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EFFECTIVE MINING SAFETY WORK PRACTICES IN THE FOURTH INDUSTRIAL REVOLUTION, A CASE STUDY OF DEBSWANA

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A research report submitted to the School of Construction Economics and Management in fulfilment of MSc Building (Construction Project Management)

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Submission Milestone: Final Research Report

DECLARATION

I, Otto Keitumetse, declare that this thesis is the outcome of my own effort and study and that all sources of materials used for the study have been duly acknowledged. This study is my own original work and has not been submitted for any degree or diploma in any other University.

Name: Otto Keitumetse **Date** Oct 20, 2021 **Signature:** Otto Keitumetse

ABSTRACT

It is now globally recognized that the Fourth Industrial Revolution (4IR) represents a fundamental change in the way we live, work and relate to one another, it is a new chapter in human development enabled by extraordinary technological advances. These advances are merging the physical, digital and biological worlds in ways that create both promise and potential. It is inevitable that, as with any revolution the fourth-industrial revolution will effect change in desirable and undesirable ways.

The purpose of the study was to investigate and obtain insights on the effective mining safety work practices in the fourth industrial revolution in Debswana Diamond Mining Company Jwaneng. From the study results, Debswana Jwaneng Mine is faring well with regards to the adoption of the latest technologies. However, the results also noted a need for improved change management as a means of enhancing employee engagement and communication, which have been noted to play a crucial role in the success of adoption of 4IR. Consequently, the study notes the need for a more inclusive approach to 4IR adoption which seek to enhance the mine's preparedness at an individual and organizational level.

Data for the study was collected using a questionnaire which was administered to various stakeholders (76) at Debswana Mining Company such as employees, project managers, and Executive committee members. The subsequent data collected were analysed through the use of Ordinary Least Squares (OLS) and Binary Logistic Regression as well as use of descriptive statistics. Ethical issues were also observed to ensure participants remain anonymous.

Keywords: Fourth Industrial Revolution, Internet of Things, Mining, Safety work practices

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TABLE OF CONTENTS

DECLARATION 2
ABSTRACT 3
ACKNOWLEDGEMENTS 4
LIST OF TABLES 9
LIST OF FIGURES 9
ABBREVIATIONS 9
1. INTRODUCTION 10
1.1 Context of the study 10
1.2 4IR in Botswana 11
1.3 EFFICIENCY 11
1.3.1 Mining History 11
1.3.2 History of Mining Technology 11
1.3.3 History of Mining in Botswana 12
1.4 Health and Safety in Botswana 13
1.5 The Case of the Organization 14
1.6 Problem Statement 14
1.7 RESEARCH QUESTION AND OBJECTIVES 14
1.7.1 Research Question and Aim 14
1.7.2 Aim 14
1.7.3 Research objectives 15
1.7.4 Sub questions 15
1.8 Rationale for the Study 15
1.9 Ethics and Participation 15
1.10 Significant of the Study 16
1.11 Scope of the Study 16
1.12 Study Limitations 16
1.13 Study Delimitation 16
1.14 Research Procedure 17

1.14.1 CASE STUDY 1 17
1.14.2 Case Study 2 18
1.14.3 Case study 3 19
1.15 Conclusion 20
2. CHAPTER 2: LITERATURE REVIEW 22
2.1 Introduction 22
2.2 Concept Definition of Fourth Industrial Revolution 22
2.3 Readiness of Debswana to Adopt 4IR Technology 23
2.4 Safety Work Practices in Mining 24
2.4.1 Safety at Debswana 24
2.4.2 Safety Aspect from 4IR in relation to Mining 24
2.4.3 Design Principles in relation to safety 25
2.4.4 Benefits of 4IR to Mining Sector 25
2.4.5 Opportunities of 4IR 26
2.4.6 Challenges of 4IR 27
2.5 4IR in SHE 28
2.6 Safety in Mining 28
2.6.1 Safety in Botswana 29
2.6.2 Safety in Debswana Mining(statistics) 29
2.6.3 Employee Readiness for 4IR 31
3. CHAPTER 3 : RESEARCH METHODOLOGY 33
3.1 Introduction 33
3.2 Research Philosophy/paradigms 33
3.3 Research philosophies/paradigms adopted by the study 33
3.3.1 Interpretivism 33
3.3.2 Research Design 33
3.3.3 Research design adopted 35
3.4 Framework for analysis 35
3.5 Research Approaches 35
3.5.1 Deductive 35

3.5.2 Inductive 35
3.6 Research Approach adopted for study 35
3.7 Target Population and Sampling Method 36
3.8 Research Strategy 36
3.8.1 Case Study method 36
3.9 Data collection procedure 37
3.10 Data Analysis Plan 37
3.11 Data Presentation method 38
3.12 Validity and Reliability 39
3.13 Ethical Considerations 40
4. CHAPTER 4 : DATA PRESENTATION ANALYSIS AND RESULTS 41
4.1 Introduction 41
4.2 Analysis of Data and Interpretation of quantitative results 41
4.3 Demographic Information 42
4.4 Results summary 44
4.4.1 Research question 1: What is the role of employee traits on perceived 4IR career development readiness? 44
4.4.2 Research question 4: What are the employee perceptions of SHE safety state of Slope Stability, PPE and Collision avoidance 46
4.4.3 Research question 5: What are the employee perceptions of Opportunities presented by 4IR 50
4.4.4 Research question 6: What are the employee perceptions of threats presented by 4IR 52
4.4.5 Research question 7: What are the employee perceptions of the role of change management and employee experience of change management 55
5. CHAPTER 5 :DISCUSSION OF RESULTS 57
5.1 Introduction 57
5.2 Objective 1:Assess Debswana Mining Company SHE safety practices 58
5.2.1 Adequacy of current technology 58
5.2.2 Inadequacy of current technology 58
5.2.3 Uncertainty and lack of knowledge 58

5.3 Objective 2:To assess the effectiveness of employee preparedness, knowledge and characteristics on SHE 4IR impacts and perceived opportunities and threats of 4IR 59
5.4 Objective 3 : To evaluate the success and challenges of the current safety practices in relation to the 4IR Debswana Mining 60
5.4.1 Inadequacy of change management 60
5.4.2 Adequacy of change management 60
5.5 Summary of findings 60
6. CHAPTER 6: CONCLUSIONS, LESSONS LEARNT AND RECOMMENDATIONS 63
6.1 Introduction 63
6.2 Recommendations 63
6.2.1 Recommendation 1: Review of change management processes 63
6.2.2 Recommendation 2: Slope stability monitoring 64
6.2.3 Recommendation 3: Wearable devices 64
6.3 Direction for future research 64
6.4 Conclusion 64
7. REFERENCES 65
8. APPENDIX 70

LIST OF TABLES

Table 1-1:Discovery dates and location of mines 13
Table 1-2:Slope Monitoring systems 17
Table 1-3:CAS Pro Monitoring System 19
Table 2-1:Debswana Mining Safety Stats 30
Table 3-1:Divisions & Sample 36
Table 3-2:Instruments, reasons for method, population and sample size 37
Table 4-1:Frequencies of study participants by age and gender 42
Table 4-2:Frequencies age and academic qualification 42
Table 4-3:Age and Duration of employment 43
Table 4-4:Level of employment 43
Table 4-5:Binary logistic regression 45

LIST OF FIGURES

Figure 1-1:History of 4IR 10
Figure 2-1:IoT technology use: remote tracking 26
Figure 3-1:Research Process Onion 34
Figure 3-2:Research Model 39
Figure 4-1:Awareness of 4IR 44
Figure 4-2:Slope Stability Safety Perceptions 46
Figure 4-3:PPE Safety Perceptions 47
Figure 4-4:Collision avoidance Safety Perceptions 49
Figure 4-5:Individual level Employee perceptions of 4IR opportunities 50
Figure 4-6:Organizational level Employee perceptions of 4IR opportunities 51
Figure 4-7:Individual level Employee perceptions of 4IR threats 53
Figure 4-8: Organizational level Employee perceptions of 4IR threats 54
Figure 4-9:Change Management Perceptions 55

ABBREVIATIONS

DEBSWANA	Debswana diamond mining company
4IR	Fourth industrial revolution
IoT	Internet of things
BOPA	Botswana press agency
IT	Information technology

1. INTRODUCTION

1.1 CONTEXT OF THE STUDY

The fourth industrial revolution describes a world where individuals move between digital domains and offline reality with the use of connected technology to enable and manage their lives (Schwab, 2015). The first industrial revolution began in 1760 with the invention of the steam engine. The steam engine, as noted by Prisecaru (2016), allowed the transition from farming to the new manufacturing process. This transition included the use of coal as the main resource while trains were the main means of transportation (Prisecaru, 2016). The First Industrial Revolution began when humans moved away from using animals and, instead, employed mechanical power by the use of machines based on water and steam (Westrich, 2017). The Second Revolution came around the 20th century with the introduction of new power generation, electricity and conveyer belts bringing about mass production (Sung, 2018). The Third Industrial Revolution came with the digital systems, the emergence of modern computers, communication technology and automation of production. Presently, the Fourth Industrial Revolution, also known as the digital revolution, builds on the progress made by its predecessor. This revolution is now characterized by a fusion of technologies that are blurring the lines between physical, digital and biological spheres (Wolf & Lambert, 2017). Figure 1-1 shows 4 phases of industrialisation from the first industrial revolution to fourth industrial revolution;

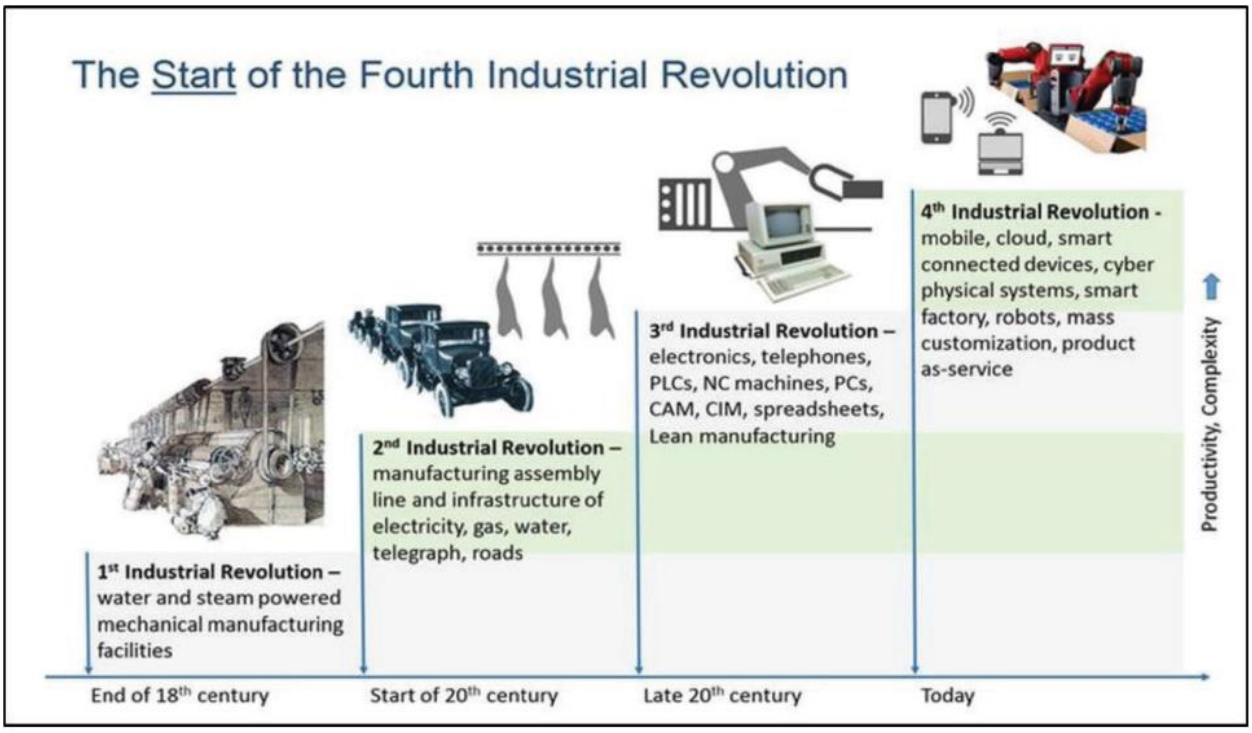

Figure 1-1:History of 4IR

Source: DFKI (2011)

1.2 4IR IN BOTSWANA

Botswana continues to underperform, especially with two of the drivers of 4IR, namely internet of things (IoT) and High-Speed Mobile internet. Digitalisation requires good speed and internet connectivity. Botswana experiences a never-ending cycle of slow to poor internet speed from service providers despite development in technologies and devices used (Moswete et al, 2019). Furthermore, Kaniwa & Phuthego (2019) highlight that 38% of the country, specifically the rural areas, experience low internet connectivity, with collaborative government interventions such as Kitsong centres gaining traction all over the country. This, although being a welcome development, does not address the concern over exorbitant internet prices in the country (Evans, 2019).

Consequently, to date, Botswana is not fully prepared with regards to the Fourth Industrial Revolution but is making strides towards the provision of resources that can enable such a transition. President Mokgweetsi Masisi highlighted Botswana's embrace of 4IR as a means of diversifying the economy away from diamonds through the creation of an entrepreneurial spirit enabling environment that would lean towards a knowledge-based economy (Preuss, 2019). However, as is noted by Mothobi (2017), the internet penetration of Botswana stands at 59% with such internet being characterized low value connectivity for higher prices, the consequences of which have implications on the country's resolve to embrace 4IR.

1.3 EFFICIENCY

Efficiency is the degree to which objectives are achieved and the extent to which targeted problems are solved. In contrast to efficiency, effectiveness is determined without reference to costs and, whereas efficiency means "doing the thing right," effectiveness means "doing the right thing. Effective strategic safety measures are derived by customizing controls relevant for specific environment in order to minimize unwanted events like injuries and reduce exposures.

1.3.1 MINING HISTORY

Mining is the extraction of materials from the earth. Materials that are mined cannot be grown or created artificially. However, they are normally of economic value to the miner. The earliest mines date as far back as 43000 years. Such mines are found in Eswatini (Swaziland) and Hungary.

1.3.2 HISTORY OF MINING TECHNOLOGY

Early miners used primitive tools for digging. Mining shafts were dug out by hand or using stone tools, making the entire process very lengthy. Eventually, the pick and hammer were replaced with fire to clear tunnels and reach greater depths at a faster rate (Brown, 2012). By piling a heap of logs near the rock face and burning them, the rock weakened and fractured. Mining technology leaped forward again in the late Middle Ages when miners started using explosives to break up large rocks. Black powder reached the West, likely from China. Black powder was eventually replaced with dynamite in the mid-

19th century. At the same time, advancements were being made in motorized mining tools, such as drills, lifts and steam-powered pumps (Coulson, 2012).

