matter in explaining,

> Automation is great for safety, as less people are underground, and productivity, but the job losses it causes is an issue in developing countries

(Table 31, 12B4). Job loss is a contextual constraint that will hold a country back from automation adoption. (Table 31, 12B5)

This contextual constraint is in complete contrast to that of Australia's contextual environment, where there are labour shortages that drive the uptake of automation. Australia's context is also a better place to automate because their operating models are less labour-intensive and their labour force tends to be on a level of education and expectation that lends itself to embracing technology. Informants pointed out that technology and automation have played a big role in the success of the Australian mining industry; it has greatly increased their ability to be productive. Informants pointed out that the "cheap" and abundant labour force on which SA built its industry means they have never has a need to drive technology, whereas other countries like Australia who have a labour shortage and expensive labour structures had a need to drive technology.

This theme presented a divide among the informant group members. A portion of informants (referred to as group A above) felt that, given this contextual constraint, SA should not be automating their mines at large. The second portion of informants (referred to as group B above) felt that the use of advanced technology, including automation, was the only way to save the declining productivity of SA's mines.

Group A emphasised that SA's mining industry is built on manual labour and that is where the focus should stay. They suggested that in a context like SA's, mines should not pursue any technological development that would deny thousands of people depending on them for work. They generally felt that one should introduce only incremental technological improvements that would make the operation safer and more efficient. They suggested this even if that meant employing double the people to get more productive (regardless of whether that meant a slightly lower profit margin). One informant explained,

> It is imperative to think about the South African context before anything else. We need to think of the unemployment problem before we think about getting smart automation. (Table 31, 12B10)

Contrary to this, group B was generally of the view that the technology needed to break current productivity boundaries in the industry would initially reduce dependence on labour, but ultimately enhance job security. In response to the group A informant's comment above,

regarding unemployment, one informant from group B pointed out that if the protection of employment and job security is truly a priority for SA, then implementing smart technology is the only sustainable way to protect this.

> Without new technology, the mines will close, if the mines close this will equal an even bigger unemployment problem then if some workers lost their jobs due to technology. (Table 31, 12B8)

The informants from group B were not suggesting that the loss of employment for these workers was something to be overlooked. Rather, they were emphasising that to truly have the workforce's best interests at heart you need to prioritise productivity so that you can protect the thousands of jobs that could be lost as a result of an unproductive mine. They were pointing out that there are other options that could be explored such as upskilling, reskilling, and beneficiation to deal with immediate job losses. They admitted that the play-off and tension that exists between human and machine is not well explored yet and they do not have all the answers. However, the current lack of understanding regarding how to deal with job losses should not be prioritised over productivity and the sustainability needs of the mine as this could cause a ripple affect across the entire economy.

The data pointed out that potential for AI in SA is immense. With careful planning and regulation of its interaction with the human workforce, AI can promote growth, development and innovation across the mining industry. At the same time, it is imperative to acknowledge and confront the difficulties that accompany these benefits, thereby guaranteeing that the advantages of AI are equitably distributed among all citizens of SA.

This debate regarding the co-existence of human and machine lead to the discussion about how contextual factors would influence the technological trajectory of a firm or country. This is represented by arrow five in the grounded model.

## 5.8 THE INFLUENCE OF CONTEXT ON TECHNOLOGICAL TRAJECTORY

The influence of contextual factors, including SA's history, were discussed quite extensively in the interviews. All informants acknowledged the terrible historical roots of SA's racial and economic segregation that still underpin much of the country today. They also mentioned how history, current context, and power relations can often influence the technology decisions made by a firm.

The horrifying inequalities of the SA's past are still prevalent in the mining industry today. SA has to deal with legacy issues, such as the fact that the industry was built on a cheap labour-intensive framework that included poor working conditions, limited safety, and unfair worker payment. The informants emphasised how these conditions have underpinned the industry for a long time. They pointed out that it is imperative for SA to have a significant portion of its focus on addressing the inequalities of the past. They noted that history should and will influence current decision making and for this reason the industry must consider how mining methods and technology brought in will address social injustices of the past. One informant mentioned that

> SA is where it is today based on its past. The past influences its present. (Table 31, 19B8)

As discussed throughout this work, the complex social environment in SA greatly affects the industry's ability to absorb new technology. Many informants highlighted that one cannot overlook these social problems when contemplating the kind and the amount of investment SA should be making into R&D. They pointed out that although government should spend money on R&D because it is a driver of economic growth, they also questioned whether they should be spending vast amounts in light of our social context. They also introduced the issue that old mining policy did not address the social imperatives in SA and it is of utmost importance that new mining policy has its primary focus on this, and not on introducing new technology.

> We are physically constrained by our social problems. This is the reality we have to deal with; we can't approach things like other first world countries do. (Table 31, 19C6)
>
> Leaders of companies should appoint proper community managers, who are tasked with community engagement. Proper social performance teams should be a priority. (Table 31, 19C7)

The expectation to place social upliftment and correction of past inequalities at the forefront of SA's priorities, was a common sentiment shared by all informants. They all agreed that addressing the inequalities of the past should be the main objective of the industry, they however, had differing opinions on how to achieve this. As noted above, for some informants (call them group X for this discussion), this priority would result in an exclusion of advanced and smart technology, such as automation since they believed that it would be in complete

contradiction of society's needs. They were mostly comfortable with the notion that context does and would continue to dictate the technological trajectory of the industry.

However, in contrast to this, some other informants (call them group Y for this discussion) suggested that to achieve and maintain the priority of social upliftment, pursuing advanced technology would be in the best interest of the industry and the community. They suggested that productivity gains through pursuing advanced technology is the vehicle needed to ensure that you reach your social objective. They highlighted that job loss as a result of automation is something that all developing countries face. It is a contextual constraint, that cannot be ignored, but should not translate into the neglect of technological advancements. The respondents pointed out that you cannot overlook the long-term effect of falling behind the innovation curve and its impacts on the industry's productivity, competitive edge and sustainability that, in turn, will only worsen the existing social difficulties.

> We have to try and get onto the automation trend, even at depth. If we don't and we keep labour intensive methods that deep, we will be uneconomical – having an even greater effect on the social inequalities that exist. (Table 31, 19A9)

Rather, a solution needs to be developed for how the human and the machine can work hand in hand. Group Y informants suggested that a solution is possible, that there would be a way to ensure that benefits are created for both social priorities and productivity (with the latter benefiting the social aspect in any case). They put forward the idea that there has been no will power to find this "dual benefit" because in many cases SA is stuck in old patterns, and it just does not want to change. SA has been using conventional ways of mining for years, and it is stuck in this pattern. One informant highlighted the notion of path dependencies and pointed out that historically people do not want to embrace technology; they just do not want to change. He said,

> Some resistance to change is based on valid reasons, some is just because we have done it like this forever, so we don't want to change. (Table 31, 19A5)

Group Y informants believed that through increased education and familiarisation with the technology benefits communities and unions could recognise that there are benefits that will result from utilising new technology. These benefits have the potential to protect the development interests of communities. One informant pointed out that

> SA is not positioned to continue doing well because of all of our constraints but also because of our lack of technology investment. If this is not addressed the deterioration of the industry will create terrible socio-economic knock-on effects. (Table 31, 1K2)

The informants pointed out that if we truly want to protect society and the wellbeing of workers and communities and redress the inequalities of the past, then a paradigm shift regarding how we view technological progress is what is needed.

## 5.9 A LINK BETWEEN THE SOCIAL NARRATIVE AND NEED FOR PRODUCTIVITY

A very important theme that the story of this research tells, is that everything happens through productivity. Productivity is the vehicle which enables positive change. Economic growth and development as well as knowledge sharing and human capital development, socio-economic upliftment, and innovation are all enabled through a productive firm and a productive economy. The respondent's data highlighted that productivity is the centre of the story. Productivity is key to all growth and all innovation.

This research suggests that perhaps the problem in SA is that the complexities of our social narrative could de-prioritise productivity gains from innovative technology which come at the expense of employment. It has highlighted a number of causal links showing how a lack of productivity causes structural breakdown for sustainability. It has pointed out that one cannot protect or support the development of a vulnerable community from an unsustainable industry and a failing economy. Rather, one needs to prioritise productivity in one's economy if one wants a sustainable plan for upliftment.

The respondents suggested that government and the industry's prioritisation of community development is correct, but they are approaching it incorrectly and will struggle to achieve it without a focus on productivity. The research suggested that displacing the importance of productivity will only worsen the social inequalities.

Overall, the respondent data highlighted the very important link that exists between prioritising the needs of the social context and understanding the important role that productivity plays in this regard. It highlighted that technology improvements, in the long-run, increase productivity

and enhance job security, which is well aligned to the mining industry's sustainability drive. This theme pointed out that everything starts with productivity. Without productivity, nothing can be sustainable and without sustainability one cannot even attempt to redress past or current social inequalities. It highlighted that one can uplift a community only when one is operating from a thriving economy. This relationship is represented by arrow six in the grounded model.