The Industrial Revolution spurred improvements in explosives and mining equipment. Mechanical drills powered by pistons, then compressed air, significantly increased the capability and efficiency of mining hard rock. Improvements in other mining processes occurred too (Sung, 2018). Hand-powered loading and hauling was replaced by electric conveyors, mine cars, and vehicles. Steam-driven pumps solved the problem of water inflow. Candles and oil-wick lamps were improved by gas lamps, and eventually battery-powered lamps. Mechanization and new technology sparked dramatic improvements in mining techniques (Coulson, 2012). The history of mining is rich and complicated. Mining has led to great advancements for society, but the dangers of mining have also resulted in the deaths of many workers. As technology continues to advance, however, mining techniques become even more accurate and efficient. In the future, revolutionary technologies may eliminate the need for hands-on involvement from miners entirely.

1.3.3 HISTORY OF MINING IN BOTSWANA

Botswana has maintained one of the world's highest economic growth rates since it attained political independence in 1966. It has transformed itself from being one of the poorest countries in the world to a middle-income country, with a per capita GDP of $16,800 (World Bank,2010). Botswana's mining history has been episodic. Table 1-1 shows the dates and locations of where the main minerals were discovered.

Table 1-1:Discovery dates and location of mines

Name of mining town	Location by district	Mineral	Year discovered	Population
Francistown	Northeast	Gold	1866	100,079
Orapa	Central	Diamond	1967	9,544
Letlhakane	Central	Diamond	1975	20,841
Selibe Phikwe	Central	Copper nickel	1966	49,742
Jwaneng	Southern	Diamond	1975	18,063
Sowa	Central	Soda ash	1991	3,599
Morupule (Palapye)	Central	Coal	1973	36,211...

Sources: Gwebu (2013)

Botswana mining has been dominated by open pit mining methods except the three operations being the Selibe Phikwe copper nickel, the Francistown Gold and the Morupule coal mines. All the Four Debswana mines are open pits and this technology was introduced by DeBeers mining company into Botswana.

1.4 HEALTH AND SAFETY IN BOTSWANA

Occupational health and safety in Botswana is regulated by various pieces of legislation. The principal laws are the Factories Act; the Agrochemicals Act; the Mines, Quarries Works & Machinery Act; the Radiation Protection Act and the Workers Compensation Act.
These laws provide for the safety, health and welfare of persons employed in factories and other places and the safety and inspection of certain plants and machineries (Factories Act); the registration and licensing of agrochemicals; the control or regulation of their importation, manufacture, distribution, use and disposal, so as to prevent pollution to the environment or harm to human, plant or animal life (Agrochemicals Act); the safety, health and welfare of persons engaged in prospecting, mining and quarrying operations including any works which are part of and ancillary to mining and quarrying operations (the Mines, Quarries Works & Machinery Act); and the compensation of workers for injuries suffered or occupational diseases contracted in the course of their employment or for the deaths resulting from such injuries or diseases (the Workers Compensation Act). Other provisions affecting

the safety, health and welfare of workers are contained in the Employment Act. In addition, there are several Regulations and Statutory Instruments published in terms of these laws.

1.5 THE CASE OF THE ORGANIZATION

Debswana Diamond Company (Pty) Limited is a unique partnership between the Government of the Republic of Botswana and the De Beers Group of Companies. The company was incorporated on 23 June 1969 under the original name of De Beers Botswana Mining Company (Pty) Limited. The name was changed to Debswana Diamond Company (Pty) Limited on 25 March 1992. Debswana is the world's leading diamond producer by value and the largest private sector employer in Botswana, with more than 5 000 employees and 6 000 contractors. Debswana operates four diamond mines in central Botswana. The mines owned and operated by Debswana are; Orapa diamond mine, Letlhakane diamond mine, Jwaneng diamond mine and Damtshaa diamond mine, this research will focus on these four mines (Debswana, 2016).

1.6 PROBLEM STATEMENT

Debswana Diamond Company has delivered significant value to all its stakeholders and shareholders for 50 years. Debswana again finds itself on the edge of an amazing opportunity as it develops its strategy and prepares for its significant and ambitious expansion plans. Though the expansion are necessary, the main problems lies in safety and applicable 4IR work practices. Debswana Mining problem arises from safety and technology complexities hence the centred problem statement is " **EFFECTIVE MINING SAFETY WORK PRACTICES IN THE FOURTH INDUSTRIAL REVOLUTION**, the case of Debswana Mining Company.

1.7 RESEARCH QUESTION AND OBJECTIVES

The following presents the research question, aim and research objectives

1.7.1 RESEARCH QUESTION AND AIM

The research aim is to explore opportunities and challenges that will be encountered at Botswana Mining Companies in the 4IR and document lessons from Debswana Mining Company experience for the benefit of interested stakeholders. The main principal research question is;

To understand how the emergence of fourth industrial revolution will affect Mining in Botswana in terms of operations and safety.

1.7.2 AIM

To assess, analyse the effectiveness of mining safety practices and the impact of the fourth industrial revolution on the Debswana Diamond Company mines

1.7.3 RESEARCH OBJECTIVES

- Assess Debswana Mining Company SHE safety practices
- To assess the effectiveness of employee preparedness, knowledge and characteristics on SHE 4IR impacts and perceived opportunities and threats of 4IR
- To evaluate the success and challenges of the current safety practices in relation to the 4IR Debswana Mining
- To consolidate and recommend ways to develop Debswana Mining Company safety practices and philosophies that can be aligned to the 4IR.

1.7.4 SUB QUESTIONS

The below are the sub questions which will enable objectives to address the problem;

- What is the role of employee traits on perceived 4IR career development readiness?
- What are the employee perceptions of SHE safety state of Slope Stability, PPE and Collision avoidance?
- What are the employee perceptions of Opportunities presented by 4IR?
- What are the employee perceptions of threats presented by 4IR?
- What are the employee's perception of safety presented by 4IR?
- What are the employee perceptions of the role of change management and employee experience of change management?

1.8 RATIONALE FOR THE STUDY

The rationale of this study and research is to assess the effectiveness of mining safety work practices in the Fourth Industrial Revolution. The organization understudy is Debswana Diamond Mining Company in Botswana. This study will assess the safety practices in mining and provide possible improvements to the current practices.

1.9 ETHICS AND PARTICIPATION

The survey questionnaires were kept anonymous for confidential and ethical reasons.

- The partakers were noted as an available sample of employees working in Debswana. A random sample method of a population of employees was used to avoid bias.
- Employees and Managers were briefed about the aim of the research and why their participation is essential.
- Participants were notified that their contribution is voluntary, made aware of the freedom to pull out from the research at any point if not interested.
- Participants have autonomy and are aware that their participation in the research should not be a stress factor.

1.10 SIGNIFICANT OF THE STUDY

The management of Debswana Mining Company will benefit from this research project by knowing how implement the effective safety mining practices that have significance of improving safety without affecting the performance levels of their employees and thus increase their productivity. To the employees of Debswana Mining Company, the research will help them to better understand the need for change and thus welcome changes taking place within their departments with no resistance. The government will use this information to advice other government institutions whether state owned or private owned on how to undertake change management without compromising on the employee performance within their organizations.

Mining Engineers and Experts together with other mining companies such as Khoemacau will benefit from the findings of this research. Precisely, this research project will be of assistance to the students of the Botswana International University of Science and Technology as it will act as a scholarly reference material. This study may contribute to the literature on safety mining and 4IR and the study will improve understanding and awareness of the meaning of mining safety practices and sustainability at a conceptual level as well as.

The results should add value to the existing body of knowledge on Mining upon which the research community, Botswana organisations, and industries, in general, could build on and utilize to rectify any unsubstantiated perceptions they might have had regarding the importance of safety and mining.

1.11 SCOPE OF THE STUDY

The scope of the study is focus on asses, analyse the effectiveness of mining safety practices and the impact of the fourth industrial revolution on the Debswana Diamond Company mines In this regard, the research sought to obtain information on various change(s) that has taken place, and is on-going within the mine to conduct the research and access information from participants.

1.12 STUDY LIMITATIONS

The study limitations arise from Cost and time will lead to collection of data on a small population. Also, the number of respondents may be low and Issues concerning ethics to be discussed further. The minimum sample size differs from discipline to discipline for a credible study. It may be advisable to expand the sample size in further change management research studies.

1.13 STUDY DELIMITATION

The constraints from the study are the access in to the Debswana for the research team, Security clearance delays or rejection and Operational pressure which might impact on the interviewee responses.

1.14 RESEARCH PROCEDURE

The research information was obtained through the questionnaire distributed in the organization across the different levels of employees. Standardized questionnaires were used in the empirical study. A factual questionnaire, entailing participant's gender, age, race, educational background and years employed is included in the measuring batter. Questionnaires were composed of closed end questions, statements that mandatorily need Likert-scale use and open questions to provide opportunity for suggestions from participants.

The context of the research is based on the effectiveness of 4IR in three key safety area in Debswana which over the years have been a safety concerns to the operations wherein an analysis was undertaken of each safety risk log processes, strengths, weaknesses, and lessons learned. The identified case studies for the research were chosen based on their varying degrees. These are:

1.14.1 CASE STUDY 1

1.14.1.1 Slope Monitoring System

The slope monitoring systems used at Jwaneng mine are summarized in the Table 1-2 below. Also included is the data acquisition method for transferring data from the instrument to the control room.

Table 1-2:Slope Monitoring systems

Instrument	Technology	Data acquisition
Slope stability Radar (SSR) radar	Real aperture radar	Remote data acquisition - Radio
Work Area Monitor (WAM)	Real aperture radar	Remote data acquisition - Radio
Imaging by Interferometric Survey (IBIS) radar	Ground based synthetic aperture radar	Remote data acquisition - Radio
Satellite InSAR	Satellite borne synthetic aperture radar	Remote data acquisition - 3rd party
Inclinometers	Geotech sensors	Remote data acquisition - GPRS
Time Domain Reflectometers	Geotech sensors	Remote data acquisition - GPRS
Tiltmeters	Geotech sensors	Remote data acquisition - GPRS
Prism monitoring	Geodetic	Remote data acquisition - Radio
Laser scanner	Geodetic	Remote data acquisition - Radio
GPS continuous operating reference stations (CORS)	Geodetic	Remote data acquisition - Radio
Precise Levelling	Geodetic	Remote data acquisition - Radio

Chiwaye et al (2015)

Each of these systems comes with its own data visualization & analysis packages. However, for more effective data management, Debswana partnered with GIS company ArcGIS to develop an integrated platform from which the data of all the systems can be viewed & analysed in one place.

The monitoring systems all have alarm thresholds that are set so as to send notifications to Geotech personnel when displacement exceed the trigger levels. The notifications are via email and sms. Control room servers & monitoring systems can be accessed remotely by the Geotech personnel from PCs in the control, from PCs in the Geotech office, or from home using tablets and all connections are via Wi-Fi.

Data analysis & interpretation is carried out manually by trained Geotech engineers, after which decisions are taken regarding the appropriate response to an alarm.

1.14.2 CASE STUDY 2

1.14.2.1 Collision avoidance

The Debswana Dispatch system uses the HxGN MineProtect Collision Avoidance System Pro 360-degree proximity detection via a non-intrusive cabin display unit protecting all mining vehicles, assets, and vehicle operators in open pit mines. Mines can be dangerous places. Heavy traffic, large equipment, poor visibility and blind spots all create the potential for accidents. The mining industry demands world-class operational performance and the highest safety levels. That means minimal traffic-related incidents with all safety data accessible digitally.

HxGN MineProtect Collision Avoidance System Pro (CAS Pro) helps mines achieve these goals. CAS Pro is the leading technology for proximity detection, built on eight years' expertise with more than 25,000 units at work worldwide.

Table 1-3:CAS Pro Monitoring System

CAS Pro		
POSITIONING:	PRODUCT/FUNCTIONALITY:	CONDITIONS:
Superior functionality plus integration with VIS and all other safety products	• Same functionalities as Advantage plus: • Automatic ramp detection • Tailgating alarm • Integration with all HxGN Mine Protect products (Fatigue Pro, Tracking Radars, FMS, PA, SCS, Etc.)	CAS FW 4.0 or above, required for VIS

1.14.3 CASE STUDY 3

1.14.3.1 Personal Protective Equipment

In pursuit of the Zero harm Debswana is committed to implement standards of safety, health and environment. Debswana subscribes to the ISO 14001, OHSAS 18001. Provision of PPE to employees doesn't eliminate the hazard but only shields them, hence training to personnel to identify hazards is paramount in the Debswana culture.

Debswana mine implemented a new phenomenon of Triple Zero concept (000), where the mine will achieve Zero Injuries and progress the company's safety culture to mate ship by 2021.

Triple Zero simply put refers to

- Zero First Aid Injuries,
- Zero Medical Treatment injuries and
- Zero Lost time and Restricted Work Injuries

This is driven by Debswana's aspiration of ZERO HARM which is a personal believe that injuries are preventable. The Triple ZERO Campaign will drive the ZERO HARM aspiration.

To achieve 0.00 TRIFR by 2021 through:

- Prevention of reoccurring incidents
- Creating an excitement in the workplace about safety

- Encouraging knowledge sharing of incidents within departments
- Encouraging the departments to maintain the basic cardinal rules
- Improving safe working culture

1.15 CONCLUSION

This chapter has explored the background basis upon which this study is carried out based on the topic of study; this chapter outlines the background of the study. It includes the description of the statement of the problem which gives the reason as to why the study has been conducted. It also gives the objectives guiding the study, significance and the scope of the study. Therefore, this acts as the principle upon which literature is reviewed, research carried out and analysis made. The current and available literature based on the research problem, and the research propositions that may result from the research conducted will be highlighted, and further explored in the following chapter.

This thesis entails six chapters as per details below:

Chapter 1: This chapter provides an overview and context of the study by introducing, defining key concepts and providing the rationale for the study. In this chapter, a high-level synopsis of the methodological choice is included.

Chapter 2: In this chapter, the perspectives on Safety 4IR/Mining and the growing trends in the technology sector globally and within the Botswana context are discussed. The chapter further reviewed the legislative frameworks that exist on the mining, with a consideration of stakeholders the modalities on the processes, levels of participation, which models and processes are currently used and the various levels of participation. This chapter concludes with a reflection on the effects, challenges and the critical success factors of safety in Mining.

Chapter 3: The chapter reflects on the methodological choice for the study reflecting on the philosophy, assumptions and research methodology regarded suitable for the study. Furthermore, detailed discussions on the case study research strategy, data collection techniques used, analysis and presentation of the research report are delineated. Including the justification of the case study method chosen and rationale for using a comparative case study of three cases in Debswana.

Chapter 4: This chapter ensues with a detailed introduction and profile of the three case studies and reports on the data collected through project reports, and questionnaires with research participants who were involved including results of an online survey of data gathered from project managers, planners, and stakeholder relations managers. The data was analysed and presented succeeded by results and discussions in chapter 5.

Chapter 5: In this chapter, the results are presented in a linear narrative form and discussed flowing from the reports as presented in chapter 4. This has been processed in reflection on the context of the

study and juxtaposed to the research objectives and questions including the literature that supports the study.

Chapter 6: Conclusions are drawn in this chapter, the contribution to the body of knowledge on the Critical success factors of effective safety practices in the 4IR. This chapter concludes by making recommendations for future research.

In summary, this chapter highlighted the context within with the research study was undertaken, where the problem statement, research question and objectives were clearly defined. The problem statement suggested that the complexity of infrastructure projects with various stakeholders' expectation is often met with different outcomes at implementation. The ensuing chapter on literature review will provide greater details on literature that was consulted to support the problem statement and the study undertaken in the investigation of the modalities and critical success factors of infrastructure project implementation.

2. CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

This chapter reviews the literature from other researchers who have studied the same field to the extent and state of knowledge on safety, mining and 4IR. According to Mugenda and Mugenda (2003), review of literature involves the systematic identification, location, and analysis of documents containing information related to the research problem being investigated. Moreover, literature review helps determine new approaches and stimulates new ideas. The chapter covers; theories related to the concept of change management and employee performance**.** The chapter further presents empirical literature and gaps to be filled, summary and the conceptual framework of the study.

2.2 CONCEPT DEFINITION OF FOURTH INDUSTRIAL REVOLUTION

The Fourth Industrial Revolution has been developing since the start of the 21st century. It is a revolutionary change characterized by mobile Internet; stronger sensors; and artificial and machine learning (Schwab, 2017). The concept of the Fourth Industrial Revolution is defined as the revolutionary change based on recent new and diverse technologies. The Third Industrial Revolution focuses on the shift from the conventional fossil fuel-based society to the renewable energy. However, the zero marginal cost society concentrates on the absence of the typical increasing marginal cost, which is caused by the spread of the latest IT, such as the Internet of Things and the 3D printer (Brynjolfsson & McAfee, 2015).

Fourth Industrial Revolution dawned with cyber-physical systems (CPSs), the Internet of Things (IoT), and services. 4IR includes the following: smart factories, cyber-physical systems, self-organization, new systems in distribution and procurement, new systems in the development of products and services, adaptation to human needs, and corporate social responsibility (Manyika *et al,* 2017). Finally, the Fourth Industrial Revolution can be defined as the revolutionary change that occurs when IT proliferates in all industries, that is, the primary, secondary, and tertiary industries. In other words, 4IR is a result of the horizontal expansion of IT. Therefore, the Fourth Industrial Revolution features the creative connection between technology and the market in all industries based on IT, that is, the creative and open combination of technology and the market through open innovation, or growth based on the open business model (Covey, 2005).

The continued rise in operating cost and complex ore bodies that have an impact on safety and the health and wellbeing of employees are putting pressure on mines to think differently about how they should operate. Mines are also working with a younger workforce that expect career progression and growth and continuous legislative changes forces mines to rethink how technology will enable them to be more efficient, effective and compliant.

Mines have an assortment of emergent opportunities when designing their digital mine, from integrated efficiencies through digitally enabled technologies to complete overhauls of business models. Dangerous, labour-intensive extraction processes will transition to safe, remote monitoring of equipment. Digitised processing will change the number of mining personnel required as well as the nature of their skillsets. Workforce mobility and flexibility will better align the timing of needed skills with the remuneration structure of those employees.

Adoption of digital technologies carry broader implications for the communities in which mines operate. Fears around job reductions as well as emerging opportunities to invest in affected communities together inform the socio-economic considerations for the digital mine.

The 4IR has brought significant changes in the manner in which organisations are run. Today's leaders have to constantly monitor and examine their organisations' strategies and visions. Tellis (2014) noted that most organisation fail to succeed due to lack of visionary leaders. Most organisations succumb to technological changes due to leader's unwillingness to execute their visions (Tellis, 2014). Yordsala, Tesaputa and Sri-Ampai (2014) also argued that organisations, nowadays, require leaders with vision and who possess high levels of flexibility. The trade unions opposition to mechanisation of mines is a clear demonstration that trade union leaders are not so flexible towards changes in the industry. Yordsala et al (2014) further argued that leaders should show readiness for technological changes .

2.3 READINESS OF DEBSWANA TO ADOPT 4IR TECHNOLOGY

Masokola (2019) stated that Debswana intends to take a lead in embracing technology for better business results. Being the largest private sector employer and biggest source of business after government. Recently Orapa Letlhakane & Damtshaa Mines (OLDM), the largest diamond mining operation in the world by volume reiterated the company's commitments to tapping into digital revolution and leveraging on the advancement of the fourth Industrial Revolution for better business output.

The Mine hosted Expo on Risk Management Business organized by Risk Management Division under the theme: "Disruption, Data, and Digitization." The expo comprised of risk management businesses and stakeholders, amongst others insurance companies, plant and equipment hiring operations. The key proceedings at the expo were conversations and opinions around the evolution of risk management functions and businesses in general into fundamental components and participants of The Fourth Industrial Revolution (4IR), as well as stall exhibitions. OLDM General Manager, Bakani Motlhabani (General Manager – OLDM) noted that modern technology is in charge and it affects all aspects of human existence, from communication, travel and most importantly how businesses operations are run (Masokola, 2019).

2.4 SAFETY WORK PRACTICES IN MINING

2.4.1 SAFETY AT DEBSWANA

Debswana maintains an excellent safety record across all its operations and has rigorous standards and processes in place to prevent injuries. All operations run initiatives to promote a common culture of Zero Harm and deploy processes to facilitate swift reporting and investigation of every incident to identify root causes, initiate remedial action, and to disseminate lessons learned. The Debswana safety performance continues to decline and there is a need to look into the declining variable factor. Based on the Occupational Safety and Health Administration's formula, the Total Recordable Injury Frequency Rate (TRIFR) for 2016 was 0.33 against a threshold target of 0.38 and a stretch target of 0.36 (Debswana, 2016).

2.4.2 SAFETY ASPECT FROM 4IR IN RELATION TO MINING

Mining is an inherently dangerous profession and safety concerns are at an all-time high. All that will change in the future. Along with incorporating location/proximity sensors and warning technology in mining equipment, companies will use the Internet of Things to integrate people tracking, communications, video surveillance and analytics, and real-time personal health management. Simply put, the Internet of Things will enable mining companies to continuously improve its safety by analysing hazards, incidents, near misses and safety observations. By connecting machines, data and people together, companies can not only perform better, faster and more reliable, but safety risks are a thing of the past (Al-Rodhan, 2015).

(Xhang & Yang, 2014) stated that that use of IoT in coal mines met the monitoring and tracking health diagnosis of mining equipment and materials production, transportation, storage, use, maintenance and other links. The coal mine safety in production, disaster early warning, and emergency rescue were realized. Mine comprehensive automation level was raised, and coal mine safety production was improved. Mine production is along with water, fire, gas and coal dust, roof and other complex natural disasters and with the characteristics of poor, dangerous working conditions. Internet of Things (IoT) as an emerging technology provides a new technique for safety and security to underground production. The recent developments in IoT for mining will help in predicting downtime, improve efficiency, revolutionize safety, catalyse decision making, automated mines which help in creating real-time multi-dimensional models and used to optimize the mine layout, operation, vehicle paths and so forth, coordinating all the moving pieces for the most efficient operation (Peters, 2017).

2.4.3 DESIGN PRINCIPLES IN RELATION TO SAFETY

The efficiency of the monitoring system should be gauged by its ability to predict failures and its economic value-add during slope angle design. The strategy focused on large open pit mines, such as Debswana Jwaneng mine, it is concluded that slope monitoring requires a multifaceted approach focusing on the survey control network, beacon design and construction, the equipment shelter, equipment selection, data collection and processing, procedures, and personnel responsibilities. All these factors are equally critical for an optimal monitoring process. Negligence in one area can negate all the good work done in other strategic areas, leading to unreliable monitoring results and safety issues. It is essential to develop a systematic approach to managing the large amounts of data collected by the different monitoring systems so that a single version of the truth can be detected from them. This approach should encompass data validation, processing, and interpretation. Beacon design and construction standards should be developed. These standards will ensure that the reference points for monitoring are robust and not easily affected by blasting activities (Mphathiwa & Cawood, 2014).

2.4.4 BENEFITS OF 4IR TO MINING SECTOR

According to Jee (2017), the core advantages that miners have recognised are:

- IoT provides advancement in automation techniques by developing a virtual network of devices used in an operation such that they can work simultaneously. This brings in more data and less guesswork.
- IoT has made mining a safer workplace by eliminating the risk of collapse of unstable shafts or injuries resulting from the operation of mining trucks by providing real-time data, which predicts where issues might occur.
- IoT in mining has made it easier to detect wear on key pieces of equipment and projecting when repair or maintenance needs to take place.
- IoT excludes guesswork out of developing and maintaining the mine site allowing more products to be extracted and processed in a shorter frame of time.
- IoT leads to large physical environments, changing market and environmental conditions, and the massive size and amount of equipment.

The recent developments in IoT for mining will help in predicting downtime, improve efficiency, revolutionize safety, catalyse decision making, automated mines which help in creating real-time multi-dimensional models and used to optimize the mine layout, operation, vehicle paths and so forth, coordinating all the moving pieces for the most efficient operation.

The Internet of Things will allow companies to improve efficiency and service by enabling physical objects like haul trucks embedded with electronics, software and sensors to exchange data with manufacturers and other machines and connected devices. Giant trucks will be programmed hauling ore autonomously, while drones monitor, and measure surface operations and equipment are located,

scheduled and monitored with adaptive feedback loops to maximize production. By improving truck availability or reducing downtime and improving the diagnostics and troubleshooting capabilities of the mine operations and maintenance teams, companies can greatly enhance the efficiency of mine operations (Gershenfeld & Vasseur, 2014). The Internet of Things is expected to be a catalyst to intelligent decision making in the mining sector and will overall improve how traditional processes and activities are done. For example, GPS tracking of material movements, as well as camera views of production, further improve the planners' decisions, providing all production information, including materials, logistics, schedules, and energy, across the plant supply chain (Miller, 2016). Figure 2-1below shows the mine engineer tracking the mine operations using IoT technology.



Figure 2-1:IoT technology use: remote tracking

2.4.5 OPPORTUNITIES OF 4IR

There are similarities between four industrial revolutions and the five ages of civilization: the hunter and gatherer age, the agricultural age, the industrial age, the information worker age, and the emerging age of wisdom. Therefore, we may infer the opportunities of the fourth industrial revolution through the characteristics of these five ages of civilization first; the productivity of each subsequent age goes up fifty times over the preceding age. Consider for example, the increase in productivity of the industrial age over the agricultural age. Second, each subsequent age destroys many of the jobs of the preceding age. The information age is replacing the jobs created by the industrial age. Much of losses in our industrial age jobs have less to do with government policy and free trade agreements than they do with dramatic shift in our economy to the knowledge worker (Goode, 2018).

In the first three ages of civilization, manual workers produced most goods and services with their body, but in the last two ages, knowledge workers produce most goods and services with their mind.

Knowledge workers are the link to a company is other investments. They provide focus, creativity, and advantage in using those investments to achieve the organization's objectives more efficiently. In other words, knowledge is an integral part of total management and cuts across functional boundaries. The main assets and primary drivers of the industrial age were machines and capital. People were necessary but replaceable. The management style of the industrial age simply does not work in the new economy (Höller et al, 2014).

Schwab (2017) stated that fourth industrial revolution would shape the future through its impacts on government and business. People have no control over either technology or the disruption that comes with the fourth industrial revolution. However, we can predict the opportunities that come with the fourth industrial revolution: 1) lower barriers between inventors and markets, 2) more active role for the artificial intelligence (AI), 3) integration of different technics and domains (fusion), 4) improved quality of our lives (robotics) and 5) the connected life (Internet). Internet of things (IoT) is the Internetworking of physical devices.

IoT is expected to offer advanced connectivity of devices, systems, and services that goes beyond machine-to-machine (M2M) communications and covers a variety of protocols, domains, and applications. (Holler et al, 2014) The interconnection of these embedded devices is expected to result in automation in nearly all fields, while also enabling advanced applications like a smart grid, and expanding to areas such as smart cities. The revolution of the connected life came about thanks to the advance of the Internet. In 1969, the first data was transmitted over the Internet and linked two mainframe computers, with the internet now connecting personal computers and mobile devices, signifying a major step in technological advancement (Wolf, 2015).

2.4.6 CHALLENGES OF 4IR

While there are many benefits of the fourth industrial revolution, there are several key challenges that lie ahead. At the same time, the revolution could yield greater inequality, particularly in its potential to disrupt labour markets. As automation substitutes for labour across the entire economy, the net displacement of workers by machines might exacerbate the gap between returns to capital and returns to labour. The scarcest and most valuable resource in an era driven by digital technologies will be neither ordinary labour nor ordinary capital. In the future, talent, more than capital, will represent the critical factor of production. People with ideas, not workers or investors, will be the scarcest resource (Wolf, 2015).

The quest for talent will give rise to a job market that may become increasingly segregated. Computers and digitization will replace low skilled and low wage jobs. The higher paid jobs requiring more skills are less likely to be replaced. This increased dichotomization can lead to an increase in social tensions

(Wolf, 2015). In addition to the threat of massive job displacement under the ongoing fourth industrial revolution, there are a variety of challenges, such as cybersecurity, hacking, risk assessment, and others (Wolf & Lambert, 2017). A higher level of alert is raised up when our lives become extensively connected to various devices, from our cell phones, cars, and light switches to our home security cameras, and smart speakers. One of the biggest trends in 2018 Consumer Electronics Show is that everything is connected and there is no going back (Goode, 2018).

Having everything interlinked the IoT is going to monumentally increase the vulnerabilities present in any given network. With more knobs, connections and burden of connectivity, systems are going to have to be more secure. The fourth industrial revolution calls for greater cybersecurity. Companies will need to map their networks, assessing the risk and critical factors relating to security. Such an assessment should examine accessibility to systems, such as possible threats from internal sources, from disgruntled employees to internal human error, and external sources including hackers and cyber terrorists (Lambert, 2017). Further, companies must assess risk and determine if these risks will be accepted, reduced, shared via insurance or other vehicles, or rejected. Risks can be from both intentional and unintentional sources. If your house lights turn on via your computer, but you have lost the wireless connection to your house, you may be living in the dark. Unintentional sources of risk can include error s promulgated by company employees or nature itself such as storms causing disruptions in connectivity (Goode 2018).

2.5 4IR IN SHE

Safety is a concept that includes all measures and practices taken to preserve the life, health, and bodily integrity of individuals (Niu, 2010). In the workplace, safety is measured through a series of metrics that track the rate of near misses, injuries, illnesses, and fatalities. In order to improve these metrics, employers and safety officials must also conduct investigations following any incident to ensure that all safety protocols and measures are being followed or to implement new ones if needed. Overview of the state of the mining sector in terms of health and safety. According to Niu (2010), Occupational Safety and Health aim at the promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations. The research and regulation of Occupational Safety and Health (OSH) is relatively a recent phenomenon (WHO, 2003).