## 5.10 CONCLUSION

This chapter provides a qualitative analysis of a series of semi-structured interviews. Using a grounded approach and thematic content analysis the interview data was coded. This produced certain relationships around technological development and the influential role of context. The findings narrative of this chapter discussed six important themes. First, the importance of investment was discussed as an overarching theme influencing the success of any rejuvenation initiative. Next was the discussion of rejuvenation. This theme included exploration, education, technological innovation, and deep-level mining as four separate but interconnected aspects needed for rejuvenation. One important concept to promote the success of technological innovation, in this theme, is the need for an innovation ecosystem that prioritises collaboration. The third theme discussed a link existing between sustainability and productivity. Theme four discussed the tension that exists between the human workforce and the introduction of smart technology. This was followed by theme five, the influential role context has on a technological trajectory. The narrative section concluded with theme six, a discussion about the inherent need for productivity to prioritise the development of society.

# CHAPTER 6: DISCUSSION AND CONCLUSION

## 6.1 INTRODUCTION

In this chapter, the results and study conclusion are discussed. Following layout and structure guidelines from Geletkanycz and Tepper (2012), who synthesise their findings and transform the results into a discussion, similarly this chapter extends the investigation from reporting the results to discussing them. The within-case and cross-case analyses were presented in chapter four. The interview-based qualitative analysis, based on a grounded application that imposed no theoretical structure, was conducted in chapter five. In this chapter, a summary synthesising the results of chapters four and five is offered. This is offered through presenting a unified theoretically grounded narrative of the study's discoveries to answer its underlying research question, that concerns understanding how a firm should negotiate the tension between radical and incremental innovations, in light of contextual imperatives, in their management of technology aimed at closing performance gaps with global competitors. This chapter followed the approach of Eisenhardt (1989) to objectively shape conclusions through the use of tables displaying supporting evidence for each conclusion made. This ensures that the narrative is well supported by substantiating facts from both methodology phases. This chapter also presents an important step of theory building which is comparing the findings (conclusions) of this analysis with existing literature. Following Eisenhardt and Bourgeois (1988) this process of contrasting findings against existing literature is useful for highlighting similar and conflicting findings. The chapter will also include a discussion of the theoretical and practical implications of the research and its limitations along with offering suggestions for future research.

## 6.2 SYNTHESIS OF THE RESULTS AND COMPARISON WITH EXISTING LITERATURE

### 6.2.1 GLOBAL CATCH UP REQUIRES A CERTAIN TYPE OF INNOVATION ACTIVITY

Both methodology phases acknowledge the powerful role technological advancements play in the development of the industry. They do, however, suggest that certain innovation activities are more useful than others when a country is attempting to catch up with global leaders in the mining industry. Based on the evidence of the findings, this research argues that the innovation

activities that are considered to be the most useful for a catching up with global leaders would require mostly radical innovations as opposed to incremental. The following table suggests, on the basis of the findings, that the development of exploration technology that will contribute to the sustainability of the industry, the development of transformative technology that will result in a new approach to mining, and the development of technology that will enable productivity increases should all come through radical changes to the current way of work.

Table 32: Concluding points for the type of innovation activity needed

| **Concluding point** | **Research finding** | **Methodology phase** | **Substantiation** | **Implicit or explicit link to the central research question** |
|---|---|---|---|---|
| Technology development should be focused on developing exploration technology. | The study highlighted that R&D for exploration technology is by far the most important component of such an effort since innovation activity that is focused largely on developing exploration technology will promote the industry longevity that is an important factor for a sustainable catch up. | Qualitative interviews | One of the main reasons SA is lagging behind other countries is because we do not conduct enough exploration. (Table 31, 1L10; Table 31, 29A7) | This data that highlights the importance of innovation activity, and that is largely dependent on the development of transformative technology, for effective exploration, points directly to the advisability of firms investing in radical technology. |
| | | | Investment into exploration also has a huge technology component because the sharper our technological tools, the higher the probability that we will find some of the resources we are looking for. (Table 31, 29B2) | |
| | | Case study research | Both firms have invested in exploration. However, a major difference here is the amount invested. RT appears to be far more committed to exploration activities compared to AA. Exploration is important if a firm is to remain competitive and sustainable. Extensive exploration activities are also often commonly linked to widespread transformative technology development that matches the exploration activity. | |

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| | | | AA's purpose, that is to imagine mining differently in a way that will improve the lives of people, will be achieved by creating the ultimate smart mine of the future. AA implies that this smart future will be achieved through exploration and the application of their innovation-centred strategy. RT on the other hand, explicitly mentions this connection. They highlight that their purpose comprises five key activities, two of which are innovation and technology focused. The first activity is utilising cutting-edge exploration technologies in the world to locate new opportunities. The second is channelling innovation activities with the aim of developing every possible area to obtain optimal and long-term productivity. | |
| Transformative technology was not needed in the past, but it is needed now to overcome industry constraints, such as those associated with deep-level gold mining. | The study pointed out the importance of focusing on the development of transformative technology as a means of overcoming industry constraints. The study suggested that incremental improvements in technology will not assist in overcoming challenges. It suggested, rather, that the more time spent on R&D in the pursuit of developing effective breakthrough mining technology, the higher the likelihood that SA will be able to rejuvenate its industry | Qualitative interviews | Past operations have worked well and there has not been a strong business imperative to develop new technology. The consequence of this is the lack of investment in R&D and tech development; this means that today we do not have the right tech that we need because there was no incentive to invest in new tech. (Table 31, 16A8)<br>Maybe it's good enough to be mechanising or modernising in the platinum or the coal sector, but perhaps because of the depths of many of SA's gold | These data points suggest that the industry needs a new approach to mining, in order to rejuvenate successfully. This new approach cannot come from making incremental improvements within the same operating model. It will require radical change to a new operating model.<br><br>They also point out that although there are contextual constraints, such as high levels of unemployment, the industry still requires extensive amounts of radical breakthrough technology—such as automation—to rejuvenate successfully. |

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| | through deep-level gold mining. | | mines, it needs full on automation to remove the people right out of these depths. (Table 31, 5B1) | |
| | | Case study research | High levels of unemployment in SA could influence AA's choice not to automate often, and to choose incremental improvements over radical changes to protect employment. | |
| | | | AA will not automate for the sake of it. They pursue automation only when it can replace a mundane task. AA would move to fully autonomous operations only in exceptional circumstances. In contrast to this, RT focuses extensively on automation to increase productivity and improve worker safety while also reducing environmental degradation and costs. They believe that automation is the future of mining. | |
| Productivity is not prioritised as much as other innovation drivers, but it should be. | This study highlights the imbalanced focus of SA's innovation drive. It suggests that other drivers of innovation are prioritised over productivity. | Qualitative interviews | We are unable to close these efficiency and competitive gaps because we don't prioritise the type of technology needed for massive productivity gains. (Table 31, 1H9) | The study results indicate that the productivity driver of innovation in SA is often neglected. To rectify this, firms would be advised to implement radical technology since this is commonly associated with the benefit of creating vast increases in productivity.<br><br>The productivity increases that are required to close the competitive gaps with global leaders will come from transformative technology that is implemented radically. |
| | | Case study research | Technology implementation in SA does not appear to spread across all drivers of innovation. Only some of AA's innovation programs have been implemented in SA, with the exception of all AA's environmental programs operational in SA. SA has the least focus on efficiency and productivity as drivers, with its greatest focus being on safety and environmental drivers. | |

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| | | | When considering various innovation drivers and their implementation in SA, it is important to note that only one out of three (33%) programme functions target efficiency; three out of seven (43%) target productivity; five out eight (63%) target safety and all six (100%) programme functions targeting environmental benefits were implemented in SA. In comparison to this, Australia's RT operations have 80% (8/10) of their programme functions geared towards productivity, 70% towards safety, and 60% towards efficiency. | |

Source: Author

The findings in Table 32 suggest that SA seems to prioritise technological developments to please certain drivers more than others. It supports the idea that if a country is generally focused on developing technology for environmental causes for instance and not for cost reduction purposes, etc. then the technology portfolio of the industry will not be very well-rounded - affecting its ability to be engrained into every aspect of business thus limiting its effectiveness.

As is very commonly discussed in literature implementing new technology into an organisation, results in many benefits (Lo et al., 2018). These benefits include creating a sustainable competitive advantage, lowering production and labour costs and generally improving business processes (Macaulay et al., 2013). The literature explains that these technological changes are motivated by different drivers of innovation. These drivers can include a focus on improving productivity and business expansion, a focus on reducing environmental impacts, a focus on safety improvements or a focus created through external pressures such as meeting industry standard requirements or requirements from customers (Nguyen, 2009). Nguyen et al. (2013) referred to these pressures as the drivers of innovation. They explained this to be part of the innovation decision process; a process that involves the

management of an organisation assessing the advantages and disadvantages of adopting new technology for different drivers. The literature supports this finding that focusing on one innovation driver over another will influence the type of technology pursued as well as the technological trajectory the firm operates in (Li & Yu, 2018).