2.6 SAFETY IN MINING

Mining is a hazardous operation and consists of considerable environmental, health and safety risks to miners (Chu et al, 2017). Unsafe conditions in mines lead to a number of accidents and cause loss and injury to human lives, damage to property, interruption in production etc. (Cox, 2008). Safety is paramount in the mining environment. The mining industry has for many years focused on injury

prevention at the workplace through procedures and training, and has achieved considerable success (Paithankar, 2011).

2.6.1 SAFETY IN BOTSWANA

Occupational health and safety in Botswana are regulated by various pieces of legislation. The principal laws are the Factories Act; the Agrochemicals Act; the Mines, Quarries Works & Machinery Act; the Radiation Protection Act and the Workers Compensation Act.
These laws provide for the safety, health and welfare of persons employed in factories and other places and the safety and inspection of certain plants and machineries (Government Gazette, 1973: Factories Act); the registration and licensing of agrochemicals; the control or regulation of their importation, manufacture, distribution, use and disposal, so as to prevent pollution to the environment or harm to human, plant or animal life (Government of Botswana, 1999: Agrochemicals Act); the safety, health and welfare of persons engaged in prospecting, mining and quarrying operations including any works which are part of and ancillary to mining and quarrying operations (Government Gazette, 1973: Mines, Quarries Works & Machinery Act). In addition, there are several Regulations and Statutory Instruments published in terms of these laws regulate mine safety and below are some of the acts;

- Radiation Protection Regulations (Chapter 24:03).
- Mines, Quarries, Works and Machinery Act 1973. No. 20.
- Factories Act 1973. No. 31.

2.6.2 SAFETY IN DEBSWANA MINING(STATISTICS)

The fatality that occurred at the Fine Residue Disposal project in 2018 and Jwaneng Open pit slope failure in 2016 represent unacceptable deviations from the mine's core value of "We Prioritize Safety, Health and The Environment" as well as the goal to achieve Zero Harm. The fatality then, was indicative of failed systems and behaviors within the mine's projects. Securing upfront commitment and proactively leading health and safety will aid the successful delivery of the organisation, as it has been proven that implementing a sensible and proportionate risk management strategy will assist in a transparent delivery process. (see the safety stats as indication of declining safety).

Table 2-1:Debswana Mining Safety Stats

Year	Total Recordable Injury Frequency Rate (TRIFR)	Target
2016	0.33	0.36
2017	0.12	0.25
2018	0.27	0.2
2019	0.19	0.18

(Source: Debswana SHE department)

The role of 4IR, its potential for disrupting the mining industry and its role in boosting productivity in mining is gaining traction among researchers and practitioners (Humphreys, 2019). Furthermore, the improved technologies continue to contribute to worker quality through better education and healthcare. 4IR technologies, as further explained by Humphreys (2019), contributes to lower social and environmental impacts. Khatiwada (2020) elucidates the manner in which 4IR leads to an evolution of jobs and consequently demands an upgrading of skills as it leads to higher quality jobs. Moreover, Khatiwada (2020) highlights the phenomenon of "deepening of automation", where technological advancements improve the productivity of tasks which were already automated. Furthermore, it is necessary that the role of 4IR in the social lives of employees is taken into account, as 4IR has the potential to either improve their work-life balance or worsen it (Ganiyu et al, 2020). Moreover, Ganiyu et al (2020) highlight the enabling of working from home by employees, shifting not only their productivity but their work-life balance, at the same time demanding upskilling in an array of skills that transcend the previous focus on specialization.

Atif et al (2020) highlights the role of 4IR in transforming the mining industry, citing as an example the COVID-19 digital screening technologies, with which the study further delineates the manner in which 4IR can be used to stop and reduce the spread of disease in the mining industry. Albrieu & Rapetti (2019) explain how technological change often requires proactiveness on the side of companies, such that they are not only dynamic in their processes so as to accommodate new technology but are also able to equip and train their workers with skills and knowledge needed to effectively use the new technologies. Furthermore, Albrieu & Rapetti (2019) note the need for workers to be able to transition through the skill spectrum such that they are able to focus on areas where technology and machines aren't good enough. Consequently, as Mpafa (2018) explains, there is a need for miner trade unions to upskill their members as a means of aligning those skills with the impending advent of 4IR.

2.6.3 EMPLOYEE READINESS FOR 4IR

In 2018, the World Economic Forum (2018) released a Readiness for the Future of Production Report which sought to measure the readiness of countries for the future of production as well as determine the drivers of production. From the report, Botswana is part of countries that are nascent, indicating that the adoption of advanced technologies in production, and human capital development were in early stages of existence, ranked 69 out of 100 countries in terms of development of drivers of production (World Economic Forum, 2018). African countries, as indicated by the report, have significant ground to cover with respect to ensuring that they are up to par with the world standards of production driven by the advent of 4IR.

The study by Mohamad et al (2020) which sought to assess the expertise required of workers in the context of Libya's 4IR noted that there was a significant discrepancy between the existing skillset levels in Libya as opposed to the required skillset for the rapidly advancing production environment driven by 4IR. Moreover, the study revealed that there were low levels of awareness of 4IR among the Libyan workforce, coupled with low levels of preparedness in required 4IR skillsets. The study utilized the responses from 326 respondents that consisted of a wide range of skillsets such as policy makers, employers/employees, teachers/students and the unemployed.

Xing et al (2018) explored the role of the 4IR in bringing about new data resources, which, as they explain, has led to companies taking advantage of the available data as well as setting up systems that allow them to effectively use data and data systems to make decisions and plan. Notably, Xing et al (2018) highlight the role of human resources, indicating that although there is an increase in automation, there is still need for human resources, such that upskilling and development become a crucial part of employee skillsets and readiness for new job environments. The study utilizes a case study in the mining industry to demonstrate the role of new data systems and the levels of efficiency that can be wrought from such systems, emphasizing the need and importance of adoption of new technologies by the mining industry to increase efficiency and levels of production(Xing et al, 2018). Moreover, the study highlights the increasing role that wearable technologies will play in the mining industry, more so that human resources will remain a critical and crucial element of mining operations, such that learning in the era of 4IR requires adaptive learning mindsets not limited to acquisition of certain skills or knowledge pieces, but one placed in a disposition ready to interact with one's surroundings.

4IR and Change Management in the Mining Industry Laig and Abocejo (2021) carried out a review of the change management process in a mining company following Kotter's 8 step change model, and outlines change readiness factors to be comprised of job satisfaction, job uncertainty, organizational commitment and change perception of the entire organization. The study, which utilized 134 mining company employees and stakeholders, noted a significant relationship between change readiness factors (job satisfaction, job uncertainty and organizational commitment) and change perception of stakeholders. Pelders et al (2019) highlights that in order for the implementation of an effective change

management process, there are several key elements that have to be in place. These, as the study elucidates, are inclusive of management and workforce buy-in, commitment and support, mitigation of potential adoption constraints, adequate communication, engagements and feedback with the relevant stakeholders. This is further buttressed by the study done by Jayatilleke and Rai (2018), highlight four questions necessary for the implementation of effective change management;

- What are the causes of requirement changes
- What processes are used for change management
- What techniques are used for change management

How do organisations make decisions regarding changes? Consequently, Jayatilleke and Rai (2018) emphasise the importance of identifying processes that are in place, and ensuring that they are analysed through a cost estimation of change.

3. CHAPTER 3 : RESEARCH METHODOLOGY

3.1 INTRODUCTION

Research methodology is the key element in any research study and it includes the total procedure of a research study, commencing from theoretical foundations and traversing to data gathering and examination (Remenyi et al, 2003). This chapter discusses the theoretical framework of research method, design, population, sample selection, data collection instrument, data analysis techniques, validity, reliability and ethical consideration that were used in this study.

3.2 RESEARCH PHILOSOPHY/PARADIGMS

The research philosophy hinges on individual mode of rational about the advance of information. Research philosophy is defined as the belief or view on about the way in which data about occurrence is collected, analysed and used. Sanders et al. (2009) asserts that research philosophy is reliant on the method the researcher deliberates around the development of knowledge. The epistemology and doxology embrace the numerous viewpoints of research approach. The intention of this research is to transform the believed into the known. The three main major philosophies identified for this study are positivism (sometimes called scientific), interpretivism (known as anti – positivism) and realism.

3.3 RESEARCH PHILOSOPHIES/PARADIGMS ADOPTED BY THE STUDY

Based on the current study, this research uses the assumption that understanding the impact of 4IR on Debswana would have significant impact on the operations and performance of Debswana. The research or the study adopted the interpretivism approach as the collection of data is based on behaviours of the targeted population and moreover it is based on the case study

3.3.1 INTERPRETIVISM

According to Saunders et al (2015) individuals place countless understandings on the circumstances in which they discover themselves and it is essential to determine the particular connotations inspiring people's engagements in command ability to understand them. Saunders et al (2009) is of the opinion that interpretivists must comprehend the intentions, engagements and targets of those being studied to derive meaningful results.

3.3.2 RESEARCH DESIGN

Cooper and Schinder (2011) defined research design as a proposal which is grounded on study questions that lead the data and assist in outlining research actions to source answers from the questions. Correspondingly, Zikmund (2003) defines research design is the core framework and basis of the research plans of action that is based on procedures for gathering and examining the information.

Saunders et al. (2015) research onion approach forms the base for the research and the onion is used to illustrate the matters essential influenced the choice of method to be used for data collection. The research method choice that was used in this study were guided by the nature of the questions used for the collection of data to answer the research problem. The layers from the onion are the direction on the framework adapted and chosen as shown in the Figure 3-1 below.

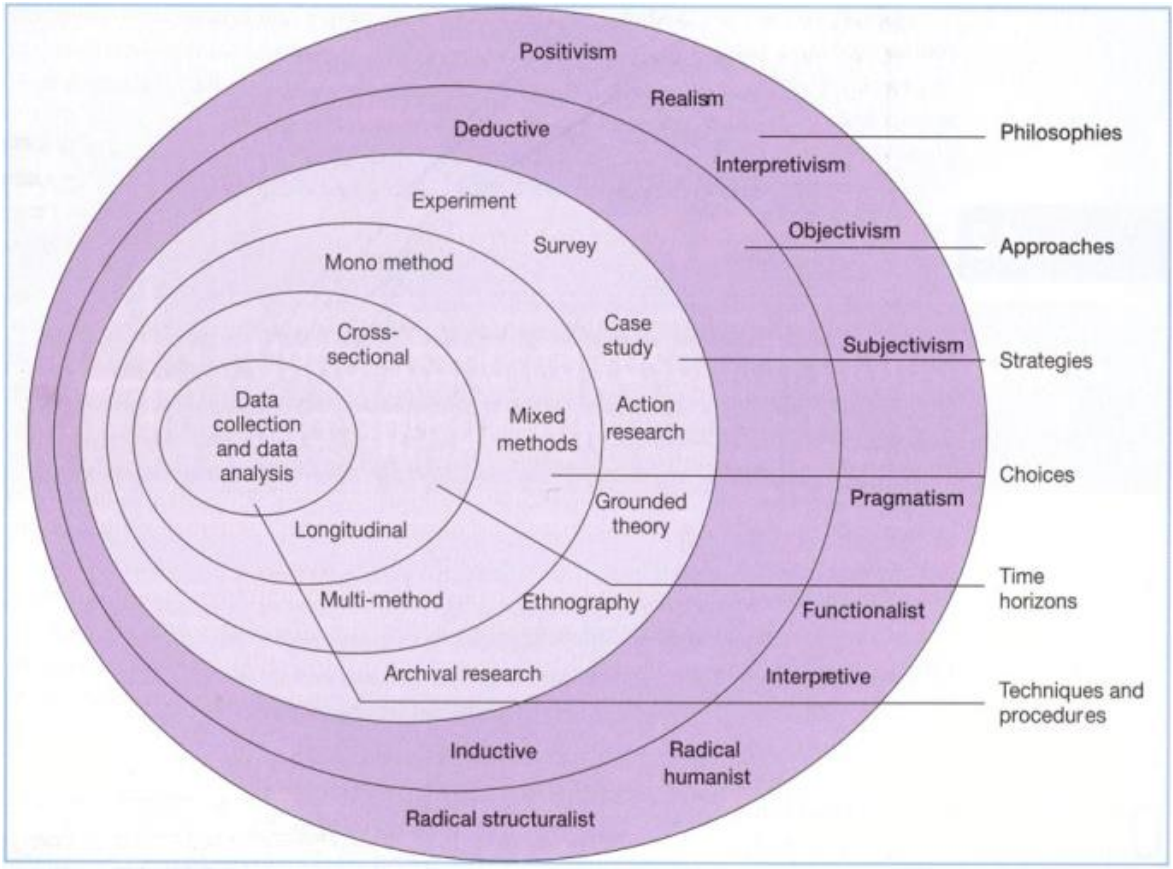

Figure 3-1:Research Process Onion

The research process 'onion' - (Saunders et al. 2015)

Saunders et al (2015) explains that categories of research can be classified into basic and applied research. Basic research is intended to enhance fundamental knowledge and applied tend to specifically resolve a specific problem.

There are two major research designs which are qualitative and quantitative. In Wolcott (1994) expounds qualitative research as research concerned with understanding existence of things through examining experiences of respondents and related behaviour. Qualitative research involves use of in-depth interviews and questions to understand social and cultural phenomenal experiences. In contrast, Creswell (1994) defines quantitative research as a systematic research that employs use mathematical models to explain some phenomena.

3.3.3 RESEARCH DESIGN ADOPTED

In this study, basic research was used to enhance the knowledge and understanding of fourth industrial revolution at Debswana. In this study, the quantitative research design was adopted through the use of OLS, logistic regression and was OLS regression, logistic regression and used as a means of addressing the study objectives.

The research seeks to gain an understanding of reasons, opinions and insights into the problem and at the same time quantify the problem through generating numerical data to quantify attitudes, behaviours and opinions.

3.4 FRAMEWORK FOR ANALYSIS

The study focuses on the role of 4IR at both the individual and organizational level. At an individual level, the study seeks to investigate and highlight how SHE affects individuals' career, wellbeing and health as well as their social life. At an organizational level, the study seeks to investigate the adaptability and readiness of Debswana, broken down into organizational preparedness, collective individual preparedness and role of change management. Additionally, the robustness of current SHE practices of Debswana are broken down into the strengths and weaknesses of slope stability, PPE and collision avoidance

3.5 RESEARCH APPROACHES

The second layer of the onion is the inductive and deductive approaches.

3.5.1 DEDUCTIVE

Saunders et al (2015) defines deductive approach as the process of reaching at conclusions based on the explanation of the denotation of the outcomes of data analysis. This is a type of logic where general statements or premises are used to form a specific conclusion.

3.5.2 INDUCTIVE

The induction approach is the process by which universal propositions based on observed facts are established (Saunders et al 2015). In this approach, data is collected, and a theory is consequently established from the analysis of the available data, (Saunders et al 2015).