This finding is also well supported by Acemoglu et al. (2023), discussed in Zickuhr (2023), who discusses the effects of asymmetry in the technological development of an economy. This work points out that not all innovations are equally created and that it is possible for various factors to distort the direction of the technology development. It illustrates how the direction of technological change pursued by the private sector may become distorted due to various market factors and social considerations.

This finding and the concluding points presented in the information and Table 32 above answer Research Objectives 4 and 5.

RO4. Determine if country contextual conditions (laws, culture, union and labour power) have created a certain path dependency that has trapped the firm in a particular technological trajectory.

RO5. Understand how technological trajectories in South African firms may be opposed to those in Australian firms.

### 6.2.2 SOCIAL UPLIFTMENT SHOULD BE THE OBJECTIVE OF THE INDUSTRY, BUT PRODUCTIVITY THE VEHICLE TO ACHIEVE THIS

The expectation to place social upliftment and correction of past inequalities at the forefront of SA's priorities, was a common sentiment in the data collected during this research. It appears to be well understood that addressing the inequalities of the past should be the main objective of the industry. However, an area lacking clarity was the role productivity should play in achieving this objective. Although there are differing viewpoints on this question, most of the data from this research indicated the existence of an overwhelmingly positive relationship between productivity and achieving social objectives. The data suggested that to promote business sustainability productivity needs to be the priority vehicle. This suggestion does not overlook the importance of all business stakeholders. Rather, it focuses on how a decision to increase productivity will actually impact the long-term interests of a stakeholder. Development efforts that cannot be sustained are somewhat futile, and these cannot be

sustained if they are not productive. As can be seen in Table 33 below, economic growth and development, knowledge-sharing and human capital development, socio-economic upliftment, and innovation are all enabled through a productive firm and a productive economy. Productivity is the vehicle that enables positive change. Table 33 below illustrates the de-prioritisation of productivity in the South African context that has negatively affected its ability to catch up. It indicates that the type of productivity improvements required by the industry would need radical changes to the technology currently utilised—changes that would enable current productivity ceilings to be breached.

Table 33: Concluding points for the link between achieving social objectives and promoting productivity increases

| **Concluding point** | **Research finding** | **Methodology phase** | **Substantiation** | **Implicit or explicit link to the central research question** |
|---|---|---|---|---|
| The study findings suggest that social narratives can cause an imbalance in the type of innovation drivers catered for in different contexts. | The study's findings highlight the human influence factor, and its sometimes-inhibiting effect on the process of technological development. The results suggest that there is often widespread resistance against implementing technology, mainly because of the fear of loss of employment. In the context of a developing country, like SA, this appears to be commonly linked to deprioritising the implementation of technology, such as automation, that greatly enhances productivity but also reduces dependence on labour. This study, however, illustrated that this view is short-term and does not consider the long-term benefit that an increase in productivity, from automation, will bring to stability and sustainability in job security. | Qualitative interviews | A company must understand that they need to be productive if they are truly going to develop their human capacity and the community. (Table 31, 8A2) | This data would suggest that a firm should develop a technology portfolio that caters for the needs of all innovation drivers, and not predominantly those that the context supports. In this case, productivity as a driver of innovation would require a focus on breakthrough technology, pointing directly to the advisability of firms pursuing radical innovations that can break current productivity boundaries. |
| | | | Everything that will benefit the human element of the workforce, in any case, happens through productivity, even the generation of human knowledge happens through productivity. (Table 31, 9A2) | |
| | | | You may come up with a technological model that works for deep-level gold mining and can remove people from harm and increase productivity, but you're actually not helping the society because you're not employing the people, or as many people as previously employed within the mine. And that's where I think the mining industry in SA has got to jump over that hurdle. This hurdle should not only | |

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| | | | think about the jobs of now, but also think about the sustainability of the future of the mine. (Table 31, 7A7) | |
| | | Case study research | AA is potentially more focused on managing social complexities of SA's environment. This could limit strategic focus on technological developments that would radically shift the current way of work compared to RT that is potentially very focused on strategy that would reduce their dependence on labour. This would promote the large-scale development of transformative technology, radically shifting the current way of work. | |
| Social sustainability and productivity are inherently linked. | The findings of this research suggest that displacing the importance of productivity will make the economic and social inequalities of the country worse. | Qualitative interviews | However, only looking at short-term gains is suicidal and not at all sustainable. Only focusing on the now, means absolutely no future. (Table 31, 7A1) | The link that this data displays between societal development and productivity, through advanced technology, would suggest that firms should prioritise the development of radical technology that will produce these increases in productivity, in order to meet social objectives. |
| | | | Without extensive use of innovative technology to ensure productivity, mining has a limited lifespan that cannot be increased. (Table 31, 7A10) | |

Source: Author

The findings in Table 33 above suggest that SA should have a larger focus on productivity as a driver of innovation as a means of addressing the drastic industry decline. This would require a focus on breakthrough technology, pointing directly to the advisability of firms pursuing radical innovations that can break current productivity boundaries.

There is a general consensus, in the current literature, on the need for drastic productivity improvements in South African mining - as an important mechanism necessary to save the

declining industry (McKinsey&Company, 2019). There are, however, mixed views on whether this should be through incremental or radical innovations. Although the conversation around incremental versus radical is still an area not well defined, there are existing bodies of knowledge that support the idea that productivity growth plays an influential role in the development of society (McKinsey&Company, 2019). This notion would then support the finding of this study, which suggests that productivity growth is linked to the development of society. It would also indirectly support the need for the uptake of radical technology as the necessary force behind SA being able to breach current productivity barriers, and positively develop its society.

This finding and the concluding points presented in the information and Table 33 above answer Research Objectives 1 and 2.

RO1. Investigate the unique social institution of SA and assess which dimensions of this system are impeding the economic technological system and affecting the mining industry's ability to catch up with global leaders.

RO2. Compare the strengths and weaknesses of these systems with the systems of a developed country, to determine the best strategic approach for technological evolution in South African mining firms.

### 6.2.3 ANALYSIS OF TRAJECTORY AS OPPOSED TO CONTEXT TO DETERMINE STRATEGY

This research found that, based on the particular socio-economic narrative of a certain context, there can be a certain amount of dictation regarding the type and focus of innovation pursued by the firm. This will, in turn, influence the type of technological trajectory in which a firm operates. It appears that a firm can get stuck in the trajectory that its context dictates. Once it is in this trajectory, it can indeed be very committed to developing its innovation activity, but with limited impact because its commitment is mainly through incremental improvements inside the parameters of this trajectory. This means that every technology implemented will be in line with the expectations of the current trajectory, all of which are likely to prevent drastic change or improvement. This research suggests that in order to break out of current trajectories, radical approaches to innovation are necessary.

Table 34: Concluding points for the use of trajectory as opposed to context to determine strategy

| **Concluding point** | **Research finding** | **Methodology phase** | **Substantiation** | **Implicit or explicit link to the central research question** |
|---|---|---|---|---|
| If context is allowed to govern technological strategy, a firm will pander to its difficult environment without stepping out onto a path that allows growth and positive change. | This research did not overlook the contextual constraints that can impede a firm's ability to leapfrog radically in terms of stages of development. However, it acknowledges these constraints more as stumbling blocks that can be overcome with the necessary strategic and holistic collaboration between industry and government. It also notes that regardless of whether the firm follows a radical or an incremental approach to innovation and technology, these stumbling blocks would in any case still need to be addressed if the country intends to attract investment into the industry. | Qualitative interviews | Automation is great for safety, as less people are underground, and productivity, but the job losses it causes is an issue in developing countries (Table 31, 12B4). | These data points suggest that to catch up with global leaders, the firm has to break out of its current trajectory and for this to happen, a radical approach to innovation and technology is suggested. |
| | | | Job loss is a contextual constraint that will hold a country back from automation adoption. (Table 31, 12B5) | |
| | | Case study research | A catch up with global leaders is unlikely to happen through incremental improvements. Incremental improvements will keep the firm in its current technological trajectory. A catch up will require a radical leapfrog shift to a new trajectory. | |
| It is not so much that a restrictive context stops a firm from conducting innovative activity; it is, rather, that it limits what activity is conducted and this can be counterproductive in many instances in relation to assisting a technological catch up with global leaders. | This study suggests that contextual constraints and firm technology drive should be viewed separately. The former should be dealt with through the joint effort of government and industry activity and the latter should have a separate focus and should prioritise the technological needs of the firm to catch up with global leaders. | Qualitative interviews | Without new technology, the mines will close; if the mines close this will equal an even bigger unemployment problem then if some workers lost their jobs due to technology. (Table 31, 12B8) | These data points allude to the technological catch phrase, "automate or die." They suggest that if a firm does not implement radical technological breakthroughs, such as automation, they will be unable to catch up with global leaders and will become uneconomical thus causing even greater societal unrest than what the initial introduction of radical technology would have caused. |
| | | | We have to try and get onto the automation trend, even at depth. If we don't and we keep labour intensive methods that deep, we will be uneconomical—having an even greater effect on the social inequalities that exist. (Table 31, 19A9) | |

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| | | | SA is not positioned to continue doing well because of all our constraints but also because of our lack of technology investment. If this is not addressed the deterioration of the industry will create terrible socio-economic knock-on effects. (Table 31, 1K2) | |
| | | Case study research | Context is a factor that cannot be overlooked when one is considering an approach to technological innovation. However, this does not mean the context has to control every aspect of the technological trajectory. If a firm in a restrictive environment intends to catch up with global leaders, it appears that this will be unlikely to happen through incremental improvements since these most commonly keep the firm on its current technological trajectory. | |

Source: Author

The restrictive context which is created through human factors, is commonly discussed in literature. The literature agrees with the concern that human factors can tend to impede all things innovation/technological. This is discussed in the work of Nelson (1977) who introduces the concept of the Moon and the Gheto. This work contemplates the question of how it is possible to land on the moon but not be able to solve the problems of the ghetto. It highlights the very uneven performance of many political economies.