3.6 RESEARCH APPROACH ADOPTED FOR STUDY

Considering the current study, the assumption on how to examine effective safety work practices in the internet of things world, the study will involve carrying questionnaires to better understand the perception of employees on their disengagement and engagement. The study adopted both the deductive and inductive approaches as it generates theory and seeks to also explain the denotations of data analysis

outcomes based on the interpretation of evidence collected alongside employee engagement theoretical information.

3.7 TARGET POPULATION AND SAMPLING METHOD

Creswell (2013) defines population as the assemblage of components wishing to make some inferences and he further defines sample as a group of respondents selected to represent a total or whole population. The population of the study will consist of 300 personnel from Debswana divisions, questionnaires were disseminated to this population.

The type of sampling method used is the proportional quota sampling which Saunders et al (2015) define as a non-probability technique that warrants that the sample signifies assured features of the population chosen by the researcher. In order to ascertain coverage of the population space as well as over different departments in Debswana Jwaneng mine, purposive sampling was used hand in hand with quota sampling. As Etikan & Bala (2017) explain, purposive sampling involves the selection of a sample based on the judgement of the researcher with regards to the objectives of the study. This sampling method is relevant as the researcher has control over the sample size.

Table 3-1:Divisions & Sample

Divisions	Total	Sample proportion
Management/ Admin	50	15
Contractors	50	10
Consultants	50	5
Employees	100	30
Community	50	20
Total	300	80

3.8 RESEARCH STRATEGY

3.8.1 CASE STUDY METHOD

The research is based on the case study of Debswana and according to Gorman and Clayton (1997), case study is defined as an investigation of phenomena within a life context. Case study literature is extensive and indicators from other writers demonstrate the method is widely used across disciplines to investigate contemporary real-life situations. Furthermore, more evidence is demonstrated by writers that case study can be used for small intensive analysis on small, medium and large-scale organizations. Past literature and researchers argue that case study can be used to closely observe data within a specific context and hence the method selects minute or very limited number of respondents for study. The above information streamlines the case study strategy to be of single case and it was adopted based on

its advantages and merits particularly for Debswana as a large-scale organization. The below table further shows instruments, reasons for method, population and sample size used in the research.

Table 3-2:Instruments, reasons for method, population and sample size

Participant	Data Collection Method	Reason for choice of method	Population Size	Sample Size	Sample Criteria
Debswana	Questionnaires	Can be used for quantitative approach	300	80	Quota

3.9 DATA COLLECTION PROCEDURE

Primary and secondary data was used in the research. The primary data encompassed questionnaire responses and secondary data involves texts, journals, published studies and dissertations dealing with the subject of fourth industrial Revolution. The initial phase of the study will involve exhaustive study on the subject topic from published and unpublished resources.

The questionnaires were administered as the pivotal data collection instrument. The questionnaire for the research was piloted to selected samples prior to distribution. The questionnaire were distributed to the targeted population through online forms sent over their emails. An online questionnaire was made use of as a means to take into account the current COVID 19 pandemic, such that it was disseminated to company management. The study utilized a questionnaire consisting of both closed-ended and open-ended questions as a means of ensuring a comprehensive investigation. Consequently, the questionnaire made use of a variation of scales (including Likert scales) where appropriate. This will give the respondents a chance to choose the view that suits them.

3.10 DATA ANALYSIS PLAN

Data analysis was done through the use of Ordinary Least Squares Regression (OLS), Logistic regression as well as descriptive statistics. . The use of quantitative analysis was adopted as a means of extracting value from the data that was obtained from the study.

Subsequently, the analysis of objective 1 (Assess Debswana Mining Company SHE) will utilize descriptive statistics that focused on research question 4 that assesses the employee perceptions of the state of safety of slope stability, PPE and collision avoidance. The ensuing results elucidating Debswana Mining company practices was used to address objective 1 in depth, hence noting the current state of safety practices in the company. Furthermore, thematic analysis was used to bore out the relevant themes that come out through the study respondents, such that a more rigorous, in-depth analysis can be obtained.

In order to address objective 2 (To assess the effectiveness of employee preparedness, knowledge and characteristics on SHE 4IR impacts and perceived opportunities and threats of 4IR), thematic analysis and quantitative analysis (OLS and logistic regression) were used through the analysis of research questions 1, 2,3, 5 and 6. The objective, (To evaluate the success and challenges of the current safety practices in relation to the 4IR Debswana Mining) was assessed through research question 7 through the use of descriptive statistics. Consequently, the resulting analyses will then be used to address objective 4 (To consolidate and recommend ways to develop Debswana Mining Company safety practices and philosophies that can be aligned to the 4IR).

Completed surveys from the respondents were collated and captured into automatically from the online questionnaire used into Microsoft Excel and data was summarized using the visualization of the data by means of frequency distributions graphs. Tables and Pie charts were used for data presentation, interpretation and discussion. For further ease of discussions and interpretation the data analysis will follow the strategy noted below;

- Proposition of the respondent in a logical manner.
- Categories segmentation based on content analysis.
- Constructs based on rank order scales after the frequency count.

3.11 DATA PRESENTATION METHOD

To find the solution to the research questions, an appropriate research presentation method is framed. As the nature of the study is such that the target population from which information can be obtained is limited with respect to both extent and quality of information, therefore an quantitative research design model is used in this study Bryman & Bell, (2003). The following Figure 3-2 is the research presentation method used for this study. The questionnaire was designed in such a way that it gathers relevant data for this study. Upon validation, the questionnaire was disseminated to the target population and the data from the population sample was analysed to come up with the findings that will lead to recommendations and conclusions for this study. The figure below is the research presentation method followed by the researcher.

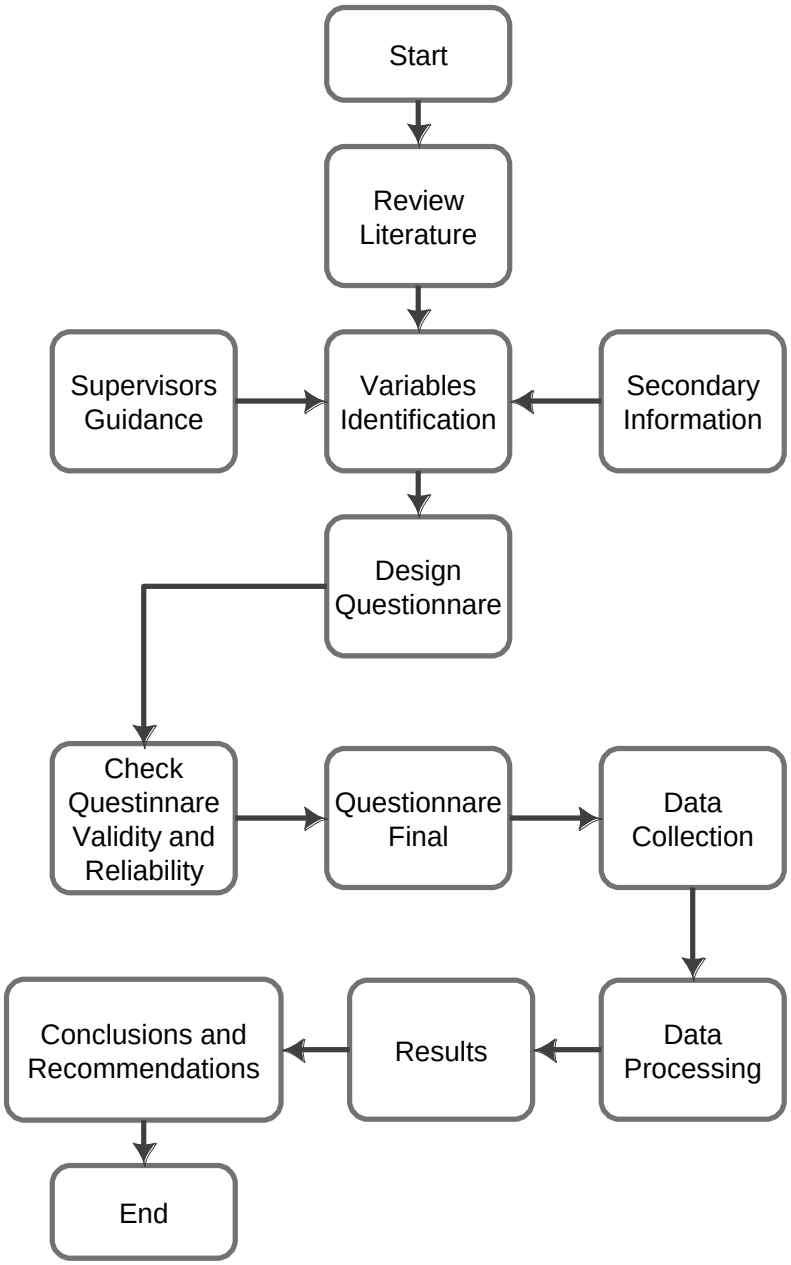

Figure 3-2:Research Model

3.12 VALIDITY AND RELIABILITY

According to (Field, 2005) reliability is determined by consistency in data measuring instrument and on the other hand, Hoberg (2009) argues that validity is the degree the data gathering instrument gauges what it is envisioned to. Zikmund (2003) contends that a thriving study should be both valid and reliable. As this study entails the use of quantitative research data, the concepts of trustworthiness, dependability, transferability, and credibility are also used. According to MacMillan and Schumacher (2006), validity is the degree to which the interpretations and concepts have mutual meanings between the participants and the researcher.

Reliability is the degree to which the findings of the research are independent of accidental circumstances. It is closely related to assuring the quality of field notes and guaranteeing the public access to the process of the publication of the research results Creswell (2013) defines reliability as the extent to which results are consistent over time and are an accurate representation of the total population under study. If the results of a study can be reproduced under a similar methodology, then the instrument is considered reliable. In order to ensure the validity and reliability of the content of the questionnaire, the questionnaires were reviewed by the official statisticians from the Department of Statistics at the University of Witwatersrand.

3.13 ETHICAL CONSIDERATIONS

The following ethical considerations were considered:

- Objectivity – use of structured validated survey to avoid bias
- Voluntary participation – allowed employees to volunteer and offered option to withdraw
- Informed consent – briefed on the procedure and purpose of the survey and its intentions.
- Confidentiality – No identifiable personal information was requested and respondent's information was handled with confidentiality.
- Data Integrity – Data management was established to protect information from the respondent.

4. CHAPTER 4 : DATA PRESENTATION ANALYSIS AND RESULTS

4.1 INTRODUCTION

This chapter presents analysis of data using linear regression (OLS) and binary logistic regression analysis. The data is presented in tables and analysis was done in order to answer the study objectives. Moreover, descriptive statistics analysis was carried out in the study, with relevant themes being identified from the data.

The study analysis focused on the following objectives and corresponding research questions;

- Assess Debswana Mining Company SHE safety practices
    - What are the employee perceptions of SHE safety state of Slope Stability, PPE and Collision avoidance?
- To assess the effectiveness of employee preparedness, knowledge and characteristics on SHE 4IR impacts and perceived opportunities and threats of 4IR
    - What is the role of employee traits on perceived 4IR career development readiness?
    - What are the employee perceptions of Opportunities presented by 4IR?
    - What are the employee perceptions of threats presented by 4IR?
- To evaluate the success and challenges of the current safety practices in relation to the 4IR Debswana Mining
    - What are the employee perceptions of the role of change management and employee experience of change management?
- To consolidate and recommend ways to develop Debswana Mining Company safety practices and philosophies that can be aligned to the 4IR.

4.2 ANALYSIS OF DATA AND INTERPRETATION OF QUANTITATIVE RESULTS

This part analyses data collected from 76 participants who are employees in Debswana Jwaneng mine. Questionnaires (online) were used to collect data and analysed through the use of regression analysis (OLS and binary logistic). The study had 76 participants, from the 80 respondents who had been approached, indicating a response rate of 95%.

4.3 DEMOGRAPHIC INFORMATION

This section provides an overview of the nature of the respondents, highlighting their age, gender, academic qualifications as well as the length of employment. This then provides insight into the better understanding of certain background characteristics of the respondents, which will allow for more in-depth analysis of results that takes into account the characteristics of the respondents.

Table 4-1:Frequencies of study participants by age and gender

		Gender	
		Male	Female
Age	15-24	1	2
	25-34	0	5
	35-44	19	7
	45-54	29	6
	55-64	3	2
	65+	0	1
	Total	**3**	**23**
	%	**69.74**	**30.26**

Table 4-1 shows the age of the respondents by gender. From the table above, there is a higher proportion of males than females, with 69 per cent of the study sample consisting of males. Moreover, the 45-64 age group, with 35 of the respondents dominates the study sample.

Table 4-2:Frequencies age and academic qualification

		Academic qualification			
		NCC	Diploma	Bachelor's degree	Post graduate degree
Age	15-24	0	0	3	0
	25-34	0	1	3	1
	35-44	0	1	16	9
	45-54	4	4	15	13
	55-64	0	0	2	3
	65+	0	1	0	0
	Total	**4**	**7**	**39**	**26**
	%	**5.26**	**9.21**	**51.32**	**34.21**

The study made use of 75 respondents, 52 (68.42 per cent) of whom were male and 23 (30.36 per cent) were female. Moreover, a majority of the respondents were bachelors or postgraduate degree holders, constituting 85.53 of the sample.

Table 4-3:Age and Duration of employment

		Duration of Employment (in years)					
		1-5	6-10	11-15	16-20	21+	Total
Age	15-24	2	1	0	0	0	3
	25-34	3	2	0	0	0	5
	35-44	2	6	10	8	0	26
	45-54	2	4	4	11	15	36
	55-64	2	0	1	0	2	5
	65+	0	0	0	0	1	1
	Total	11	13	15	19	18	76

Table 4-3 highlights that the majority of respondents had more than 11 years of experience with the organization, with 18 of the respondents having more than 21 years' experience in the mining sector.

Table 4-4:Level of employment

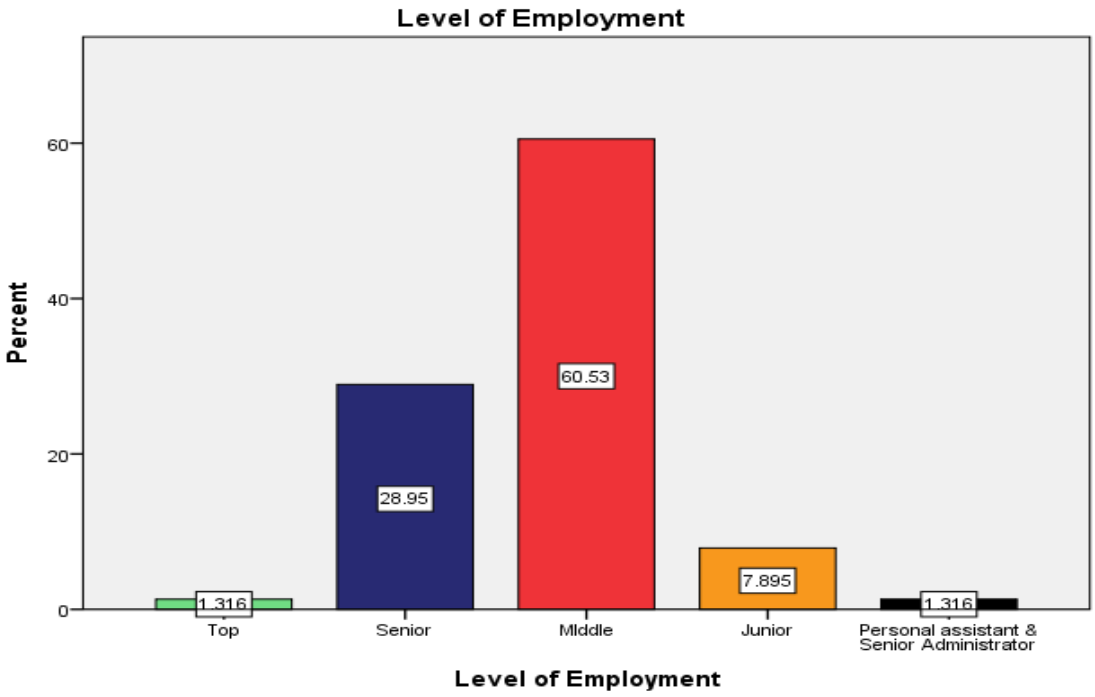

Table 4-3 above highlights the level of employment of the study respondents. The majority of the respondents were in middle management, followed by senior and junior management at 60.53, 28.95 and 7.9 per cent respectively.

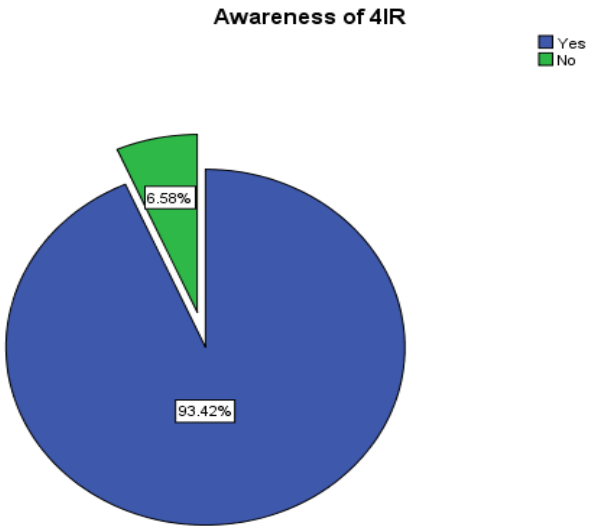

Figure 4-1:Awareness of 4IR

5 of the 75 respondents indicated that they were not aware of the concept and meaning of the Fourth Industrial Revolution, constituting a 6.58 per cent of the study sample.

4.4 RESULTS SUMMARY

4.4.1 RESEARCH QUESTION 1: WHAT IS THE ROLE OF EMPLOYEE TRAITS ON PERCEIVED 4IR CAREER DEVELOPMENT READINESS?

The first research objective sought to investigate the role of employee traits on perceived 4IR career development readiness through the use of the following hypothesis:

H_{01}: Employee traits do not significantly predict 4IR career development readiness.

In order to assess the above hypotheses binary logistic model was ran using a Enter entry method of the variables under analysis so as to ensure analysis of all variables entered into analysis in a single step.

Table 4-5:Binary logistic regression

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Gender	.071	.500	.020	1	.888	1.073
	Age	.593	.343	2.998	1	.083	1.810
	Academic qualification	-.390	.294	1.765	1	.184	.677
	Level of Employment	-.917	.472	3.777	1	.052	.400
	Duration of Employment in years	.113	.215	.277	1	.598	1.120

a. Variable(s) entered on step 1: Gender, Age, Academic qualification, Level of Employment, Duration of Employment in years.

A logistic regression was performed to ascertain the effects of employee traits on their perceived 4IR career development readiness. The logistic model was statistically significant, $\chi 2(5) = 18.228$, $p < .05$ at 0.003. The model explains 28.4% (Nagelkerke *R2*) of the variance employee perceived 4IR career development readiness and correctly classified 72.4% of the cases (refer to appendix). The age variable is significant at 10% significance level. From the results, older respondents were 1.81 times more likely to perceive themselves as ready for career developments brought about by 4IR than those who are younger. Moreover, the level of employment variable is significant at 10% significance level. From the results, respondents in higher levels of employment/positions were 0.4 times more likely to perceive themselves as ready for career developments brought about by 4IR than those in lower levels of employment/positions. However, the other employee traits were statistically insignificant at predicting perceived employee 4IR career development readiness.

The results speak to the role of age and level of employment in being instrumental in 4IR preparedness, which, as noted by the World Economic Forum Report (2018), highlights the transition level of knowledge and technology utilization in Botswana. This, as indicated by Mohamad et al (2020) who spoke to the high levels of unemployment in Libya and their role in slowing down adoption of and development of relevant skillsets for 4IR, is synonymous with Botswana. Botswana's levels of youth unemployment levels are at 38% as per the World Bank (2020), which places those already employed at an advantage in being ready to adapt to 4IR developments in their careers. From the study, 70 of the 76 respondents are in the 35+ age ranges, thus highlighting the role of age and advancement in career and their role in career readiness for 4IR developments.

4.4.1.1 Analysis of Findings: Descriptive Statistics

This section provides a summary of responses through descriptive analysis, presented through graphical representations of common and recurring responses which were summarized to represent thematic elements from responses of each research question.

4.4.2 RESEARCH QUESTION 4: WHAT ARE THE EMPLOYEE PERCEPTIONS OF SHE SAFETY STATE OF SLOPE STABILITY, PPE AND COLLISION AVOIDANCE

4.4.2.1 Slope Stability Safety Perceptions

The respondents were asked to give their perceptions with regards to the robustness of the current safety practices regarding slope stability. From these responses, the majority of the respondents agreed that the current safety practices were robust;

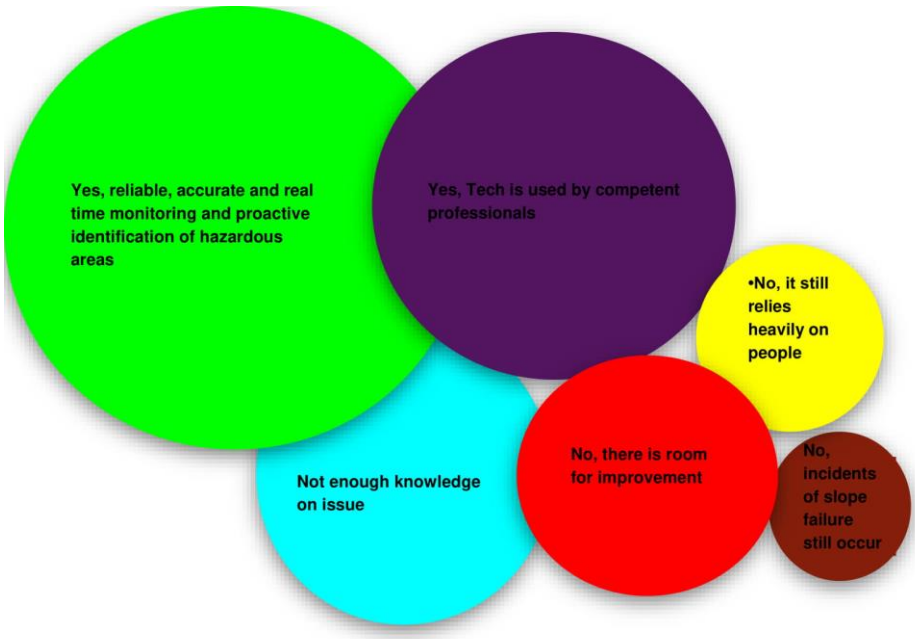

Figure 4-2:Slope Stability Safety Perceptions

Theme	Number of respondents	Percentage of respondents
Yes, reliable, accurate and real time monitoring and proactive identification of hazardous areas	25	
Yes, tech is used by competent professionals	16	
Not enough knowledge on issue	12	
No, there is room for improvement	9	
No, it still relies heavily on people	8	
No, incidents of slope failure still occur	6	

From the themes identified in the figure above, the recurring theme related to the agreement of respondents with regards to the robustness of the current slope stability safety, citing the real time monitoring that allows for proactive identification of hazardous areas. Moreover, the respondents highlighted that the technology used by Debswana was the latest in slope stability detection, hence their belief in its reliability. Among these respondents, respondent R14 working in the SHE department as part of senior management, with 20 years' experience noted that "yes, they are both highly accurate and predictive in pit slope stability detection," when speaking to the robustness of the slope stability system. This was buttressed by respondent R54 working in H2 Projects as part of senior management, with 25 years of experience, who noted that "Yes, I believe the slope stability is being continuously monitored and configured to alert relevant officials to take appropriate action depending on the alarms published by the system" This is also highlighted in the second theme, which noted that in addition to there being latest technologies in use, it was used, manned and supervised by competent, well trained professionals. However, a significant number of respondents highlighted lacking knowledge on slope stability. In addition, a number of respondents indicated that there was still room for improvement, with some respondents highlighting the fact that the technology was still highly dependent on people. Among these respondents was respondent R24, working in the Process department in middle management, with 25 years' experience, who noted that the slope stability system "needs to be automated with AI to take out human opinion, especially under pressure for production."

4.4.2.2 PPE safety Perceptions

The respondents were asked to give their perceptions with regards to the robustness of the current safety practices regarding Personal Protective Equipment (PPE) such as head, eye, face and foot protection. From these responses, several themes and recurring issues were identified;

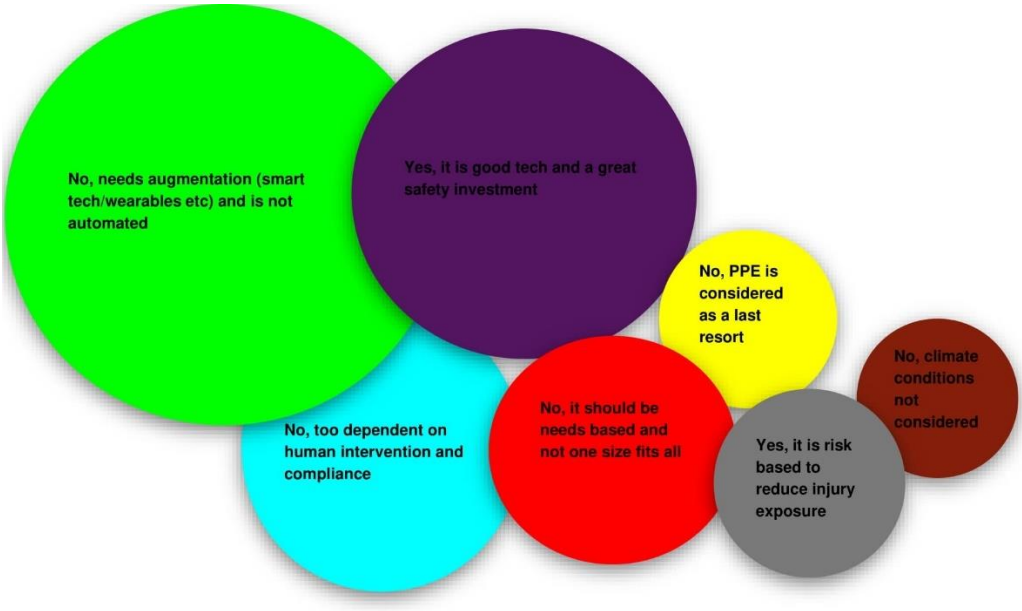

Figure 4-3:PPE Safety Perceptions

Theme	Number of respondents	Percentage of respondents
No, needs augmentation (smart tech/wearables etc.) and is not automated	19	
Yes, it is good tech and great safety investment	16	
No, too dependent on human intervention and compliance	12	
No, it should be needs based and not one size fits all	10	
No, PPE is considered as a last resort	9	
Yes, it is risk based to reduce injury	7	
No, climate conditions are not considered	3	

At the crux of the responses, was the belief that PPE safety was not adequate as it lacked automation in the form of wearables that can track vital signs of workers in real time, hence noting the inadequacy of PPE with regards to the current advent of 4IR, hence the need for augmentation. This was indicated by respondents R19, currently employed in the Engineering department at senior management, with 25 years of experience, who noted that "No! There is still no automated way of picking up transgressions and limiting people from getting access on the bases of non-conformance." However, a sizable majority of respondents believed that the PPE safety measures in place were adequate as it is good technology and a great safety investment. Nonetheless, the role of human intervention and compliance was cited to be problematic, with some respondents arguing that PPE safety was considered as a last resort, which, in its implementation, was not needs based and often a one size fits all approach. The role of reduced exposure to injury prompted some respondents to argue in agreeing with the robustness of the PPE safety measures, with another respondent arguing that PPE did not consider climate conditions.

4.4.2.3 Collision avoidance safety Perceptions

The respondents were asked to give their perceptions with regards to the robustness of the current safety practices regarding collision avoidance.

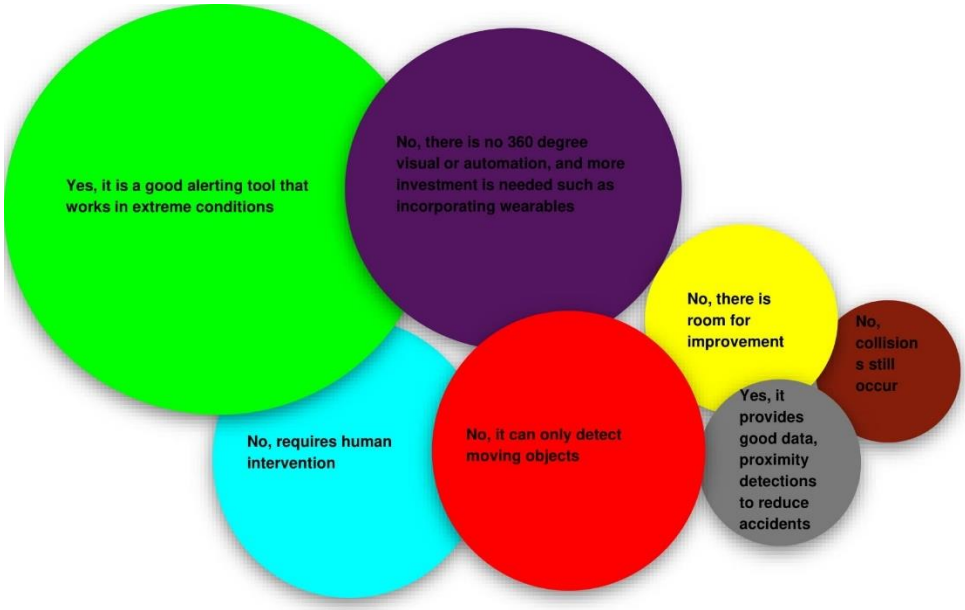

Figure 4-4:Collision avoidance Safety Perceptions

Theme	Number of respondents	Percentage of respondents
Yes, it is a good alerting tool that works in extreme conditions	23	
No, there is no 360-degree visuals or automation, and more investment is needed such as incorporating wearables	21	
No, it requires human intervention	13	
No, it can only detect moving objects	12	
No, there is room for improvement	4	
Yes, it provides good data, proximity detections to reduce accidents	2	
No, collisions still occur	1	

The robustness of the collision avoidance system was noted by a significant number of the respondents who highlighted the efficiency of the system as an alerting tool in extreme conditions. In addition, an even smaller portion of the respondents cited the provision of good data and the collision avoidance system's ability to reduce accidents as a reason to agree to its robustness. However, the majority of the respondents argued that the collision avoidance system was not robust. These included respondent R2 in the Engineering department employed at senior management level with 15 years' experience, who noted that "the deployed technology is a collision detection technology and does not have avoidance capability." Moreover, among the reasons cited was that there is no 360-degree visual or automation in the system, in addition to the lack of wearables. Moreover, the high role of human intervention was noted as a hindrance to the robustness of the system, owing to, in addition, the fact that the collision avoidance system only detects moving objects. Consequently, a number of respondents argued that the

system still had more room for improvement. Such was noted by respondent R14, who indicated that "the current collision avoidance system is frequently malfunctioning, and the other practices are administrative by nature and therefore prone to violation."