Although the literature analyses how contextual factors can create restrictive contexts (Ghebrihiwet, 2019; Hermanus, 2017; Leeuw, 2018; Maisiri et al., 2021; Palavar, 2014;

Pretorius et al., 2021), it does not support the idea that the contextual narrative and the technological needs of the firm should be viewed separately. This finding does not suggest that context should be overlooked. It rather suggests that context be addressed through other public-private partnerships or business initiatives, but not utilised as a determining factor when one is considering the correct approach to technological innovation. If contextual constraints play the dominant role in determining the type of technology needed for mining operations, it may negatively impact the suitability and the successfulness of this technology. This will only worsen the difficult contextual constraints.

This finding and the concluding points presented in the information and Table 34 above answer Research Objectives 3 and 6.

RO3. Analyse the R&D and technological efforts of a firm to assess the extent to which fixing the technological lag in SA is dependent on the firm, and/or the extent to which the firm is at the mercy of its context.

RO6. Identify and characterise differences across technology implementation strategies between South African and Australian mining firms.

### 6.2.4 INVESTMENT UNDERPINS THE ABILITY TO REJUVENATE

The most prevalent theme from this research was the major concern with the declining levels of investment in the SA mining industry. This factor underpins the success of all attempts to rejuvenate the industry. The data illustrated two main areas of concern in this regard; the first is the variety of difficult contextual factors that shape investor climate negatively and the second is the difficult geology of South African mines that creates limits to current technological productivity improvements. This research found that both these constraints require a radical change to the current way of mining to overcome these concerns and allow investment to flow into the country.

Overcoming these difficult contextual constraints may predominantly require extensive government intervention and as mentioned in the finding above, should not be a factor that prevents the implementation of suitable technology required for the firm to succeed. However, the role the firm could play in overcoming these contextual constraints, to attract investment, would be through a radical change to current mining methods, resulting in more profitable

mining activity that will, in turn, be able to contribute to local growth and development (reducing the existence of contextual constraints).

The second investment deterrent is the difficult geology of SA's mining environment that, in some instances, can limit productivity. This concern is a responsibility of the industry. However, the research suggests that the development of this technology can sometimes be neglected because of the difficult contextual issues spoken about in point one. The research indicated that to break this cycle and attract investment, new technology and radical changes to the current way of work are needed to overcome this productivity barrier. The findings suggest that once these dwindling productivity levels are overcome, this could break the cycle, allowing the increased profit to circle back to developing the economy and community, that could, in turn, attract investment into the industry.

Table 35: Concluding points on the need for investment for a successful rejuvenation

| **Concluding point** | **Research finding** | **Methodology phase** | **Substantiation** | **Implicit or explicit link to the central research question** |
|---|---|---|---|---|
| There is an investment crisis in SA given the difficult contextual environment. | The research suggested that developing the investor climate in SA should be a government responsibility and priority as well as a strategic objective through which all other decisions are filtered. | Qualitative interviews | The number one contributor to reduced investment is far less about policy and far more about corruption. People are concerned that what they invest will not be spent in the right way. Corruption in the government has created this image that investment will be squandered on personal gains. This hinders money coming into the country. (Table 31, 1G6) | These data points indicate that a firm should assist with these contextual constraints through running a profitable operation, promoting economic growth, and giving back to the community. However, after this point, they should be advised to acknowledge that this is a government responsibility, and one that should not interfere with the technological needs of the firm.<br><br>The firm should consider what its current technological needs are; these are likely to be radical given the need for vast increases in productivity to save the industry, and they should manage this innovation type in a way that best develops these contextual constraints. They should not neglect |
| | | | SA has not spent enough on educating people to decent standards, this hampers the country. Government has to come to the party in areas like education – they have to make better education systems for all, that produce well educated individuals that can be trained and moulded | |

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| | | | for different jobs. (Table 31, 26B4) | this technological need because of the difficult context. |
| | | | I think the cycle is harsh; difficult context equals declining investment, but declining investment also means worsening context. I think it's best to say that the dwindling investment is coupled with incompetence, lack of education, lack of serious qualifications, poor administration of power stations, roads, dams, airports, all contributing to the decline. To fix this decline both sides of the equation need to be addressed. (Table 31, 1E1) | |
| | | | The South African government haven't done anything to change [its] poor image. They should have an international campaign to lift the image as much as possible. (Table 31, 1E5) | |
| SA's difficult geology causes productivity challenges and contributes to declining investment. | The data suggests that unless the bettering of contextual constraints happens in unison with the prioritisation of technology needed to overcome the declining productivity, the country cannot hope to achieve the desired level of investor confidence. It is only when SA has taken the necessary steps to create an investor climate that fosters sustainable economic growth will it then be able to open the doors to new investment opportunities and build a brighter future for itself. | Qualitative interviews | SA has challenges with labour and capital productivity. This is partly due to lack of new investment into the mining sector, and partly due to geology. (Table 31, 1H2) | These data points indicate that if SA is to catch up with global leaders, they will need to become more efficient and more productive. This points directly to the advisability of firms investing in radical technology that can transform their current operation. |
| | | | These challenges effect commercial viability of products and then products elsewhere in the world become more attractive. All of this has resulted in lost competitiveness; because costs have gone up, efficiencies gone down, productivity has gone down, and we are less efficient than other countries. (Table 31, | |

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| | | | 1H1) | |
| | | | The type of transformative technology which could create more efficiency ultimately spirals into needing to attract more investment and doing more exploration. (Table 31, 1L5) | |
| Reduced investment impacts the entire industry and worsens social difficulties | This study found that a decline in mining investment often causes a decline in surrounding industries and value chains. This poor investment scenario creates a number of negative impacts, such as reduced job creation, slower economic growth in the region, and limited expansion of current and new operations. | Qualitative interviews | Low levels of investment in the mining sector, the drop in FDI, is such a big deal. It affects all aspects of the industry and inhibits growth and long-term success. The mining industry is heavily reliant on FDI. You are not going to get all the capital you need internally; you will have to rely on other sources (Table 31, 1E7). | The multiplier effect that a decline in mining productivity has on the rest of the economy is a strong indication that in order to protect the community and uplift society the firm would be advised to invest in radical technology that has the possibility of creating a turn-around for the industry. |

Source: Author

Increasing costs and declining efficiencies – which contributes to a decline in investment, is a central theme addressed in the literature through the possibility of economics of scale. Scale improvements in productivity are possible from technology. The literature supports the idea that we would be unable to close these efficiency and competitive gaps without prioritising the type of technology needed for massive productivity gains (Deloitte, 2018b; Pretorius et al., 2021).

### 6.2.5 CONCLUDING SYNTHESIS

The above findings indicate how an imbalanced innovation focus and a restrictive context could be contributing factors to why firms in the South African mining industry lag behind their global competitors in terms of technological adoption. It highlights that to properly manage innovation and technology and to optimise the interaction with its environment, a firm should view the needs of its context and its technological needs separately, understanding that by prioritising the technological needs of the firm it will be positively contributing to and

meeting the needs of society. The above findings explain that for firms to negotiate the tension between radical and incremental innovations they should assess their satisfaction with their current technological trajectory. In this case, SA's current trajectory is not well aligned to that of global leaders, and for this reason it is highly unlikely that incremental improvements will enable this catch up. In this case, South African firms would require radical interventions that break them out of their current paths, placing them on a new trajectory that understands the role of productivity as a vehicle to achieve social objectives, one where a catch up is plausible.

## 6.3 THEORETICAL AND PRACTICAL IMPLICATIONS

The above findings have a theoretical implication on the underlying theories, which are the Nelson and Winter Evolutionary Theory of Economic Change and the Neo-Schumpeterian Long Wave Theory, explaining the mechanisms for technological change. There is currently a gap that is overlooked regarding the decision between an incremental and a radical approach to innovation, and to what extent this is influenced by context.

This work brings reconciliation to these seemingly divergent perspectives by shedding light on a link that may exist between these mechanisms of change and the concept of a technological trajectory. This finding suggests that when negotiating this tension, one would acknowledge the role that context has played in creating the existing trajectory. However, context would not be the deciding factor used to determine which approach to innovation is more suitable. Rather, it would be the trajectory. If a supportive or a restrictive context has created a "positive" trajectory that enables a firm to reach its intended goals then the firm should be encouraged to approach innovation incrementally or radically, whichever is most suitable in the given case. Contrary to this, if a supportive or a restrictive context has created a "negative" trajectory that will prevent a firm from achieving its goals, the firm should be encouraged to pursue predominantly radical approaches to innovation to break out of this current trajectory. Utilising the trajectory as opposed to the context to deal with this theoretical tension is beneficial to developing countries. This is because developing countries often have restrictive contexts, and if this is the deciding factor in determining whether a country will innovate incrementally as opposed to radically, it is likely that the country will continue innovating incrementally. This could potentially mean that the needs of only a few innovation drivers are met. This could significantly slow down a chance for catch up.

This is a meaningful theoretical advance since it will, at least potentially, enable scholars, government officials, and mining managers to better conceptualise the application of these theories, thus enabling an improved approach to the management of innovation and technology in mining. This finding is not only a theoretical advance, as mentioned above, but the implications that it could create for the management of technology mean that is also significantly contributes to the mining industry in a practical way. A better management approach may reduce human resistance to technological development, promote appropriate technology development for a wider variety of innovation drivers that cater to all the industry's needs, and ultimately enable a catch up with global leaders.

## 6.4 LIMITATIONS OF THE STUDY

As with other studies of this nature, proposing theory after considering only two firms in the analysis leads to a limitation. It is difficult to generalise the study's findings to other phenomena which are not in the scope of this study, given that the analysis has considered only two examples. However, as was noted by Biniari (2007), her study did not claim that its intention was to test the proposed findings in relation to the entire population, but aimed, rather, to conduct a granular analysis that could be used as a basis to guide future research. Following this approach, the study attempted to mitigate this limitation by using a great deal of granularity and focus on producing in-depth explanations of firm behaviours and relationships.

Al Shamsi (2020), who also conducted a qualitative case study, pointed out that a limitation with case study research is its dependence on subjective data that is informed by the feelings and opinions of the participants. In an attempt to mitigate this a number of activities to enhance trustworthiness, such as triangulating methods, were conducted in this study (Guba & Lincoln, 1985). This approach was similarly seen in work conducted Stake (2005) as cited in Al Shamsi (2020).

Another study limitation is the lack of ability to verify the results of the study. The open-ended nature of qualitative studies is that researchers have a great deal of control over the interpretation and the display of the data. This may reduce the objectivity of the findings as the results may be greatly influenced by what the individual's perception of the data is (Chetty, 2016). However, this was dealt with by keeping a reflexive journal during the data collection and analysis phase, with the intention of detecting any researcher opinions and bias.

## 6.5 AVENUES FOR FUTURE RESEARCH

Future research could include a similar study but one with additional firms in similar contexts added to the analysis. This could include, for example, the addition of a firm in Brazil (for a comparison with the South African context) as well as a firm in Canada (for a comparison with the Australian context). This addition would be useful to foster an understanding of how the theoretical predictions of this study relate to other firms in similar contexts.

Future researchers would be advised to follow a range of different methods. It may be useful for this to still include the qualitative approach to ensure they are able to dig deeply into understanding the complexities of the study. However, they could additionally add a quantitative analysis to this understanding. This would enable them to test the theoretical predictions that have been derived.

Future research could prioritise a prolonged engagement session which could potentially lead to more nuanced insights and richer data, with the intention of enhancing the validity of the findings. Spending additional time in the field is a possible mechanism for future research to overcome the current limitation of subjective findings that can be difficult to verify.

There is also a future avenue for research to extend the understanding of contextual differences described in this study with the addition of how geological differences between mines in different countries may influence their approach to innovation and technology.

## REFERENCE LIST


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## APPENDIX

Appendix 1: Contributions from Existing Literature

Table 1: Primary contributions from previous literature

| Title | Author(s) and Date | Contribution | Knowledge gap | This study's contribution |
|---|---|---|---|---|
| **Innovation in the Mining Industry: Technological Trends and a Case Study of the Challenges of Disruptive Innovation.** | Sanchez, F.<br>Hartlieb, P.<br>(2020) | Very informative study.<br>Explains the critical role innovation plays in the mining industry as a mechanism to improve performance.<br><br>Explains how technological advancements are crucial for exploration, particularly in more intricate scenarios such as deeper ore bodies.<br><br>Includes a review of the drivers of technological development.<br><br>Additionally, it includes a case study analysis that illustrates the technical and economic impacts of implementing a disruptive innovation project. | The case study is conducted in Chile, not SA. | I will build on this study by following their research points, but basing all findings on the South African mining industry. |
| **Implication of new, advanced technology in mining industry and its application in Ivory Coast, China.** | Kouama, A. J. K.<br>Jiang, F.<br>Feng, Y.<br>Zhu, S.<br>(2017) | Discusses the evolution of science and technology.<br><br>Highlights the opportunities for and benefits of increased technology in mining.<br><br>Discusses various types of new | This study is not tested in the South African context so most of the findings regarding the benefits of new technologies are not relevant to SA. | I will build on this study by considering the many benefits of the technologies discussed. I will consider how each of these could be appropriate for the South African context. |

| Title | Author(s) and Date | Contribution | Knowledge gap | This study's contribution |
|---|---|---|---|---|
| | | technological developments, and different uses for each. | | |
| **Mining redesigned – innovation and technology needs for the future – a South African perspective.** | Hermanus, M. (2017) | Discusses SA's difficult context.<br><br>Highlights why the implementation of innovation is necessary to save the mining industry.<br><br>Includes examples useful innovation in mining, such as the use of 3D printing.<br><br>Highlights the importance of changing the business culture to one that will enable the adoption of new technology.<br><br>Explains how the historical context of Apartheid in SA affects mining.<br><br>Considers the distinctive socio-economic system in SA, and lists the problems related to this. | Even though the study is conducted in SA and considers the distinctive socio-economic system in this country, it lists only the problems that exist in this system and does not propose any solutions. | I will build on this study by going a step further than listing all the problems that exist in the socio-economic system in this country; and will instead have a solutions oriented approach. |
| **The nature of mining input technology in SA.** | Leeuw, P. Mtegha, H. (2018) | Discusses SA's context.<br><br>Discusses the importance of economic linkages to ensure growth in the mining industry and economy. Linkages looked at include production linkages (backward, forward, and sideways linkages) as well as other linkages such as consumption, and special and lateral migration. | Even though the study is conducted in SA, and proposes good ideas for growth through increasing linkages, it does not take into account the distinctive socio-economic system in SA. It overlooks various workforce related problems (such as low levels of education and, in some cases, illiteracy) that would affect the implementation and execution of these ideas on growth. | I will build on this study by utilising the insightful knowledge regarding the importance of economic linkages, as a method to combat unemployment caused by mining automation. I will, however, remain sensitive to the contextual factors that South African mining firms operate in, and how this may inhibit these ideas for growth. |
| **Mining Production Optimisation in SA.** | Palavar, D. (2014) | Discusses mining productivity metrics | This study lacks focus on considering how | I will build on this study by adjusting the |

| Title | Author(s) and Date | Contribution | Knowledge gap | This study's contribution |
|---|---|---|---|---|
| | | and points out how production, in South African mining, has fallen so drastically in the last decade.<br><br>Conducts a thorough analysis of factors affecting production.<br><br>Determines whether the production techniques used by South African mining firms are efficient enough to allow SA to compete in an increasingly globalised sector. | technology could be the main technique to increase production and close the gap with global competitors. | focus to how the decline in production can be addressed using technology. I will also consider, given the contextual terrain of SA, whether the implementation of this new technology should be incremental or radical. |
| **FDI technology spillovers in the mining industry: Lessons from SA's mining sector.** | Ghebrihiwet, N. (2019) | Based in the South African context.<br><br>Considers the impact of South African contextual factors.<br><br>Explains the benefits of increased use of technology, including firm benefits and country related benefits such as increased FDI and linkage creation. | Through its use of a quantitative methodology, this study lacks rigour in its understanding of the complex relationships in this phenomenon. | I will extend on this previous study by changing the methodology to a qualitative, comparative case study analysis. This will potentially enable the study to gain more information rich explanations regarding the complex relationships. |
| **The strategic competitiveness of the South African mining industry in the age of the 4IR.** | Pretorius, M.W.<br>Zulu, M.S.<br>van der Lingen, E. (2021). | Based in the South African context.<br><br>Acknowledges the impact of the many contextual challenges that have hampered the success of the industry.<br><br>Elaborates on the opportunities and | Even though the study is conducted in SA and considers the contextual environment that a firm would be operating in; it refers to this context in relation to how it has negatively impacted and contributed to the decline in the | I will build on this study by utilising the information on firm resistance to technological change but will additionally adjust the focus to country contextual challenges that create a resistance to technological change. I will also use these |

| Title | Author(s) and Date | Contribution | Knowledge gap | This study's contribution |
|---|---|---|---|---|
| | | many benefits the 4IR brings for the mining industry.<br><br>Explains reasons why a large number of firms have been unsuccessful in their introduction of new technology.<br><br>Uses their findings of reasons for failure to assist the industry in future innovation strategy development. | industry. It does not refer to this context in relation to challenges that arise when implementing the new 4IR technology. The challenges mentioned are instead in relation to organisational context, such as resistance to technological change or lacking skills.<br><br>In this paper's section on future innovation strategy development, it does not include any mention of how its findings influence the choice regarding incremental or radical technological evolution. | findings to go a step further than the previous paper did, and suggest how these factors influence the choice to follow the radical or incremental approach to evolving technology. |
| **The future of mining in Africa: Navigating a revolution.** | Deloitte. (2018b). | Highlights the many benefits the increased use of technology will bring in the mining industry.<br><br>Explains how 4IR technologies will determine the shape of the future of the mining industry. This includes a discussion regarding the changes that need to take place to support these technologies.<br><br>Suggests a variety of reasons why mining firms should be thinking broadly and radically when it comes to technology implementation. | This paper does not consider the challenges that exist in a developing country that could hamper the implementation of this new technology. For this reason, it does not consider strategic approaches that would best suit the introduction of technology into the South African mining industry. | I will build on this study by utilising the useful and very important information offered, but I will add an additional layer of focus by considering the effect of the challenging operating environment on the implementation. This will be useful for strategic development and technology implementation. |

| Title | Author(s) and Date | Contribution | Knowledge gap | This study's contribution |
|---|---|---|---|---|
| **Factors that Inhibit Sustainable Adoption of Industry 4.0 in the South African Manufacturing Industry.** | Maisiri, W., van Dyk, L., & Coeztee, R. (2021). | Discusses useful information regarding the barriers and drivers to 4IR implementation. This is discussed in relation to specific country contexts. This study was conducted in SA to understand factors that may prevent sustainable development of 4IR in the countries manufacturing industry.<br><br>Follows a qualitative methodology conducting interviews with a variety of specialists in the industry. This approach is useful in ensuring that the results are very specific and are able to reduce the complexity of this problem.<br><br>Identifies important strategies to encourage sustainable adoption of 4IR. This includes understanding the influence of context and implementing appropriate technologies, bolstering policy and regulatory space, repairing the education system, and focusing on developing primary manufacturing. | This study covered a great deal of important information, all of which considered the context in SA, and suggested ways to work through the difficult context. Despite all of this, it is not in relation to the mining industry. It, therefore, lacks relevance.<br><br>It is also lacking in an analysis on the different theoretical approaches to the evolution of technology, and how managers should approach this tension in their management of technology. | I will build on this study by following their research points and a similar use of methodology, but basing all findings on South African mining industry.<br><br>I will also add an additional focus on the important decision managers are faced with, regarding the management of technology (i.e. radically or incrementally). |

| Title | Author(s) and Date | Contribution | Knowledge gap | This study's contribution |
|---|---|---|---|---|
| **Mining-related national systems of innovation in southern Africa: National trajectories and regional integration.** | Fessehaie, J., Rustomjee, Z., & Kaziboni, L. (2016). | Explains some important points that contribute to the formation of a national innovation system.<br><br>Considers how certain dynamics such as skills development, collaborative initiatives between research institutions, industry and government, will shape the innovation system. | Despite the very important points covered in this paper, it does not suggest how these differences in context may influence the trajectory of innovation in a country. | I will include the variables that this study analysed to understand what influences the formation of an innovation ecosystem. I will then use these findings to suggest how contextual inputs may influence the trajectory of innovation in a country. |
| **Innovation in mining: what are the challenges and opportunities along the value chain for Latin American suppliers?** | Olvera, B.C. (2021). | Discusses factors that influence the ability to create an innovative mining industry.<br><br>Highlights the important role R&D plays and discusses the different approaches to R&D. These include in-housed, outsourced, open source collaborations, venture collaborations.<br><br>Discusses the effect these different approaches will have on R&D management.<br><br>Contributes to ideas regarding the interaction between a firm's approach to R&D and their corporate strategy.<br><br>Discusses the importance of | This study is not tested in the South African context so most of the findings regarding the how to approach developing an innovative industry do not take into account specifics of the South African context. It is not relevant to SA. | I will build on this study by adjusting the focus to building this innovative industry within SA.<br><br>I will also consider, given the contextual terrain of SA, whether the implementation of this new technology should be incremental or radical. This would influence the findings on the interaction between type of R&D, strategy and management. |

| Title | Author(s) and Date | Contribution | Knowledge gap | This study's contribution |
|---|---|---|---|---|
| | | innovation along the entire mining value chain.<br><br>Discusses methods in which innovative suppliers can be developed in Latin America. | | |
| **Towards an Integrated Approach to Improving Innovation Management System of Mining Companies.** | Yuliia, L., Olga, g., Svetlana, G., & Irina, V. (2019). | Examines central components of an innovation management system that are necessary for sustaining the innovation practices of a company and improving its innovation performance through radical innovations.<br><br>Highlights central managerial areas where attention should be concentrated to improve innovation capabilities and innovation performance. | Although the paper does mention the importance of pursuing radical/breakthrough type technologies, it does not consider any South African contextual factors that may hamper this. | I will build on this previous study by including the challenges of the South African context, to better understand if a radical approach is the best strategic option for the South African mining environment. This will potentially enable the study to gain more information rich strategies for the future of the mining industry. |
| **Technology trajectories and strategies.** | Bye, P., Chanaron, J. (1995). | Explains the important role R&D plays in the development of a certain technological trajectory.<br><br>Contributes to the understanding around how different | Although this is an excellent explanation of what a technological trajectory is, and how it is shaped differently depending on its support from R&D and investment | I will utilise the important knowledge of what a technological trajectory is and what important R&D activities are necessary for its formation. This will |

| Title | Author(s) and Date | Contribution | Knowledge gap | This study's contribution |
|---|---|---|---|---|
| | | investments will influence trajectory differently.<br><br>highlights the relationship between the amount of resources allocated to developing creative technology and the position of a firm within a technology trajectory. | activities; it does now consider how context will influence the formation of this trajectory.<br><br>The paper mentions that a technological trajectory can take place within a Nelson & Winter, evolutionary approach or a Schumpter, revolutionary approach. It however, doesn't consider how this difference is actually a tension that needs to be navigated by managers in their approach to managing technology.<br><br>This study uses a quantitative approach, which can adequately describe the R&D and investment inputs required in a trajectory, but is unable of explaining complexities that exist around a trajectory or that could influence a trajectory, such as context. | be utilised in the case study to understand what R&D activities the firm is pursuing.<br><br>I will build on these findings by changing the methodology to a qualitative approach to better understand the complexities, such as contextual environment, that may affect the trajectory.<br><br>I will also add an additional focus on understanding how a manager should negotiate the tension between a radical or an incremental approach to technology and understand how this will influence trajectory. |

Source: Author

Appendix 2: Semi-structured Interview Guide (South African Interviewees)

The layout of the interview schedule, set out below, has been built on the interview schedule of a previous study conducted by McCune (2017).

## Semi-structured interview (for South African interviewees)

*A study on embracing technology to rejuvenate South African mining. A comparative case study analysis of a South African and an Australian mining firm.*

## SETTING AND PARTICIPANT DATA

Date of interview:
Time of interview:
Location of interview:
Participant Name & Number:
Occupation:
Contact Information:

## GREETINGS AND INTRODUCTION

Good day Sir/Mam, thank you for agreeing to be a participant in this study. The aim of this research is to understand how technology could be a driving force to rejuvenate the South African mining industry. It also aims to understand how South African managers should negotiate the tension between radical and incremental innovations, in light of contextual imperatives, in their management of technology aimed at closing performance gaps with global competitors.

The interview will be approximately 45 minutes long. The audio from the conversation will be recorded and a transcript will be created which will be sent to you for review. If there are any inaccuracies or additions you would like to make, please advise and I will include them in the revised transcript.

Would you like a copy of the completed study?

May we proceed with the interview or do you have any questions?

**GENERAL INTERVIEW QUESTIONS**

1. How would you explain your experience in the mining industry?
2. What is your position in the company (say the name of company)?
3. How many years have you worked for the company?
4. What qualification do you have (mining degree, financial degree)?
5. Why do you think the South African mining industry has declined so drastically since the early 2000s?

   Prompts:

   - Other than decreasing ore grades, are there other operational problems that could have greatly affected production outputs?
   - What would you say is the biggest barrier in preventing industry leaders from overcoming these problems?
   - Do you believe that increased use of technology could rejuvenate SA's mining industry?
6. List, in order of importance, the different ways in which increased use of technology would be useful to the South African mining industry?