4.4.3 RESEARCH QUESTION 5: WHAT ARE THE EMPLOYEE PERCEPTIONS OF OPPORTUNITIES PRESENTED BY 4IR

4.4.3.1 Individual level

The respondents were asked to give their perceptions with regards to the opportunities presented by 4IR in the organization at an individual level, with the themes arising from the responses highlighted in the diagram below;



Figure 4-5:Individual level Employee perceptions of 4IR opportunities

4IR opportunities for individuals in Debswana	Number of respondents	Percentage of respondents
Improvements in work, qualifications and social life, production efficiencies and career enhancement, safety improvements	29	
Skills development, upskilling	25	
Not sure/Nothing I can think of	20	
Innovation, transformation, and a broader scope of roles	2	

The respondents cited various opportunities which 4IR could pose to them individually, the majority of which related to job improvement in terms of production efficiencies, career enhancement as well as safety improvements. These, as the respondents noted, opened up way for skills development and upskilling, with a number of respondents citing the innovation and transformation that could be brought by 4IR, such that a broader scope of roles could be attained in the process. A significant number of respondents noted not being sure or knowing of the opportunities that 4IR could bring.

4.4.3.2 Organisational level

The respondents were asked to give their perceptions with regards to the opportunities presented by 4IR in the organization at an organisational level, with the themes arising from the responses highlighted in the diagram below;

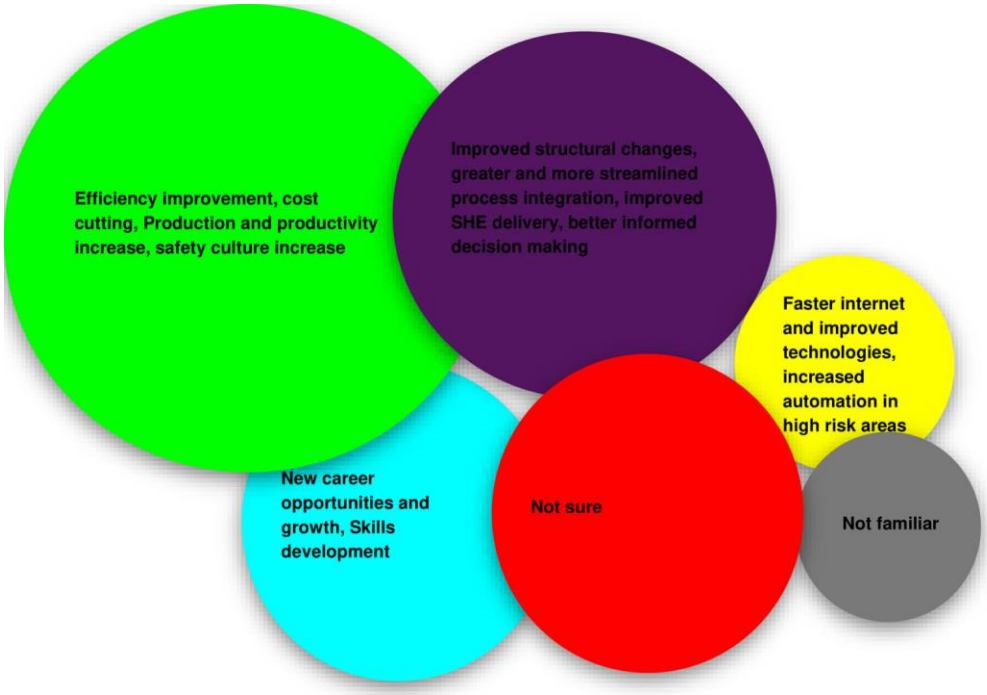

Figure 4-6:Organizational level Employee perceptions of 4IR opportunities

4IR opportunities for Debswana	Number of respondents	Percentage of respondents
Efficiency improvement, cost cutting, production and productivity increase, safety culture increase	24	
Improved structural changes, greater and more streamlined process integration, improved SHE delivery, better informed decision making	18	
New career opportunities and growth, skills development	14	
Faster internet and improved technologies, increased automation in high-risk areas	5	
Not familiar/Not sure	15	

At an organizational level, the respondents noted opportunities relating to efficiency improvement, cost cutting and reduction, production and productivity increase as well as increases in safety and safety culture. Moreover, improved structural changes that bring about greater and more streamlined process integration, improved SHE delivery as well as better-informed decision-making owing to improvements in available technology and data were also noted. Furthermore, the respondents highlighted the opening up of new career opportunities within the organization as well as skills development. Additionally, faster internet and other improved technologies that could lead to increased automation were further indicated as opportunities that could arise from 4IR for the organization. However, a number of respondents highlighted their lack of knowledge on the opportunities that 4IR could bring about.

4.4.4 RESEARCH QUESTION 6: WHAT ARE THE EMPLOYEE PERCEPTIONS OF THREATS PRESENTED BY 4IR

4.4.4.1 Individual level

The respondents were asked to give their perceptions with regards to the threats presented by 4IR in the organization at an individual level, with the themes arising from the responses highlighted in the diagram below;

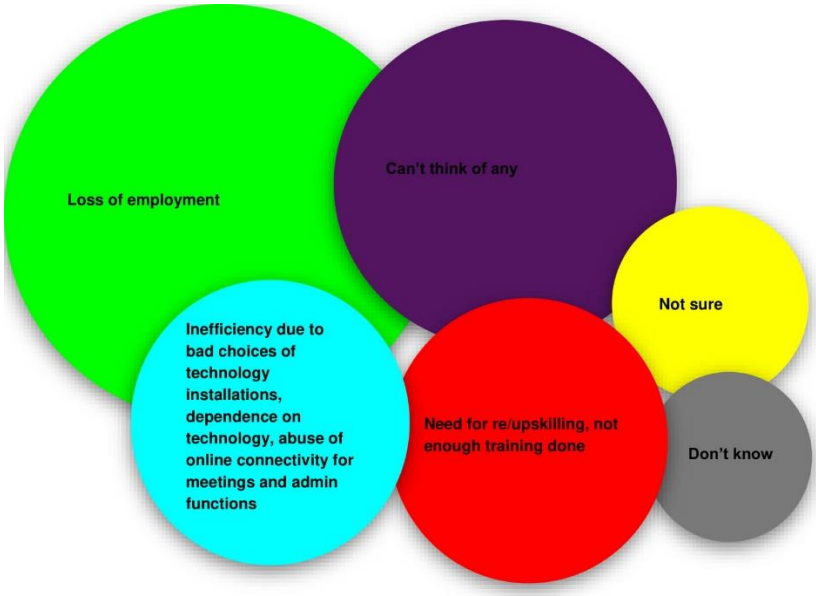

Figure 4-7:Individual level Employee perceptions of 4IR threats

4IR threats for individuals at Debswana	Number of respondents	Percentage of respondents
Loss of employment	25	
Inefficiency due to bad choices of technology installations, dependence on technology, abuse of online connectivity for meetings and administrative functions	17	
Need for re-upskilling, not enough training provided or done	13	
Can't think of any/Not sure/Don't know	21	

An overwhelming majority of respondents cited loss of employment as a threat that could be brought about by the advancement of 4IR technologies. Other respondents expressed concern over the manner in which 4IR technology may be implemented, citing possibility of inefficiency due to bad choices of technology installations as well as over-dependence on technology, abuse of online connectivity for meetings and administrative functions. However, a significant number of respondents highlighted not being knowledgeable on the possible threats of 4IR technologies.

4.4.4.2 Organizational

The respondents were asked to give their perceptions with regards to the threats presented by 4IR in the organization at an organizational level, with the themes arising from the responses highlighted in the diagram below;



Figure 4-8: Organizational level Employee perceptions of 4IR threats

4IR threats for Debswana	Number of respondents	Percentage of respondents
Job losses, high turnover rate, lower-level employees' jobs at risk due to skills gap, strained union relationships, difficulty to abide by labour laws, low employee morale	22	
Loss of investment due to poorly researched and implemented technology, inefficiencies caused by mistakes to be expected in learning new technologies, overdependence on technology, high cost of implementation	17	
Reluctance of employees to adapt to change, privacy concerns by employees, low engagement levels	13	
Increased vulnerability to online/security attacks and threats	11	
Loss of social license to operate due to over-automation	7	
Loss of opportunities to competitors due to slow adaptation to new technologies	4	
Not sure	2	

Organizationally, the respondents cited various threats, the majority of which related to job security and losses, with a possibility of high turnover rates. Moreover, the risk to lower-level employees owing to the skills gap was noted, which, in turn could result in strained labour union relationships and low

employee morale. In addition, the possibility of loss of investment as a consequence of poorly researched and implemented technology was highlighted. Furthermore, as a consequence of adjustment period for learning new technologies, respondents noted the inevitability of mistakes being made in the early learning process, with the culmination of such resulting in high costs of implementation and eventual overdependence on technology.

Moreover, the respondents argued that there could be a reluctance of employees to adapt to new technologies, with the possibility of privacy concerns by employees who could in turn have low reciprocity with regards to engagement. The responses also highlighted the increased vulnerability to online/security attacks and threats to the organization as a consequence of the increased connectivity. Furthermore, the possible loss of social license to operate due to over automation, both perceived and real, was noted by the respondents. However, there does exist a possibility of lost opportunities to competitors if Debswana does not adapt 4IR technologies in a timely manner.

4.4.5 RESEARCH QUESTION 7: WHAT ARE THE EMPLOYEE PERCEPTIONS OF THE ROLE OF CHANGE MANAGEMENT AND EMPLOYEE EXPERIENCE OF CHANGE MANAGEMENT

The respondents were asked to give their perceptions with regards to the role of change management and employee experience of change management in the organization, with the themes arising from the responses highlighted in the diagram below;



Figure 4-9:Change Management Perceptions

Change management has been noted to be good and well-structured with an efficient reward system, and is noted to be well received by a sizable portion of the respondents, who also note that it is often slow but effective, hence needs continual improvement. However, the majority of respondents cited the poor implementation and monitoring of change management, which was often pushed down on employees and characterized by poor employee engagement. Furthermore, the respondents highlighted the lack of a clear strategy in place, with change management often being poorly documented and bringing with it, initiative overload that wore out employees. Additionally, respondents noted the minimal level of ownership of changes often brought about, more so at inception. However, some respondents noted that change management was still developing and evolving in the process, and its effects have been visible.

These results are in line with the literature on change management and its effective implementation. A significant number of the respondents highlighted lack of clear communication, poor employee engagement and poor implementation and monitoring of change management initiatives. This is noted by Pelders et al (2019) who stressed the importance of ensuring that there is employee buy-in done through adequate communication and feedback provision to relevant stakeholders. Moreover, the study results speak to the change perception of the organization as being low/negative, a factor LAig and Abocejo (2021) indicated to be driven by job satisfaction, job uncertainty and organizational commitment. The study results then indicate a worrisome picture for Debswana in relation to adapting its employees as well as the organization to change management relating to implementation of 4IR initiatives.

5. CHAPTER 5 :DISCUSSION OF RESULTS

5.1 INTRODUCTION

The results, as indicated by the analysis in the previous chapter highlights insights on the effective mining safety work practices in the fourth industrial revolution in Debswana Diamond Mining Company Jwaneng, with a focus on the following objectives and corresponding research questions;

The study analysis focused on the following objectives and corresponding research questions;

- Assess Debswana Mining Company SHE safety practices
    - What are the employee perceptions of SHE safety state of Slope Stability, PPE and Collision avoidance?
- To assess the effectiveness of employee preparedness, knowledge and characteristics on SHE 4IR impacts and perceived opportunities and threats of 4IR
    - What is the role of employee traits on perceived 4IR career development readiness?
    - What are the employee perceptions of Opportunities presented by 4IR?
    - What are the employee perceptions of threats presented by 4IR?
- To evaluate the success and challenges of the current safety practices in relation to the 4IR Debswana Mining
    - What are the employee perceptions of the role of change management and employee experience of change management?
- To consolidate and recommend ways to develop Debswana Mining Company safety practices and philosophies that can be aligned to the 4IR.

This chapter will discuss the results in detail, highlighting how the insights from the respondents address the objectives as a whole.

5.2 OBJECTIVE 1:ASSESS DEBSWANA MINING COMPANY SHE SAFETY PRACTICES

In order to assess the SHE practices of Debswana Mining Company, they were assessed through focusing on slope stability, PPE and collision avoidance. The three focal areas highlighted not only the mine's safety practices, but also brought light to the perception's employees harbour regarding the role of 4IR and the manner of improvement and subsequent challenges that could be obtained through its adoption. Several common themes were noted in the responses that can be summarized as;

5.2.1 ADEQUACY OF CURRENT TECHNOLOGY

Within this theme, respondents highlighted the need for improvement of the technologies in use despite their belief in the adequacy and reliability of the technologies present in the mine. Moreover, respondents noted that the mine had competent and highly skilled operators for the technologies in use, hence arguing that the technology being used was being fully utilised. Furthermore, the ability of the technology to monitor in real time, effectively identify hazardous areas, provide good data as well as reduce incidents and accidents was deemed to be a boon to the company and as such, was a good investment.

5.2.2 INADEQUACY OF CURRENT TECHNOLOGY

Other respondents argued that the technology being made use of was inadequate, citing the fact that there was no automation. This was highlighted with regards to collision avoidance and slope stability technologies, which often depend on human intervention and act as alerting mechanisms. Furthermore, the lack of wearable technology was noted by the respondents as a shortcoming, noting that PPE should have real time monitoring such that every employee's health state is monitored within the mine as a means of increasing safety practices as well as efficiency. This, as argued by the respondents, boiled down to the overdependence of the current technology on human intervention and compliance.

5.2.3 UNCERTAINTY AND LACK OF KNOWLEDGE

There was a sizable number of respondents who noted that they did not know much about the three safety focal areas explored in this study (slope stability, PPE and collision avoidance). This, given the nature of the respondents, among whom held administrative duties, was not surprising.