   Prompts:

   - What factors have the greatest influence on your previously mentioned answer?
   - Do you have any past experiences with the use of technology in the mining industry that shaped your view?
7. What impacts could an increased use of technology have on reducing operational costs and increasing productivity (Groenendaal, 2013)?
8. Do you consider investment in technological R&D important to support large scale technological development in the mining sector?
9. Does the effectiveness of innovative technology depend on which commodity is being mined – and why (Groenendaal, 2013)? (They might say it has to do with the orebody or the mining method)

   (Prompt ☺)

   - (Could you please elaborate on your answer?)

10. Do you believe that the effectiveness of new technologies is influenced by company culture and climate?

    Prompts:

    - Do you think that South African mining organisations have a culture that is willing to embrace technological change?
    - If not, what would you say is the biggest area of resistance?
    - How would you suggest this be dealt with?
    - (How would you suggest dealing with resistance from labour unions?)
    - Increased investment in R&D tends to result in long term benefits. Do you think this causes resistance from organisational leaders who may not reap immediate benefits and, therefore, choose largely to stick with current methods?

11. What measures would you recommend putting in place to mitigate reduced employment caused by the increased use of technology?
12. What advice would you give to South African mining firms with regards to technology in order to improve their performance?
13. Do government policies support FDI in South African mining firms?

    Prompts:

    - Is policy uncertainty hampering investment in mining?

14. Do South African government policies encourage investment in technological R&D, promote innovation and the implementation of new technologies?

    Prompts:

    - Do you believe that these initiatives are successful?

15. Do you believe that various country contextual factors (such as …) will affect SA's ability to increase its use of technology?

    Prompts:

    - Listed in order of importance, which contextual factors, would you say, have the greatest effect on implementing new technology?
    - How do you suggest SA should deal with these?
    - Do you consider absorptive capacity to be an important factor regarding SA's ability to become more technologically oriented?

16. Do you believe that absorptive capacity levels in SA are high enough for mining firms to adequately absorb technological knowledge occurring from possible FDI and technology spillovers?

17. Are universities and the industry working together to make sure that individuals with suitable skills enter the mining job market (Groenendaal, 2013)?
18. Does SA have enough skilled people to support large scale technological development in the mining sector (Groenendaal, 2013)?

    Prompts:

    - Is reskilling current mining employees for other positions in the mining value chain an option (Groenendaal, 2013)?
    - What opportunities could be created for reskilled employees (Groenendaal, 2013)?
19. To what extent is a mining company's response to increased use of technology controlled by the strength of contextual factors, (meaning that the response is actually limited)?
20. Why do you think that SA lags behind other countries, such as Australia, in its commitment to technological R&D?
21. How would you suggest that strategic managers in South African mining firms negotiate the management of technology in light of contextual imperatives?
22. What kind of path dependencies in technological trajectories do you believe have been set in motion in SA?

    Prompts:

    - How do you think these path dependencies were initially set in motion?
    - How do you think path dependencies in SA's differ from Australia?
23. Do you think that SA should be trying to replicate various technological implementation methods that Australia has used?
24. Do you think that the adoption of technology should be radical or incremental?

    Prompts:

    - What is your reason for this choice?
    - Do you believe that a country's specific contextual factors contribute to the choice of whether to innovate radically or incrementally?

Appendix 3: Semi-structured Interview Guide (Australian Interviewees)

The layout of the interview schedule, set out below, has been built on the interview schedule of a previous study conducted by McCune (2017).

## Semi-structured interview (for Australian interviewees)

*A study on how embracing technology to rejuvenate South African mining. A comparative case study analysis of a South African and an Australian mining firm.*

## SETTING AND PARTICIPANT DATA

Date of interview:
Time of interview:
Location of interview:
Participant Name & Number:
Occupation:
Contact Information:

## GREETINGS AND INTRODUCTION

Good day Sir/Mam, thank you for agreeing to be a participant in this study. The aim of this research is to understand how technology could be a driving force to rejuvenate the South African mining industry. It also aims to understand how South African managers should negotiate the tension between radical and incremental innovations, in light of contextual imperatives, in their management of technology aimed at closing performance gaps with global competitors.

The interview will be approximately 30 minutes long. The audio from the conversation will be recorded and a transcript will be created which will be sent to you for review. If there are any inaccuracies or additions you would like to make, please advise and I will include them in the revised transcript.

Would you like a copy of the completed study?

May we proceed with the interview or do you have any questions?

## GENERAL INTERVIEW QUESTIONS

1. How would you explain your experience in the mining industry?
2. What is your position in the company (say the name of company)?
3. How many years have you worked for the company?
4. What qualification do you have (mining degree, financial degree)?
5. What do you think is the main reason for Australia's success in the mining industry?
   Prompt:
   - Do you believe that Australia's approach to technology has played a role in this success?
6. In contrast to the increasing success in the Australian mining industry, why do you think the South African mining has declined so drastically since the early 2000s?
   Prompts:
   - Other than decreasing ore grades, are there other operational problems that could have greatly affected production outputs?
   - What would you say is the biggest barrier in preventing industry leaders from overcoming these problems?
   - Do you believe that increased use of technology could rejuvenate SA's mining industry?
7. List, in order of importance, the different ways in which increased use of technology has been useful in Australia?
   Prompts:
   - What factors have the greatest influence on your previously mentioned answer?
   - Do you have any past experiences with the use of technology in the mining industry that shaped your view?
8. To what extent has the increased use of technology had on reducing operational costs and increasing productivity (Groenendaal, 2013)?
9. Do you consider investment in technological R&D important to support large scale technological development in the mining sector?

10. Does the effectiveness of innovative technology depend on which commodity is being mined – and why (Groenendaal, 2013)? (They might say it has to do with the orebody or the mining method)
    (Prompt ☺)
    - (Could you please elaborate on your answer?)
11. Do you believe that the effectiveness of new technologies is influenced by company culture and climate?
    Prompts:
    - To what extent do Australian mining organisations have a culture that is willing to embrace technological change?
    - Have there been any areas of resistance to change?
    - How was this resistance dealt with?
    - Has Australia faced any resistance from labour unions?
    - Increased investment in R&D tends to result in long term benefits. Do you think this causes resistance from organisational leaders who may not reap immediate benefits and, therefore, choose not to increase investment in R&D?
12. What measures have been put in place to mitigate reduced employment caused by the increased use of technology?
13. What measures have Australian mining firms put in place, with regards to technology, in order to improve their performance?
14. What advice would you give to South African mining firms with regards to technology in order to improve their performance?
15. Do government policies support FDI in Australian mining firms?
    Prompts:
16. Do Australian government policies encourage investment in technological R&D, promote innovation and the implementation of new technologies?
    Prompts:
    - Do you believe that these initiatives are successful?
17. Did Australian mining firms have any contextual factors (such as…) that affected the process of increasing their use of technology, and if so how did they overcome these obstacles?
18. Do you believe that various country contextual factors (such as …) will affect SA's ability to increase its use of technology?

Prompts:

- Listed in order of importance, which contextual factors would you say, have the greatest effect on implementing new technology?
- How do you suggest SA should deal with these?
- Do you consider absorptive capacity to be an important factor regarding SA's ability to become more technologically oriented?

19. Do you believe that absorptive capacity levels in SA are high enough for mining firms to adequately absorb technological knowledge occurring from possible FDI and technology spillovers?
20. Are Australian universities and the industry working together to make sure that individuals with suitable skills enter the mining job market, and how? (Groenendaal, 2013)?
21. How has Australia made sure that there are enough skilled people to support large scale technological development in the mining sector (Groenendaal, 2013)?

    Prompts:

    - Has reskilling mining employees for other positions in the mining value chain occured (Groenendaal, 2013)?
    - What kind of opportunities have been created for reskilled employees (Groenendaal, 2013)?

22. To what extent is a mining company's response to increased use of technology controlled by the strength of contextual factors, (meaning that the response is actually limited)?
23. Why do you think Australia is one of the world leaders with regards to its commitment to technological R&D?
24. Why do you think that SA lags behind other countries, such as Australia, in its commitment to technological R&D?
25. How do you think SA could remedy this?
26. How have strategic managers in Australian mining firms negotiated the management of technology?
27. How would you suggest that strategic managers in South African mining firms negotiate the management of technology in light of its contextual imperatives?
28. What kind of path dependencies in technological trajectories do you believe have been set in motion in Australia? (Might have to explain what this is)

Prompts:

- How do you think these path dependencies were initially set in motion?
- How do you think path dependencies in Australia differ from SA?

29. Do you think that SA should be trying to replicate various technological implementation methods that Australia has used?
30. Do you think that the adoption of technology should be radical or incremental?

Prompts:

- What is your reason for this choice?
- Do you believe that a country's specific contextual factors contribute to the choice of whether to innovate radically or incrementally?

Appendix 4: Participant Information Sheet

*Embracing technology to rejuvenate South African mining: a comparative case study analysis of a South African and an Australian mining firm*

Dear Sir/Madam

My name is Tarryn Vink. I am a full-time Master of Commerce student at the University of the Witwatersrand, Johannesburg. I am registered with the School of Business Sciences, in the faculty of Commerce, Law and Management. As part of my studies I have to conduct a research project. I am investigating how embracing technology could rejuvenate South African mining, utilising a comparative case study analysis of a south African and an Australian mining firm.

The intention of this research is to better understand and explain why firms in the South African mining industry lag behind their global competitors in terms of technological adoption. It aims to understand how differing contextual factors influence firms' strategic management responses to the use of technology, and importantly, how these differing contextual factors may influence the choice between an incremental and a radical approach for adopting technology. This knowledge will, potentially, be useful to firms for discovering the most appropriate management approaches to overcome this problem.

I would like to invite you to participate in an individual interview. This activity will involve an online meeting (Microsoft Teams, Skype or Zoom) which will be a maximum of 45 minutes long. With your permission, I would also like to audio record the meeting using the recording tool on the meeting platform. This recording will be stored on a password protected computer and only I will have access to this recording. It will be deleted after three years.

There will be no personal costs to you if you participate in this project. There are no direct benefits for participating and also no disadvantages or penalties if you choose not to participate. You may withdraw at any time and refrain from answering any question. The interview will be

completely confidential and anonymous. Neither your name nor your identity information will appear in the research report. The information you provide will be held securely and not disclosed to anyone else.

If you have any questions about this research, you are welcome to contact me using the details listed below. This study will be written up as a research report which will be available online through the university website. If you wish to receive a summary of the report, I would happily send it to you. The data collected from this research project will be stored in a password protected computer and will be kept for three years. With your permission, the data collected from this research project may be used by other researchers in an anonymised format. If you have any concerns or complaints regarding the ethical procedures of this study, you are free to contact the University Human Research Ethics Committee (Non-Medical): email hrecnon-medical@wits.ac.za or telephone +27(0) 11 717 1408. This research will be conducted under the supervision of Professor Chris Callaghan.

May I ask you please to respond to this email and indicate whether you are willing to participate in the individual interview or not, and if yes, whether you would like a copy of the final research project? If you are willing to participate, I will be in contact with you regarding a suitable date and time for the interview and will provide you with a consent form that needs to be completed and signed prior to the interview.
Thank you for your consideration of the above.
Sincerely,

Tarryn Vink (researcher)
Mobile: +27 76 533 3383
Email: 1636520@studetns.wits.ac.za

Professor Chris Callaghan
Mobile: +27 72 222 2190
Email: chris.callaghan@wits.co.za

Appendix 5: Consent Form

**Embracing technology to rejuvenate south African mining: a comparative case study analysis of a South African and an Australian mining firm**

Researcher: Tarryn Vink

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

(Please circle the relevant options below).

I agree that my participation will remain anonymous
YES
NO

I agree that the researcher may use anonymous quotes in his/her research report
YES
NO

I agree that the information I provide may be used anonymously after this project has ended, for academic purposes by other researchers, subject to their ethics clearance being obtained
YES
NO

I agree that the researcher may audio record the interview which I participate in
YES
NO

……. (signature)
……. (name of participant)

……. (date)

Appendix 6: Ethics Approval

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

Research Office

**HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)**
R14/49 Vink

| | |
|---|---|
| **CLEARANCE CERTIFICATE** | **PROTOCOL NUMBER: H21/09/40** |
| **PROJECT TITLE** | Embracing technology to rejuvenate South African mining: A comparative case study analysis of a South African and an Australian mining firm |
| **INVESTIGATOR(S)** | Ms T Vink |
| **SCHOOL/DEPARTMENT** | School of Business Sciences/ |
| **DATE CONSIDERED** | 17 September 2021 |
| **DECISION OF THE COMMITTEE** | Approved<br>Risk Level: Minimal |
| **EXPIRY DATE** | 27 October 2024 |

**DATE** 28 October 2021 **CHAIRPERSON** J. Wright
(Professor J Knight)

cc: Supervisor: Professor C Callaghan

**DECLARATION OF INVESTIGATOR(S)**

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

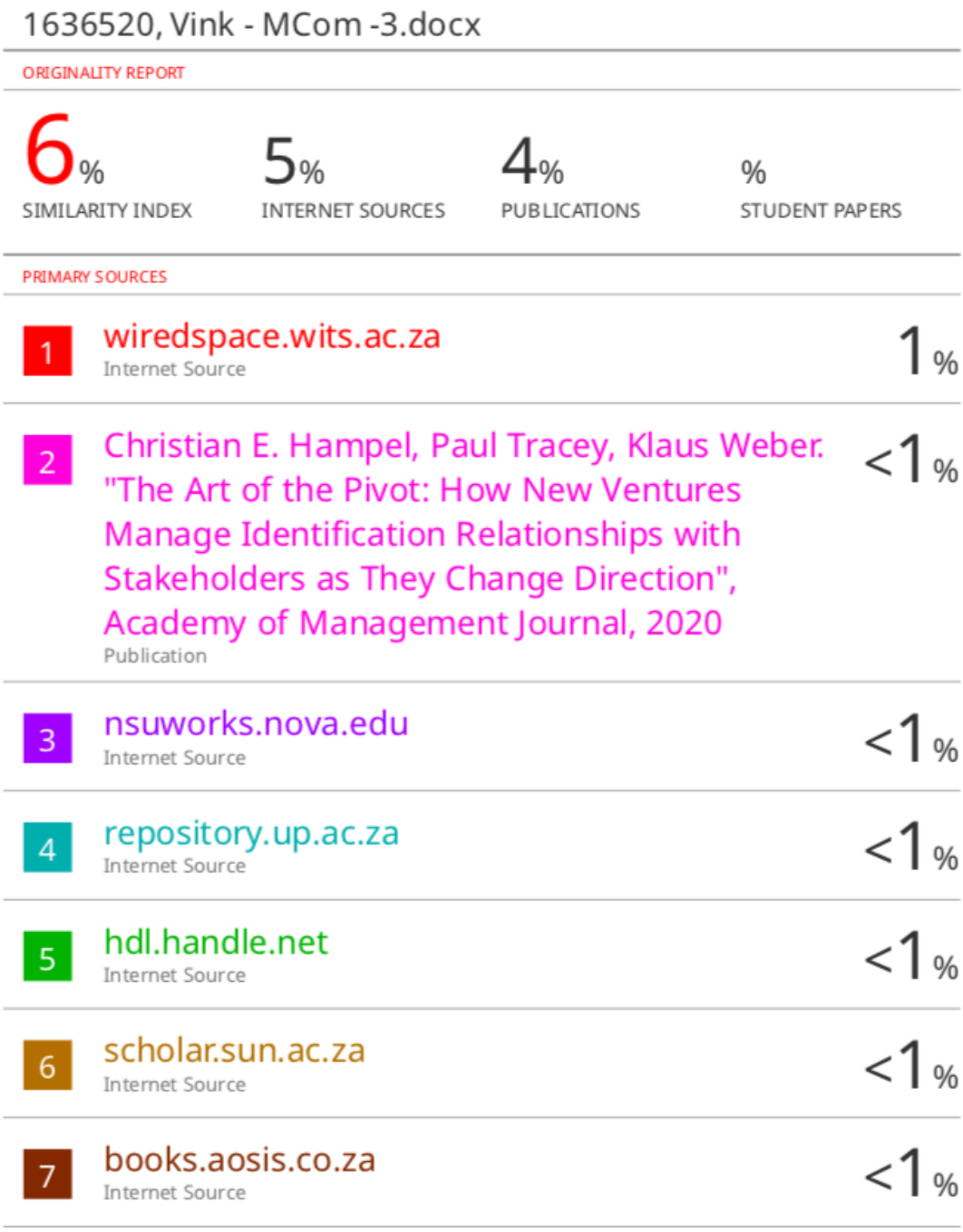
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to submit an amendment of the protocol to the Committee. **I agree to completion of a regular progress report. For Minimal and Low studies, this is due annually on 31 December. For Medium and High Risk studies, this is due twice annually on 30 June and 31 December.**

T. Vink
**Signature**

28 / 10 / 2021
**Date**

**PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES**

Appendix 7: Summary of Turnitin Report



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Appendix 8: Proof of Language Editing

**Ann Smith**

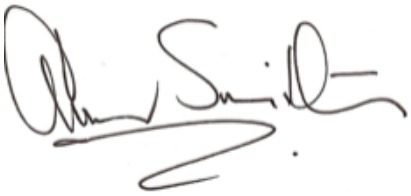
10 April 2024 at 19:01

Details

Editing Tarryn Vink's thesis

To: Tshepo.Mohlakoane@wits.ac.za, Cc: Tarryn Vink

Dear Mr Mohlakoane,
This is to certify that, as an academic editor, I edited Tarryn Vink's thesis entitled "Embracing technology to rejuvenate South African mining: A comparative case study analysis of a South African and an Australian mining firm" and returned it to her on 03 October 2023.
Should you require any further information please feel free to contact me.
Sincerely yours,
Ann Smith.



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