5.3 OBJECTIVE 2:TO ASSESS THE EFFECTIVENESS OF EMPLOYEE PREPAREDNESS, KNOWLEDGE AND CHARACTERISTICS ON SHE 4IR IMPACTS AND PERCEIVED OPPORTUNITIES AND THREATS OF 4IR

Through the use of OLS regression, the effect of individual level preparedness on knowledge of 4IR impacts was assessed. From the results, awareness of technology changes and challenges of 4IR in SHE has a positive effect on the knowledge of 4IR impacts in the workplace. However, the results also highlight how the respondents' individual preparedness (career, health and socially) has no effect on knowledge of 4IR impacts. This result implies that there is a lack of individual preparedness for 4IR by Debswana employees which then reflects on their level of knowledge of 4IR impacts in the workplace.

In assessing organizational level knowledge effects on knowledge of 4IR impacts, employee beliefs on whether 4IR will bring improvements to mining efficiency were found to be positively related to knowledge of 4IR impacts. This result has implications on the role of employee engagement, ownership and buy-in with regards to the adoption of any new technology. That is, the success of 4IR and the knowledge of its impacts is dependent on employee buy-in to 4IR technologies. This is also reflected in the role that employee characteristics play in knowledge of impact of 4IR, with academic qualifications increasing the likelihood of knowledge of 4IR amongst employees.

Moreover, an analysis of employee perceptions was done, focusing on perceived opportunities and threats at both individual and organizational level. From the results, the respondents noted individual level opportunities such as improvements in work efficiencies, career enhancements, safety improvements, skills development and upskilling as well as a broader scope of employee roles. These were in alignment with perceived organizational opportunities such as cost cutting, production and productivity increase, safety culture enhancement and improvement, streamlined process integration, automation in high-risk areas as well as new career opportunities and skills development.

Nonetheless, the respondents also highlighted threats that could be wrought by 4IR technologies. The loss of jobs/employment was the most highlighted threat at both individual and organizational level by the respondents. However, at an organizational level, the respondents also noted the increased risk to low skill employees, possible strain on relationships with labour unions as well as low employee morale. Furthermore, the respondents noted the possible loss of investment due to poorly researched and implemented technology, high cost of implementation, increased vulnerability to online attacks and loss of social license to operate due to possibility of increased automation and conflicts with communities in this regard.

The threats and opportunities noted by the respondents revealed overlaps with the results from the quantitative analysis which posited that knowledge of 4IR impacts was a consequence of awareness of technology changes and challenges of 4IR in workplace, employee beliefs on whether 4IR will bring

improvements as well as the employee level of education. These are reflected by the noted opportunities which related to improved work conditions and efficiencies but were also countered by the threats which heavily leaned towards job losses. These perceived threats, as was highlighted in the results which indicated that employees were not well prepared for 4IR changes at an individual level (career, health and socially), are in line with employee perceptions. Moreover, the opportunities noted such as improved work efficiencies, streamlined process integration as well as cost cutting complement the threats noted such as possible loss of investment due to poorly researched and implemented tech as well as increased vulnerability to online threats highlights the manner and role of change management in Debswana.

5.4 OBJECTIVE 3 : TO EVALUATE THE SUCCESS AND CHALLENGES OF THE CURRENT SAFETY PRACTICES IN RELATION TO THE 4IR DEBSWANA MINING

The role of change management as has already been highlighted in previous analyses, dictates the manner in which employees perceive new technologies, the capability of the company to successfully implement technologies as well as the manner in which employees prepare for said changes. Change management in Debswana is viewed through several lenses of mixed reactions whose themes culminate into two clear themes being;

5.4.1 INADEQUACY OF CHANGE MANAGEMENT

The respondents noted poor implementation and monitoring of change management, which was often pushed down on employees and characterized by poor employee engagement. Furthermore, the respondents highlighted the lack of a clear strategy in place, with change management often being poorly documented and bringing with it, initiative overload that wore out employees. Additionally, respondents noted the minimal level of ownership of changes often brought about, more so at inception.

5.4.2 ADEQUACY OF CHANGE MANAGEMENT

The respondents who noted the adequacy of the change management culture in Debswana noted that it was good and well-structured with an efficient reward system, but most of the respondents also noted that it was still developing and evolving in the process, but its effects have been visible.

5.5 SUMMARY OF FINDINGS

The purpose of the study was to investigate and obtain insights on the effective mining safety work practices in the fourth industrial revolution in Debswana Diamond Mining Company Jwaneng. From the study results, it can be noted that

- The technology currently in use is adequate and robust, but is lacking in several aspects that mostly relate to automation (need for reduced dependence on human intervention and compliance)
- The level of preparedness for 4IR at an individual level for Debswana employees is lacking and has a notable non-effect on their knowledge of 4IR impacts in the workplace
- The level of preparedness for 4IR at an organisational level is dependent on the efficiency of the communication in the organisation and change management
- The main opportunities that 4IR presents relate to career enhancement, improved efficiency (productivity and production), improved process integration in the mine as well as improved safety culture
- The main threats presented by 4IR relate to the possibility of job losses, poor change management and communication (high costs, poor implementation etc) and loss of social license due to possible over automation resulting in conflicts with mining communities
- The level of change management in the organisation requires improvement with regards to communication, employee engagement and improved clarity of change management initiatives

From these, insights on the effective mining safety work practices in the fourth industrial revolution in Debswana Diamond Mining Company Jwaneng are drawn, noting the need for a more inclusive approach to 4IR adoption.

Technology in mining has advanced so significantly over the last 10 years and will no doubt see exponential growth over the next 10 years. The top three macro trends that will have the biggest impact on Mining over the next 15 years according to the Biennial Mining Survey 2017 Report are:

- Technological change and disruption.
- Environmental pressures- Climate change and energy consumption.
- Technically aware generation entering the workforce.

Designing new mines and processing facilities as they were designed 20 years ago locks the current ways of working down for the next 30 years or much less if we don't improve the economics. Debswana's leadership proposes to guide the organization through a period of substantial transformation, harnessing major changes in the global economy to unlock the full potential of the business and its people. Technology and digital advances hold the promise of unlocking the latent potential in the mining industry. Designing for comprehensive adoption of technology and digital advances is the key to:

- Unlocking Debswana's human potential: better safety, more rewarding ("Knowledge Economy") work.
- Greatly reduced capital per unit of output 30-40% lower unit operating costs.

The Stay in Business Debswana projects must act as a catalyst to assist the government of Botswana to achieve its VISION 2036 – To become a knowledge economy. The advent of the Fourth Industrial Revolution (4IR) has necessitated that countries develop new policies, strategies and innovation plans to enable an inclusive whole of society approach with Government playing a leadership responsibility.

Botswana currently has different elements of the 4IR spread across Government, the private sector and civil society but there is currently no single plan or blueprint, which brings together all key role players into a single focus. The problem of the foregoing statement is that mining houses have not had any prior experience in dealing and managing safety in a digital environment, where the focus is on artificial intelligence, robotics and autonomous trucks amongst others. Therefore, how effective will safety work practices in the mould of systems, tools, measures, processes, procedures and technologies be in that pioneering landscape. This occurrence is likely to bring uncertainty, risks and anxiety to all concerned in the mining industry especially in the case study which is Debswana Mining Company. Underlying this problem is the fact that there is no prior research in this area at macro level in Africa and Botswana at micro levels therefore necessitating this investigation.

6. CHAPTER 6: CONCLUSIONS, LESSONS LEARNT AND RECOMMENDATIONS

6.1 INTRODUCTION

The research report investigated and critically analysed the critical impact of safety in the 4IR within the Debswana Mine operations with specific reference to the Jwaneng Mine looking at the three key areas of Slope stability, Collision avoidance and Personal protective clothing chapter 1, the context of the study and key concepts of the study were introduced. The context was succeeded by literature review in chapter 2 on the existing body of knowledge with a focus on the modalities of public participation processes, the legislative frameworks and current practices. The methodical choice for the purpose of this study were discussed. In chapter 4, on data presentation, analysis and results commenced with the introduction of case study projects and presented data gathered under the four research objectives, a comparative analysis report of the case study and the results of the online survey were presented. The results of the study were discussed in chapter 5 that emerged from chapter 4. In this chapter a conclusion is drawn on the modalities of public participation and infrastructure project implementation.

This research was undertaken to establish, the effectiveness of safety in the 4IR in the Debswana operations? In the investigation, an exploratory case study strategy within a quantitative research methodology was adopted. To contribute to the body of knowledge, a robust data gathering of online survey form employee and those involved in the Safety Business units was undertaken.

Notwithstanding the growing global interest, Debswana is new to the concept of consulting the general populace and soliciting their opinions on how the 4IR will impact safety. Since safety infrastructure is multi-layered, costly and technical, there has to be a new awakening of inserting employees' participation as an integral part of 4IR safety initiatives. What is beginning to emerge is that proper timing, methods and communication techniques used are the cornerstone of a successful relationship with the general workforce. It is imperative that at each stage of the Safety strategies be defined accurately, the scope and techniques utilized be contextually relevant.

6.2 RECOMMENDATIONS

The following recommendations are proposed informed by findings and the literature review which set the context and baseline for the study:

6.2.1 RECOMMENDATION 1: REVIEW OF CHANGE MANAGEMENT PROCESSES

In light of the study results, there is a need for a review of the change management process such that it is made more inclusive, with improvements in employee engagements as well as integration of processes throughout the organization such that changes are communicated clearly and in tandem. This

will, as noted by the study results, have a positive impact on the manner the 4IR technologies are perceived, received as well as prepared for.

6.2.2 RECOMMENDATION 2: SLOPE STABILITY MONITORING

There is an opportunity to move into the space of machine learning and big data analytics to automate some of the data analysis & interpretation. This presents an opportunity to be a first mover, more so given that this level of automation of monitoring data interpretation is still an active area of research.

6.2.3 RECOMMENDATION 3: WEARABLE DEVICES

In lieu of the study results that noted the need for automation as well as wearable devices, the researcher recommends the use of wearable devices such as HxGN Mine Protect Personal Alert and Deloitte's M3SAFE. These will assist ensuring 360-degree visibility of personnel around heavy equipment, reducing the impacts of blind spots, noise, heavy traffic, and poor visibility in addition to personnel detection and instant notification.

6.3 DIRECTION FOR FUTURE RESEARCH

During the study, the researcher was exposed to an issue which was not necessarily part of the scope of this research that being the opportunity to move into the space of machine learning and big data analytics to automate some of the data analysis and interpretation. It is recommended that, further research be undertaken on developing a clearly defined model of data analysis and interpretation in the geotechnical infrastructure as it has not been explored in the mining industry.

6.4 CONCLUSION

The study sought to draw insights on the effective mining safety work practices in the fourth industrial revolution in Debswana Diamond Mining Company Jwaneng, from which recommendations in regards to 4IR, the possibility of its adoption and the mine's preparedness were assessed. As noted in the study, there is a need for improved change management within the organization in a manner that encourages employee engagement and improved and open communication. Moreover, Debswana mine has been noted to be fairing well with regards to the use of the latest technology, with recommendations leaning towards improved automation and the adoption of wearables.

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8. APPENDIX

Effective Mining Safety Work Practices in the 4th Industrial Revolution: A Case Study of Debswana Jwaneng Mine

Good day!
My name is Otto Keitumetse, a University of Witwatersrand MSc (Building and Construction Project Management) student. I'm currently carrying out my research project and am asking for your assistance through filling out this questionnaire. The information collected will remain strictly confidential and will solely be used for academic purposes.
* Required

Your participation is voluntary. Please tick here to indicate your informed consent to participate in this study. *

- [ ] I agree to participate in this study
- [ ] I decline participation request in this study

Section A: Personal Information

2. Gender *

Mark only one oval.

- ◯ Female
- ◯ Male
- ◯ Prefer not to say
- ◯ Other: _____

Age *

- 15-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65+

4. Academic qualification *

Mark only one oval.

- NCC
- Diploma
- Bachelor's degree
- Postgraduate degree (Masters, PhD)
- Other: _____

5. Level of Employment *

Mark only one oval.

- Junior
- Middle
- Senior
- Top
- Other: _____

6. Departments *

Mark only one oval.

- ◯ Management
- ◯ Process
- ◯ Mining
- ◯ Engineering
- ◯ IT
- ◯ SHE
- ◯ Other: _____

7. Duration of Employment (in years) *

_____

Section B: Understanding of 4IR

8. I am knowledgeable on 4IR and its role, impacts and effects on the workplace and in SHE *

Mark only one oval.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral
- ◯ Agree
- ◯ Strongly agree

I am aware of technology changes and challenges in 4IR relating to SHE *

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

10. Careerwise, I am well equipped for 4IR developments in SHE *

Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

11. Health wise, I am well equipped for 4IR developments in SHE *

Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

12. With regards to my social life, I am well equipped for 4IR developments in SHE *

Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

13. The use of 4IR will improve mining efficiency *

Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

14. Employees are engaged in the SHE 4IR initiatives that will improve mining efficiency *

Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

I am aware of the company SHE 4IR initiatives *

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

16. The current safety practices are adequate to effectively address the safety challenges within Debswana Mining Company *

Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

17. I believe 4IR will improve operational efficiency within Debswana Mining Company *

Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

Do you believe the current safety practices regarding SLOPE STABILITY are robust? Explain why. *

Do you believe the current safety practices regarding PPE are robust? Explain why. *

Do you believe the current safety practices regarding COLLISION AVOIDANCE are robust? Explain why. *

25. What are the opportunities presented by 4IR in Debswana safety for individuals (in terms of career growth, health status and social life)? *

The current Debswana safety practices are aligned to the 4IR *

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

Section C: Experience and Perception of 4IR

19. Are you aware of the 4IR (Robotics, Autonomous trucks, Internet of Things, Artificial Intelligence)? *

Mark only one oval.

- Yes
- No

20. What skills do you believe are required to adapt to SHE changes caused by the 4IR in mining? *

21. Which SHE 4IR initiatives are you aware of in Debswana? *

22.

26. What are the opportunities presented by 4IR in Debswana as a company? *

27. What are the threats presented by 4IR in Debswana safety for individuals (in terms of career growth, health status and social life)? *

28. What are the threats presented by 4IR in Debswana as a company? *

29. What is your view about the status of SHE maturity at Debswana and how 4IR could influence it? *

30. What is your experience of change management at Debswana in relation to SHE? *

31. Are employees fully engaged and involved in the definition and practice of SHE both at work and home? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Other: _____

32. How will company culture influence decisions on the adoption of 4IR on SHE practices? *

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Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	6.547	5	.257
	Block	6.547	5	.257
	Model	6.547	5	.257

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	30.193[a]	.084	.216

a. Estimation terminated at iteration number 7 because parameter estimates changed by less than .001.

Classification Table[a]

			Predicted		
			Awareness of 4IR		Percentage Correct
			Yes	No	
Step 1	Awareness of 4IR	Yes	70	0	100.0
		No	5	0	.0
	Overall Percentage				93.3

a. The cut value is .500

Signature:

Email: