THE 4TH INDUSTRIAL REVOLUTION AND ITS IMPLICATIONS FOR MINING-DEPENDENT COUNTRIES

INSIGHTS FROM SOUTH AFRICA AND ZAMBIA

HSRC Human Sciences Research Council

SATRI SAM TAMBANI RESEARCH INSTITUTE

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Executive Summary

This interdisciplinary study broadly sought to determine the scope, nature of opportunities, and threats the Fourth Industrial Revolution (4IR) presents to the mining industry in Africa. It examined these threats and opportunities along the entire mining value chain. The study sought to gain empirical knowledge on the current state of mining practices in SADC countries in relation to the increasing adoption of new 4IR technologies. In this report, the countries of focus were South Africa and Zambia. These technologies have transformed mining practices with the result that tasks that were undertaken by human beings are now accomplished by robots and autonomous machines. This transformation has profound implications for mine workers and their communities. The transformation also has radical consequences for trade unions as they have to re-position themselves so that they remain relevant and thus sustainable.

The opening chapter of the report gives the background to the study, highlighting the centrality of the mining sector to SADC economies. It is noted how the mining industry is key to the economic fortunes of many countries in Africa. The sector is a major earner of foreign exchange, a significant source of employment, and a potential catalyst to the industrialisation of the continent. The chapter then traces the history of the industrial revolution, from the First Industrial Revolution to the 4IR. Insights are made into what exactly constitutes the 4IR, and how it is likely to affect all the key stakeholders in the mining sector. The objectives and aims of the study are also outlined in this chapter. The key research question is about how the mining sector in Southern Africa is engaging with the 4th Industrial Revolution, if at all, and how the 4IR is affecting labour dynamics in both new and mature mines. Part of the objective of the study was also to look into the implications of the 4IR for socio-economic development of mining countries as well as what proactive measures can be undertaken to mitigate the negative socio-economic effects of the 4IR in the mining sector on the continent.

The second chapter gives an overview of the mining landscape in SADC in general, and in South Africa and Zambia in particular. The point is made that the mining sector remains one of the key factors shaping the social, political, and economic landscape of most of the Southern African Development Community (SADC) member states.

The third chapter outlines the methodology of the study. It is noted that in each country (South Africa and Zambia) the research gathered a diverse set of both qualitative and quantitative data using multiple methods that include interviews, surveys, and document reviews. The study itself was intensely participatory in nature to enable meaningful inputs and buy-in from key stakeholders, as well as ultimate ownership of the knowledge-products deriving from that by the stakeholders in the focal countries and other key actors on the continent. Relevant literature, policy, and legislative documents were reviewed to build the knowledge base on technology innovation in the mining sector. Semi-structured questionnaires/interview guides were used to collect the data, basically covering three main thematic areas, namely: general mining experiences, the 4th Industrial Revolution and labour dynamics, and impact on mining industry value chains. It is stated in this chapter that for South Africa, there were two separate research studies undertaken – the first was for the rest of the country while the second focused only on the Northern Cape Province. As a result, in this report the data from the Northern Cape baseline survey is given separately from that of the rest of the country.

The fourth and fifth chapters focus on Zambia and South Africa, respectively. This section of the report provides the profile of the mining companies that participated in this study in

the two countries. The two chapters look at the current status of technology in mines in the participating countries, focusing especially on the use of new technology in the new mines. A key interest of the section is to examine the impact of the 4IR on labour, where it is observed that massive job losses have generally characterised the introduction of automation in the mining sector. The section also investigates the general awareness of the 4IR among mineworkers, and perceptions thereof. The dynamics of new technologies in selected mines are also explored, as well as the impact of these changing practices on mining communities.

The sixth and seventh chapters look at the voice and position of trade unions in Zambia and South Africa, respectively. This section of the report focuses on the unions' response to the 4IR and examines awareness of the 4IR concept by unions. The section takes a look at the disruptions of labour dynamics and how unions are preparing for the future of work in the 4IR era. Trade unions in Zambia concede that data and information from cutting edge research is critical for informed decision making in building a transformative society. The unions call for compact and collaborative planning and research to ensure that workers are not the casualties of new 4IR technologies.

The attitude of organised labour in Zambia towards technological change is not well documented. Nevertheless, the evidence suggests that trade unions are not fully opposed to new technological innovations at mines, they are only concerned about workers' welfare. The trade unions insist that technologies should not destroy livelihoods. Cooperation and consensus are what is needed between mining management and organised labour to reduce the negative effects on workers. Unions are calling for the up-skilling of workers to help them cope with the technological advancements.

In South Africa, trade unions are mainly concerned about protecting the interests of workers and ensuring that workers do not lose their jobs. It is noted that the 4IR will bring about massive changes to the mining sector. With these changes comes threats of job losses to workers, but on the other hand there is safer and more effective production on the side of mining companies. Thus, the 4IR can in many ways benefit the employer more than it benefits the employee. As a result, trade unions only have one major concern: How will the role of trade unions be affected in the 4IR? The lifeblood of trade unions is in fact employees - who are trade union members. The 4IR is most likely going to undermine the bargaining power of trade unions. This notion immediately raises a lot of uncertainty and anxiety among trade unions, particularly around the topic of their sustainability and relevance in the 4IR era.

The report closes with a conclusion (Chapter 8) wherein cross-cutting issues are identified. These issues include the voice of the unions, new technology deployment in mines and effects on production, and awareness of the 4IR among mineworkers. On awareness, the study shows that the general level of awareness across the respondents in both countries is well over 60%. Most of the mineworkers in both countries acknowledge the positive impact of the 4IR on health and safety across the mines, with more respondents from Zambia indicating that latest technologies have improved health and safety in the mines. However, the unions in both countries are agreed that new technology deployment and the new mining methods pause a threat to the sustainability of jobs.

1. INTRODUCTION

1.1 Background

The mining industry is key to the economic fortunes of many countries in Africa. The sector is a major earner of foreign exchange, a significant source of employment, and a potential catalyst to the industrialisation of the continent.

The continent dominates the production and export of mineral commodities. Despite this, the continent remains poor, characterised by inconsistencies in economic progress - linked to the over-dependence on this mineral wealth. Despite this, in many countries the mining sector remains key to economic and social development. Recently, there has been a renewed interest in using mining and mineral resources as a catalyst to local industrialisation, a key pre-requisite for sustainable improvement of the wellbeing of the region's citizenry.

The mining sector in Africa, traditionally, had to contend with different challenges including low-value mineral resources export, fluctuating commodity prices, and transfer pricing. The emergence of the Fourth Industrial Revolution (4IR) and accompanying technologies pose both threats and opportunities in mining countries.

This revolution is characterized by a range of new technologies that are blending the physical, digital, and biological worlds in virtually all disciplines, economies, and industries. This blending is blurring distinctions between humans and machines. Most concerning is that the various forms of this revolution - that among others include machine learning and artificial intelligence (AI) - could lead to a loss of familiar and well established professions and jobs. The mining sector is a source of employment in many countries, particularly in Africa, and changes in the industry under the 4IR could lead to a severe loss of jobs. Even though some new jobs will be created, this does not quell the concerns around severe job losses. The recognition that the 4IR technologies will lead to job losses and disruptions to the local socio-economic system therefore requires proactive introduction of interventions to mitigate these undesirable effects of the 4IR. The processes towards such interventions need to be informed by technologies that mining companies currently have and are likely to introduce under the 4IR era. Furthermore, it needs insight into how these technologies affect people at all levels of the mining value chain.

Due to the strategic nature of technology in the mining business environment, mining companies may not be willing to divulge in detail the technology they plan to introduce in the future. However, an examination of the technologies that new mining companies introduce is a proxy indictor of the emerging technologies in the sector and potentially the trajectory of future technological advances. The effect of these technologies can also be observed through the employment and socio-economic impacts of the new technologies in communities where new mines are located compared to those in old and established mines.

The second element of changing technologies under the 4IR and socio-economic development of mining-dependent countries relates to how this will affect the aspiration of local industrialisation and trade efforts. Local industrialisation and external trade are key in creating sustainable jobs beyond the extractive sector and contributes to the general improvement of people's welfare in a country.

As the various African countries contemplate economic diversification through industrialisation, the mining industry is in flux trying to contribute to the effort while simultaneously managing the typical sector challenges that include minerals price volatility, the highly dynamic and unpredictable geo-political environment, the politics of labour relations, and the spiralling costs of mineral production. The 4IR adds additional challenges, most notably the issue of balancing issues of productivity, profitability, and safety on the one hand and the availability and safety of some jobs on the other hand. Clearly this revolution presents both opportunities and threats.

Despite the emerging of the 4IR, the mining sectors of different countries are still at various stages of technology transformation to adopt and adapt to changes in this space. This makes it imperative to reflect on technology deployment in the mining industry. This reflection is important in shaping and broadening the understanding of not only the stage at which the mining companies are operating in this context, but also the complex dynamics and implications of the current and future changes to the mining sector. To better comprehend and deepen the understanding the next section looks at the evolution of the Industrial Revolution.

Evolution of the Industrial Revolution

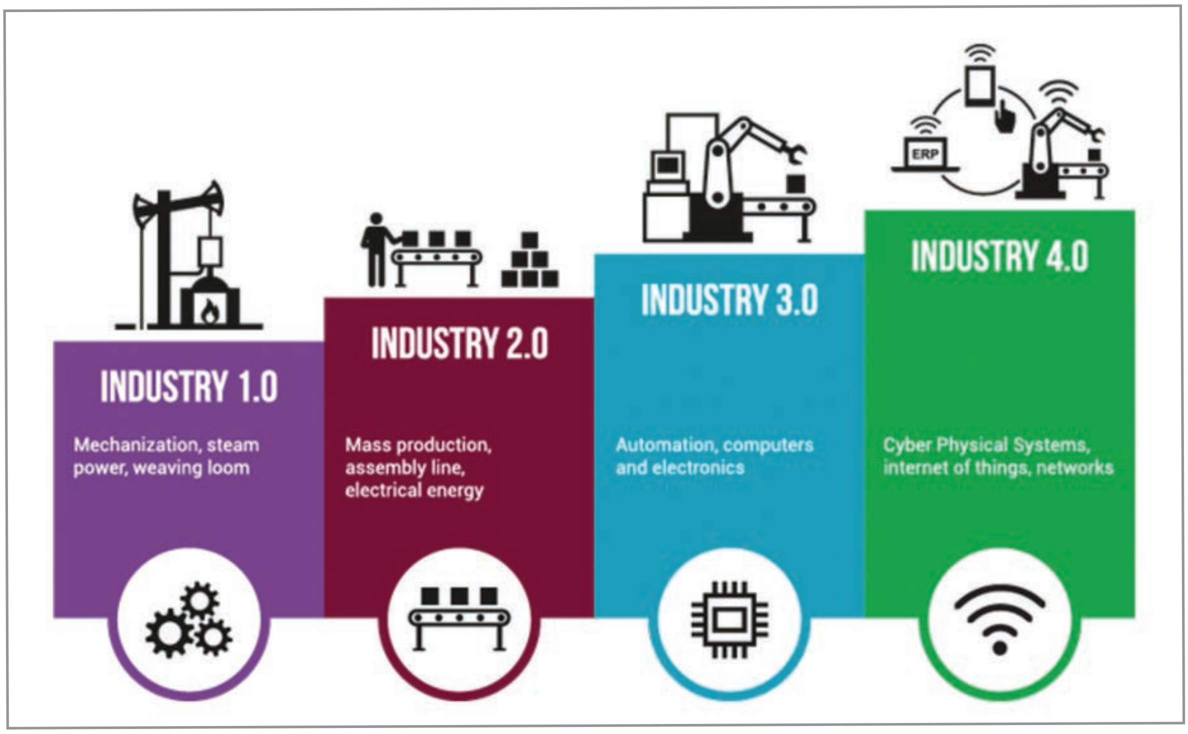


Figure 1. The Major Technological Advances that Charaterise each Industrial Revolutions Leading to the 4IR (Source: NetObjex, 2019)

The 1st Industrial Revolution mechanised the means of production. The revolution witnessed a switch from a self-sustaining organic economy to a mineral resource depleting inorganic economy, particularly in countries such as Britain, Belgium, France, and German. A significant discovery of the era was the use of steam power which increased the demand for coal (Robert Wilde, 2018). During this period, coal became a key factor in the success of industrialization; it was used to produce the steam power on which industry depended. The 19th Century thus heavily relied on fossil fuels for steam powered mechanical production (Hermanus, 2018). The advent of the 2nd Industrial Revolution also known as the era of mass production and technology revolution (Mid-19th Century) brought new innovations in steel production, petroleum, and electricity. The period witnessed the burgeoning of the industrial base, particularly in Europe. Likewise, in Southern Africa the discovery of minerals during the late 19th Century brought about significant change to society. Notably, the discoveries of gold and diamond deposits in South Africa that exceeded those in any other part of the world led to a substantial foreign capital injection into the country. Over the course of the 20th Century, South African mining companies such as Anglo American, De Beers, Rand Mines, JCI, and Gold Fields grew to become global giants. Until well into the 1980s, these companies invested across and beyond the mining value chain. In the early years, as mining grew, small engineering works and companies supplying support services were established around the gold mining industry, and local production of much of the equipment essential for deep-level mining got also developed. These developments drove industrialization in South Africa (Turok, 2014; Innes, 1984).

The 3rd Industrial Revolution has been characterised by electronics and is driven by semi-conductor industries known as the phase of automation. Evidence from World Semi-conductor Trade Statistics (WSTS) points towards exponential growth propelled by block chain technology through the Internet of Things. Phones, computers, and intelligent robots are used in this regard (WSTS, 2018).

The 4th Industrial Revolution is ushering in a new dimension of advanced technological innovations. The revolution is driven by, among others, machine learning and artificial intelligence, complemented with block chain technology and the Internet of Things. In the mining sector, automation is gaining favour particularly to overcome difficult working conditions, poor deposits, and other efficiency and productivity concerns across the value chain.

Fourth Industrial Revolution technology in mining generally refers to the integration of emerging digital technologies into mining practices. It is a high-tech strategy being used by the sector to fundamentally alter the world of work for humans and machines, and the interplay between the two to produce goods and services. The core technologies of 4IR have been broadly identified as: the Internet of Things (IoT), Big Data Analytics (BDA), Cloud, 3D printing, Robots, Artificial Intelligence (AI), Machine Learning (ML), and 5G technology.

1.2 Problem Statement

Whether the 4IR can contribute substantively to broad-based economic growth and income security remains a subject of intense debate. Fears around this revolution are intractable, particularly in the developing countries that face high levels of unemployment. With its bulging and increasingly educated youth population, Africa is seized by this debate. The mining sector is important to the economies of many economies in Africa where it is a major earner of foreign exchange as well as a source of employment. However, the industry faces many challenges that include increasing production costs relating to labour, exhausting surface mineral deposit, as well as environmental and employee safety concerns. The importance of these issues is rising at a particularly inauspicious time as the 4IR gets underway. In this realm there are fears of the 4IR rendering the parts of traditional workforce and their tasks redundant due to increased automation. This is against the vision of creating jobs to address the entrenched high levels of unemployment typical in many developing countries. How the 4IR is and will affect the mining sector (the mainstay of many countries in the SADC region) and their national development dynamics is yet to be fully explored. Existing literature presents numerous speculations on the impact of this revolution on the mining sector with limited empirical evidence. There is a paucity of comprehensive analysis of the 4IR-linked emerging trends across value chains in the mining industry and the overall contribution of the sector to national development. This research seeks to address this paucity.

Adopting the value chain framework approach is important because it presents intuitions on strategies that could develop general and specific industry infrastructure, leading to a viable African mining industry that is integrated into and out of both local and global value chains. This is critical to the continent's industrialisation efforts. The 2030 agenda for sustainable development dictates that industrialisation simultaneously addresses broader social and environmental factors. This calls for the need to develop a re-imaging and restructuring of the discourses in the exploitation of mineral resources to advance the development of an Africa domicile manufacturing industry base that considers the local and global contexts. The 4IR is critical in this endeavour.

1.3 Broad Research Objective

Against the backdrop of these global developments and trends, this proposed interdisciplinary study broadly seeks to determine the scope, nature of opportunities, and threats the 4IR presents to the mining industry in Africa. It examines these threats and opportunities along the entire mining value chain. Essentially, it seeks to respond to a few broad questions:

- How is the mining sector in Southern Africa engaging with the 4th Industrial Revolution, if at all?
- How is the 4th Industrial Revolution and accompanying technologies affecting labour dynamics in new and mature mine ventures and mining business in general?
- What are the implications of 4IR for socio-economic development of mining countries?
- What proactive measures can be undertaken to mitigate the negative socio-economic effects of the 4IR in the mining sector on the continent?

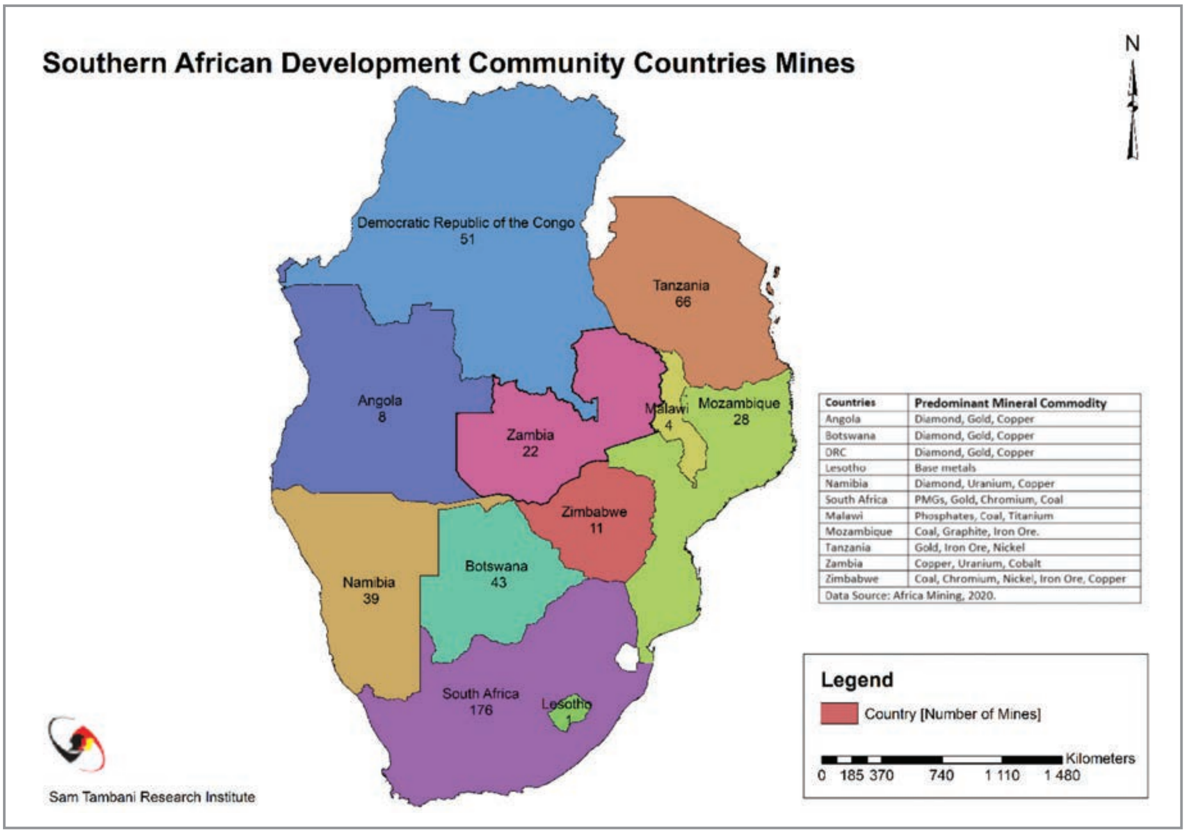
1.4 Specific Objectives

a. Undertake a baseline assessment of technology application across mining value chain in the selected case study countries.
b. Establish the awareness level of 41R in the mining sector.
c. Assess the impact of the 4IR-related technologies on labor dynamics for both new and existing mining ventures.
d. Establish what elements of mining and mining business are being rendered obsolete by the 4IR technologies.
e. Evaluate the impact of 4IR-related technologies in the mining sector on local industrialization imperative.
f. Recommend how to mitigate adverse socio-economic effects of 4IR-technologies for the mining sector in the selected SADC countries.

2. REGIONAL MINING LANDSCAPE

2.1 Context of Mining in Southern Africa

The mining sector remains one of the cornerstones shaping the social, political, and economic landscape of most Southern African Development Community (SADC) member states. Essentially, the mining industry is part of the SADC regional developmental processes which create wealth, employment, and a market for other industries such as manufacturing and services. Most of the countries are endowed with unique mineral commodities which make a significant contribution to the national gross domestic product, and they depend on mineral exports for their foreign exchange earnings. Approximately 50% of the world's vanadium, platinum, and diamonds come from the SADC region, in consort with 36% of gold and 20% of cobalt (SADC, 2019). Mineral resources mined in the different SADC countries are summarised in Figure 2 below:



Countries	Predominant Mineral Commodity
Angola	Diamond, Gold, Copper
Botswana	Diamond, Gold, Copper
DRC	Diamond, Gold, Copper
Lesotho	Base metals
Namibia	Diamond, Uranium, Copper
South Africa	PMGs, Gold, Chromium, Coal
Malawi	Phosphates, Coal, Titanium
Mozambique	Coal, Graphite, Iron Ore.
Tanzania	Gold, Iron Ore, Nickel
Zambia	Copper, Uranium, Cobalt
Zimbabwe	Coal, Chromium, Nickel, Iron Ore, Copper
Data Source: Africa Mining, 2020.	

Figure 2: Southern African Development Community Mines

Given the pivotal role played by the mining industry in the region, SADC launched a protocol on mining which guides and harmonises policies, standards, and legislative and regulatory frameworks for mineral resources exploration and extraction in the region. Central stakeholders in this sector are the state, citizens, and the private sector. Essentially, the mineral resources belong to the citizens, and mineral rights are vested in the state for the benefit of the citizens. Private sector companies are granted the rights to exploit these minerals on specific terms while also realizing returns to shareholders on their investments. A closer look at the mining landscape of each of the selected countries will aid in understanding how technological innovation has a bearing on the mining sector for the selected countries (South Africa and Zambia) and how this shapes the mining sector in general and the labour dynamics given the specific mineral commodities found in these countries.

2.2 South Africa's Mining Landscape

For several years the mining sector has been the backbone of the South African economy. Among the several mineral commodities mined in the country, gold, diamonds, platinum, and coal and metals are the most mined. In addition chrome, vanadium, titanium and a number of other lesser commodities are among the numerous minerals found in the country. According to the Department of Mineral Resources, in 2018 the mining sector contributed R351 billion to the South African gross domestic product (GDP). The same year, a total of 453,543 people were employed in the mining sector (MCSA, 2019). Table 1 illustrates the disaggregated fast facts for a few selected mineral commodities which show the significance of the mining sector in the country. Evidence shows that the sector has for many years attracted valuable foreign direct investment to South Africa.

Table 1: An Overview of selected Key Mineral Commodities

(Source: Table drawn based on figures from Mineral Council of South Africa, 2019)

Commodity	Main Region	Total Employed	% Total national employment mining Sector	Revenue	Production (million tonnes-(Mt))
Coal	Mpumalanga	86,919	19%	R139 billion	252.6 Mt
Gold	Witwatersrand Basin (NW, FS & Gauteng)	101,085	22%	R69.9 billion	132.2 tonnes
Diamonds	Kimberley, Transvaal	16,666	3.7%	R16.3 billion	10.5Mct
Platinum	Bushveld Igneous Complex	Dominated by Gencor, JCI and Lonrho. Corporate actions eventually saw the mines in these groups housed under Implats, Amplats, and Lonmin (key players in the sector) and responsible for producing up to 80% of the world's PGM supplies.			

2.3 Zambia's Mining Landscape

Zambia is internationally recognised as a major producer of copper and cobalt (ranked as the seventh and second highest world producer, respectively). It also produces precious metals (gold, silver), gemstones (amethyst, aquamarine, emerald and tourmaline), coal, and industrial minerals. Essentially, Zambia's copper mining has been the backbone of economic and socio-economic development since the discovery of the Cu-Co deposits in the Copperbelt Province. The mining industry in Zambia is dominated by copper and cobalt commodities. It possesses the world's highest-grade deposit of copper and has substantial reserves of copper (690 million metric tons) and cobalt (270 thousand metric tons). The majority of Zambia's copper deposits yield a high grade between 2–3 per cent in comparison with the global average yield of roughly 0.8 per cent. Zambia is expected to become one of the world major copper producers in future due to high grade reserves and several expansion plans by current mining companies. Besides copper and cobalt, Zambia also produces precious metals (gold, silver), gemstones (amethyst, aquamarine, emerald and tourmaline), coal, industrial minerals, and potential energy resources including uranium and hydrocarbons. Zambia produces nearly 20% of the world's emeralds and is among the world's top three producers. Although Zambia is the least coal producer in Southern Africa, it has substantial coal reserves and production is expected to grow from 281 000 tons in 2014 to more than 2 million tons. Lead and Zinc are the next in importance to copper and cobalt production, with 11 metric tons of ore containing 40% combined zinc and lead. Kabwe has the highest-grade zinc and lead deposits in the world.

Other key commodities mined in Zambia include emeralds, gold, and nickel. The top producer of emeralds in Zambia is Gemfields. The company has a mining joint venture with the government of Zambia and produces ethical, conflict-free gemstones, with a clear certification of origin. The company accounts for nearly 20% of the global emerald supply. In Zambia, emeralds are found in the Miku-Kafubu area. Zambia houses the world's largest emerald mine, Kagem Mine, and Gemfields holds a 75% share in it.

Since the year 2000, the mining industry of Zambia has attracted investments of nearly USD8 billion. The mining industry employs more than 80 000 people formally. The mining sector accounted for 12% of Zambia gross domestic product (GDP) and more than 78% of the exports in 2015. The mining industry is a significant source of government revenue and of formal employment, both directly and indirectly. The mining industry has long been considered the bedrock of the Zambian economy. According to the Central Statistical Office, GDP from mining in Zambia averaged ZMK3.3 billion per quarter from 2010 until 2020, reaching an all-time high of ZMK3.8 billion in the second quarter of 2020 - with a growth rate of 14.2%.

Rapid economic growth and new mining developments have increased the demand for power in the past few years. Hydropower accounts for 95% of power production. Increasing coal production is expected to alleviate power supply deficits.

The country currently has 13 major mining projects owned by 12 companies. These include Lubambe Copper Mine, Mopani Copper Mine, Konkola Copper Mine, Barrack Gold Mining Corp and First Quantum Minerals, Kagem Mining, Gemcanton Mining Services, Kalumbila Copper Mine, Chibuluma Mine, Kasenseli Gold Mine, and Chambeshi Copper Smelting Company to mention but a few.

Government has recently acquired 100% of local operations of Glencore's Mopani Copper Mine and Vedanta's Konkola Copper Mine (KCM) in the past two years. The takeover of KCM was, however, through ZCCM IH liquidation process after complaints by local contractors and suppliers of not being paid for extended periods of time.

3. METHODOLOGY

3.1 Introduction

Adequately addressing the research question requires the study of mining ventures in almost all the SADC countries. However, financial and time limits do not permit this. Consequently, the study adopted a discrete case study design that employs multiple qualitative and quantitative methods (Yin, 2009). Where applicable the study employed a comparative analysis between and within selected countries, their mineral commodities and mining firms. This case study approach permits a concurrent examination of organisational, sectoral, and sub-sectoral as well country specific dynamics simultaneously with the investigation of temporal, cross-sector, and cross-country subtleties (Levi-Faur, 2002).

3.2 The Focal Countries

The selection of the focal countries is mainly based on a set of criteria that ensures broad-based representation of the mining industry within the SADC region. Some of the considerations were:

- focus on mining dependant countries: countries whose economies largely depend on mining;
- mining foot prints;
- commodities for exploration;
- presence of multi-national companies.

The four case countries (South Africa, Zambia, Zimbabwe, and Tanzania) have experiences with large-scale and small scale mining. South Africa has the largest and perhaps most sophisticated mining industry among the four case countries. This industry is served by an equally sophisticated input goods and services industry. Zimbabwe had a fairly sophisticated mining industry which has since collapsed with the national economy. Nevertheless, the country's mining industry still remains and efforts to revive it face a number of challenges. Copper has been and remains the mainstay of the mining industry in Zambia. The industry is currently dominated by firms from China. It will be interesting to observe how the influence from China is shaping how the mining industry in Zambia is engaging with the 4IR. Tanzania is an emerging mining economy. This is to a large extent led by the gold mining industry. A key focus of this research is how this relative young mining economy is engaging with the 4IR compared to the relatively mature industries in the other countries.

This report, however, focuses on two and not four focal countries - Zambia and South Africa which are part of Phase One of the study. The study was phased because of time and resource constraints, and the impact of Covid-19 on fieldwork across the original four countries.

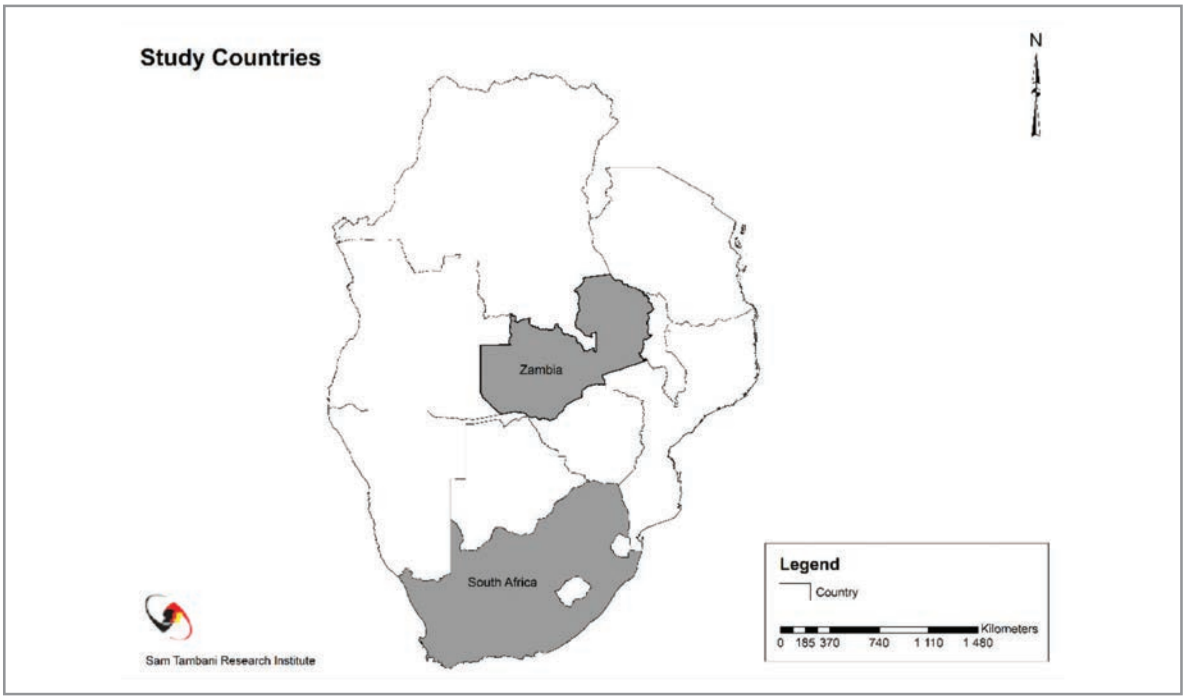


Figure 3: Study Countries

3.3 Methods

In each country the research gathered a diverse set of both qualitative and quantitative data using multiple methods that include interviews, surveys, and document reviews. Key questions used during data collection were developed taking into account the study specific objectives. The study itself was intensely participatory in nature to enable meaningful inputs and buy-in from key stakeholders as well as ultimate ownership of the knowledge-products deriving therefrom by the stakeholders in the focal countries and other key actors on the continent. Relevant literature, policy, and legislative documents were reviewed to build the knowledge base on technology innovation in the mining sector.

As aforementioned, empirical fieldwork work was carried out in Zambia to obtain both qualitative and quantitative data revealing the prevailing situation on the ground regarding new technology deployment in the mining sector for extraction of selected mineral commodities. The fieldwork included a rapid assessment using a semi-structured questionnaire-based survey instrument for in-depth interviews carried out with key informants. Due to Covid-19 restrictions, the questionnaire was converted to an electronic one which was sent to all potential participants for self-administration. Additionally, secondary data (quantitative and qualitative) was collected and collated to build the needed data-base. This included analysis of public opinion data from the chamber of mines and statistics and other relevant institutions in each country.

Specific methods and procedural steps followed during the study were as follows:

Step 1: Desk-based documentation review

During this phase, a detailed review of relevant literature and policy documents was carried out to gain a broad understanding of the prevailing situation of mining in the selected case countries. Among others, relevant strategic documents at national and regional levels were reviewed as well as global level literature on industrial revolution and the labour dynamics in the mining sector.

Step 2: Sampling

The study was originally set to be implemented in four focal countries in Southern Africa, namely: South Africa, Tanzania, Zambia, and Zimbabwe. Only South Africa and Zambia were studied in this Phase One as mentioned before. Purposive and snowball sampling was done to determine the key respondents to be targeted during the study. Personnel from relevant government departments, unions, academics, and the civil society active in the mining sector were contacted so that they could provide the bulk of the respondents for this study. The targeted number of respondents was 15 officials per country. If the researchers managed to reach out to more respondents, it was considered as an added advantage. In other words, the study targeted those key informants who are already known or expected to have knowledge about developments of the 4IR in this sector. These targeted respondents were contacted through telephone and physical visits (that is, before Covid-19) and invited for the interviews.

For each country a minimum of 4 commodities was to be selected considering the convenience and limited time frame to undertake the field work. Again for each commodity a minimum of 2 mining companies were selected; if the researchers managed to visit more than 2 that was to be an added advantage. Apart from interviewing the executive management and the technical directors, the field workers were also interviewed – with a target of at least 10 workers per mine.

A comprehensive list of potential respondents and key stakeholders to target was drawn up and purposively selected as a first step in enabling the researchers to carry out the in-depth interviews and/or sending the electronic questionnaire link for self-administration.

Step 3: Development of data collection instruments

The researchers designed and pre-tested relevant data collection instruments such as questionnaires and/ interview guides to be used during the fieldwork. Pretesting was done in one of the coal mines in Mpumalanga. Essentially, the instrument was divided into two sections namely 'Management' and 'Non-Management'. An online link was developed and circulated to the target respondents.

Step 4: Data Collection - Key informant interviews

Relying on a pre-determined minimum sample size, the researchers used face-to-face in Zambia and telephonic and online meetings were used (where possible) to engage and obtain information from the respondents. The interviews followed a semi-structured questionnaire which was designed to guide these interviews. The questionnaire was designed to addresses the key objectives of the study and the major thematic areas of labour dynamics and the fourth industrial revolution. Where possible, the researchers attempted to ensure gender-balanced coverage by interviewing both females and males.

Step 5: Data analysis and research report writing

This data was analysed through the thematic analysis approach (Braun and Clarke, 2006). The analysis was done at both the semantic and latent levels, in each case seeking to generate plausible insights into how firms and countries are engaging with the 4IR discourse in both the policy and practice spheres of their mining industries. A consolidated report covering the case countries was developed.

3.4 Research Questions Covered by Data Collection Tools

Semi-structured questionnaires/interview guides were used to collect the data, basically covering three main thematic areas, namely: general mining experiences, 4th Industrial Revolution and labour dynamics, and impact of industry on mining value chains. Some of the main research questions targeting both new and existing mine ventures that were included on the questionnaire were as follows:

i. Are there any latest 4IR specific technologies that have been deployed or you intend to deploy to enhance mining operations?

ii. What labour effects if any have you envisaged from the introduction of new technologies?

iii. Are there any elements of the mining business that have been rendered obsolete by the 4th Industrial Revolution?

iv. What can be done to mitigate the effects of the 4IR?

It needs to be stated that for South Africa, there were two separate research studies undertaken – the first was for the rest of the country while the second focused only on the Northern Cape Province. As a result, in this report the data from the Northern Cape baseline survey will be given separately from that of the rest of the country.

3.5 Covid-19 and its Impact on the Project

The Covid-19 pandemic impacted research activities and outputs across the Research and Development (R&D) sector in many ways. Travel and social and funding restrictions imposed in response to the Covid-19 pandemic have taken a toll on scientific research worldwide. Similarly, this project faced unprecedented disruptions.

In particular, the confirmed field work visits with respective mines and identified key informants could not take place as planned. No one ever anticipated to see the restrictions prolonging beyond a full year from March 2020 to beyond March 2021.

Not only that, but this comes at a time when the sector has had to adapt to new ways of working all while what the research enterprise does - drive new discovery and understanding to aid society - has never been more critical. In response to this, the project team had to convert the data collection instrument to a virtual platform, although obtaining authorisation from the respective mines remained a daunting task.

4. ZAMBIAN CONTEXT

4.1 Introduction

This section provides the profile of the Zambian mining companies that participated in this study. Seven mining companies were represented, including Konkola Copper Mines (KCM), Mopani Copper Mines (MCM), Kansanshi Mine, and Lumwana Copper Mines, Kalumbila Copper Mine, and Non-Ferrous Company Africa. These mines are a fair representation of the mining industry in Zambia as they include Zambia's biggest mines which are Lumwana, Kansanshi, MCM, and KCM; and they account for approximately 80% of the copper production in the country. In addition, both new and old mines were represented. A large proportion (66.7%) of the respondents represented mines which have been in operation for more than 20 years (See Figure 4, Table 2, and Figure 5 below).

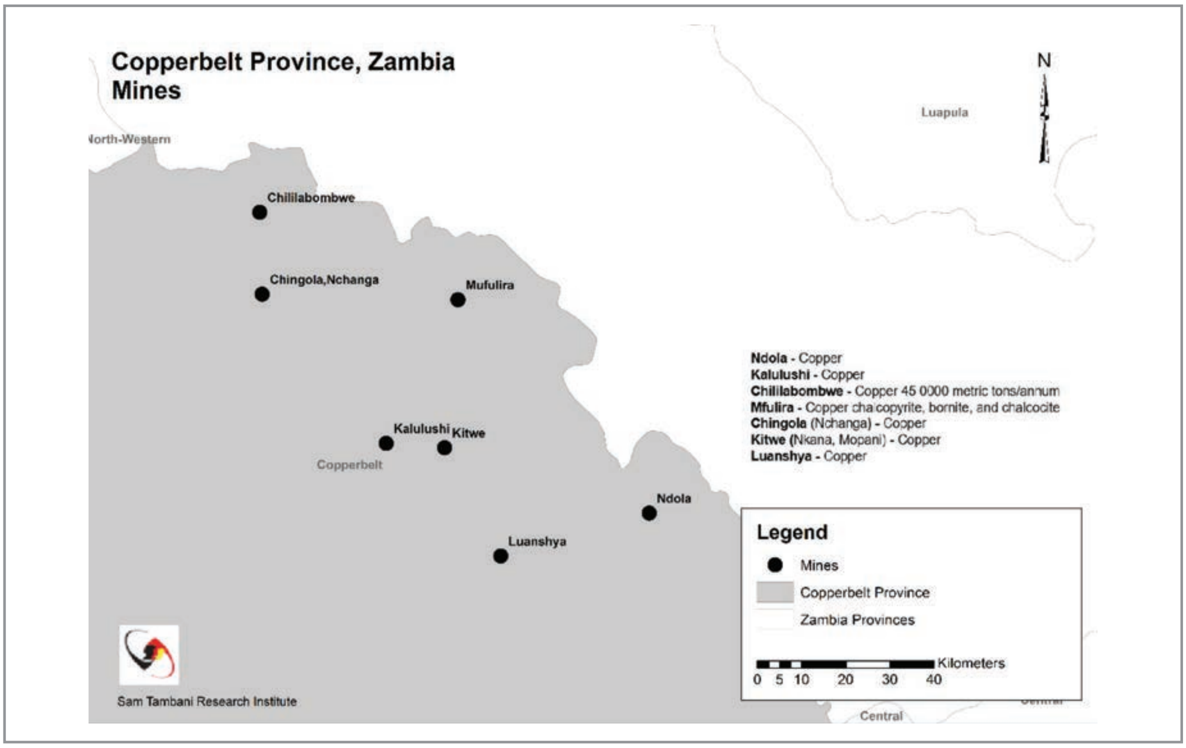


Figure 4: Major Mineral Commodities and Mine Companies in Zambia

Table 2: Mining Companies which Participated in the Study

Company	Mines	Location	Mine type	Commodities	Owners
Konkola Copper Mine (KCM)	Konkola Nchanga Nkana	Chingola Kitwe Chililabombwe Nampundwe	Underground and open pit	Copper	Vedanta Resources PLC-80% Zambia Consolidated Copper Mines Investment Holding Group -20.6%
Mopani Copper Mines	Mufulira Nkana	Mufulira Town Kitwe Town Copperbelt	Open pit & Underground	Copper & Cobalt	Zambia Consolidated Copper Mines Investment Holding Group -80%

Kansanshi	Kansanshi	Solwezi, North Western Province	Open pit	Gold Copper	First Quantum Mineral Ltd - 80% Zambia Consolidated Copper Mines Investment Holding Group - 20%
Lunwana	Malundwe and Chimiwungo	North-Western Province	Open pit	Copper	Barrick Gold Corp - 100%
Kalumbila Minreals Ltd	Sentinel mine	North-Western Province	Open pit	Copper	First Quantum Minerals Ltd -100%
Luanshya Copper Mines		Luanshya, Copperbelt	Open-pit and Underground	Copper Cobalt Uranium	China Non-Ferous Metals Company Limited - 80% Zambia Consolidated Copper Mines Investment Holding Group - 20%
NFCA	Chambishi Main Mine Chambishi West Mine Chambishi South-East Mine	Kitwe, Copperbelt	Underground	Copper	China Non-ferrous Metals Company Limited ("CNMC") - 80% Zambia Consolidated Copper Mines Investment Holding Group -20%

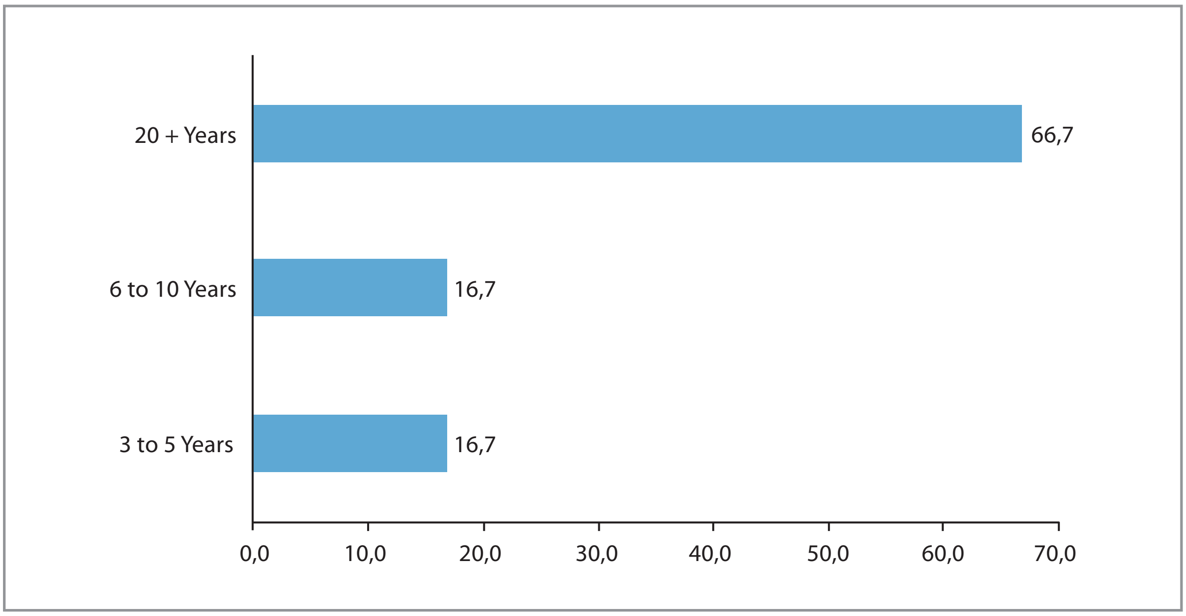


Figure 5: The Number of Years the Mine has been in Operation

4.2 Demographics

Figure 6 illustrates the demographics of the respondents who participated in the study. As depicted in Figure 6a, most of the respondents were male (94.1%). Less than 5% of respondents were female. In terms of the employment position, approximately two-thirds (64.7%) of the respondents were employed in non-management positions. Respondents employed in management position accounted for 36.3%. About 29.4% of respondents have been working for 11-20 years, while 23.6 % have only been working for less than 2 years. Only 11.8% of the respondents were employed for more than 20 years. As revealed by the management, a larger proportion of the workforce is comprised of males. The female workforce makes up less than 20% of the mine employees. In terms of racial distribution, most of the mine employees are black, while other races accounted for roughly 5%.

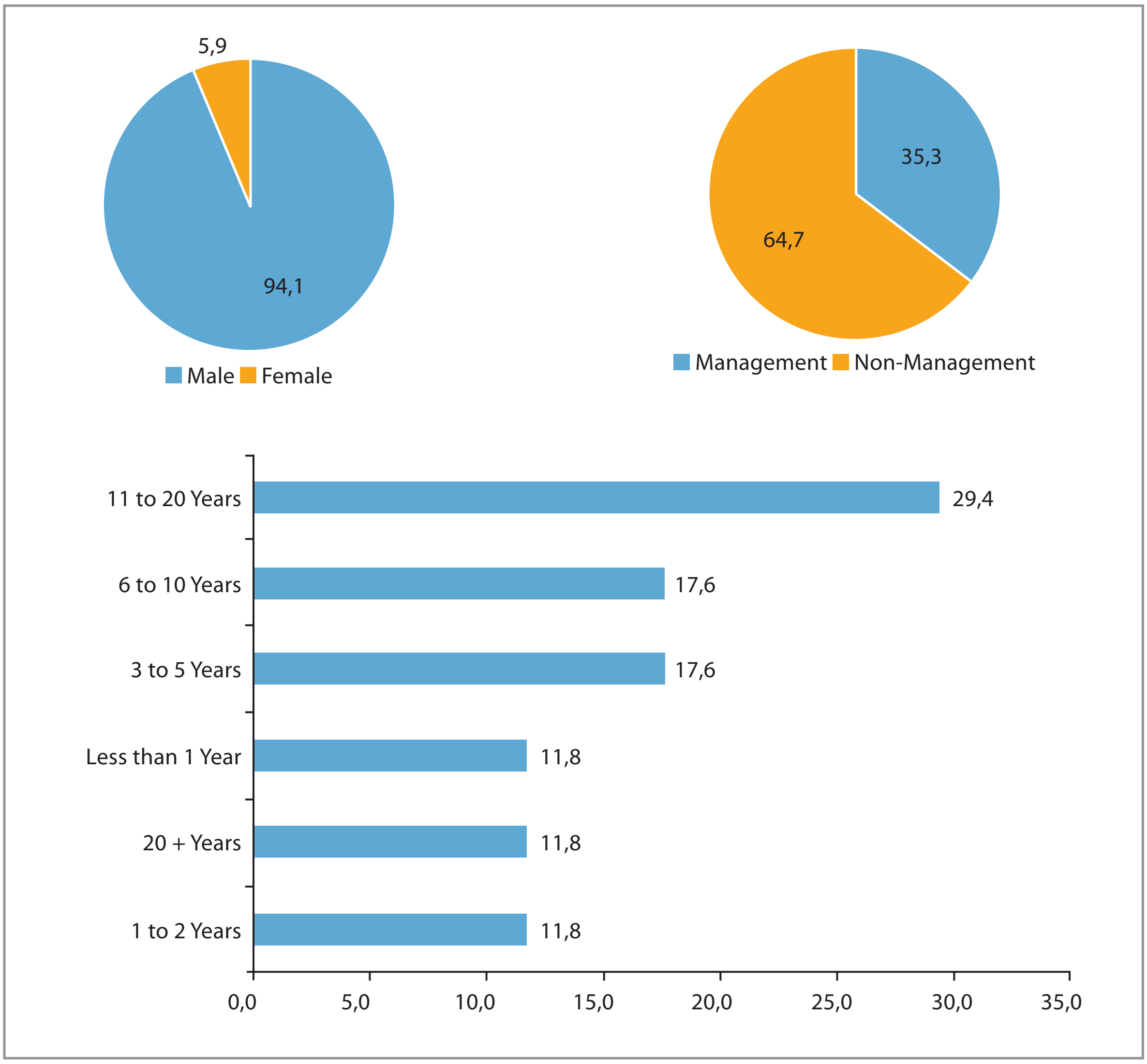


Figure 6: Demographics of the Respondents: a) Gender b) Position c) Number of Years Employed

4.3 Current Status of Mining Technology

The privatization of mines from the late 1990s to 2000s brought about a lot of changes in the mining industry in Zambia. This was mainly driven by the state of the mining industry, which was characterized by the depletion of high-grade ores, low productions ores, and complex geology (Sikamo, Mwanza, and Mweemba, 2016).

The results of our study show that some of the Zambian mines are making use of new technologies in their mining operations. Mines making use of the new technologies are new mines that are less than 10 years old. These mines include Kalumbila, Kansashi, and Lumwana. These mines are characterized by lower grades, hence the deployment of high-tech machinery. Mining in Kalumbila started more than 50 years ago but was abandoned due to low grades. It is only after the availability of new technologies that mining operations resumed. The old mines in traditional Copperbelt region still use old mining technologies despite the better ore grades. It is primarily new mines where new technologies are adopted. In old mines primarily located in the Copperbelt, new technologies are used in new shafts. For example, new shafts in Mopani Copper Mines are deploying newer and modern technologies. Also, the mining operations are transitioning to a new concentrator. In 2001 at KCM, there were 10 fatalities due to landslides, which then became a catalyst for introducing new safety technologies.

Since then, slope monitoring radars have been in use for slope stability; these are advanced tools meant for greater improvement in productivity and safety procedures. KCM Mines have introduced anti-collision devices following the horrific accidents the mines have experienced. Some of the mines in Zambia are using robotic technologies for the drilling process for safety reasons:

> *'You will be aware that the equipment such as drills and loaders, hauling equipment, dump trucks and supporting equipment's heavily lean on robotics in the way they operate.'* (Key informant interview 1)

Among the common technologies has been compressed airlines and nitro-controlled drilling. Although the mining industry in Zambia is slowly adopting new mining technologies, they face several challenges that hinder full adoption. Among the challenges is the issue of power cuts which are frequent and affect production and use of technologies. In addition, mines in Zambia are the primary sources of employment for most of the population, and the adoption of new technologies with the possibility of changing labour dynamics pose serious challenges for mining companies. Most mining companies were granted permission to mine on condition that they will employ only local people. Lastly, these technologies are costly, and most mines cannot afford.

As far as the mining industry is concerned, the concept of the 4th Industrial Revolution can be highly contested. However, the mining industry in Zambia is slowly adopting 4IR technologies. For instance, 30% of the mining operations in KCM are digitized. Also in use at KCM mines are the drone technologies that replace theodolites in open cast mines.

4.4 The Use of New Technologies in Mining Operations

Findings emanating from our study reveal that the Zambian mines deploy 4IR technologies at different stages of the mining process. As depicted in Figure 7, half of the respondents indicated that they use the new technologies during the operation value chain, while 16.7% indicated that they also used technologies during the exploration, rehabilitation, and closure stage of the mines.

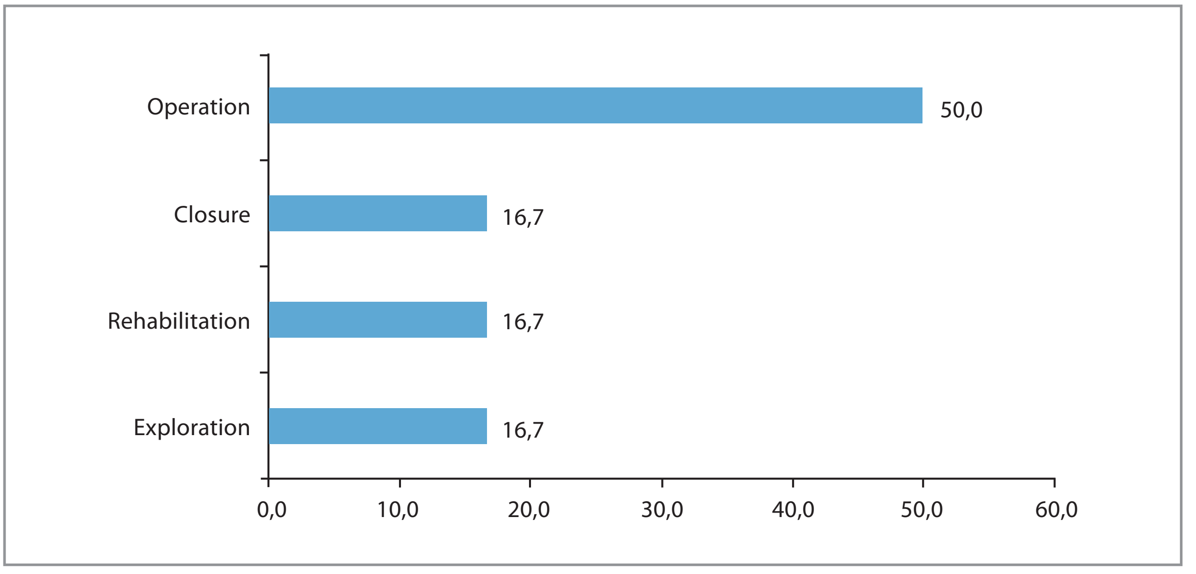


Figure 7: Technologies Application at Mining Value Chain

When asked about the source of these technologies, most respondents revealed that most of the new technologies are imported. The patents for these technologies remain with the companies. These new mining technologies are imported from China, Europe, India, Australia, and the United States of America. New technologies have been used in all stages of mining in the past 3-5 years. It is only in exploration and operations that new technologies have been in use for more than 5 years. Apart from the technologies, inputs for mining are also imported from countries such as South Africa and Australia.

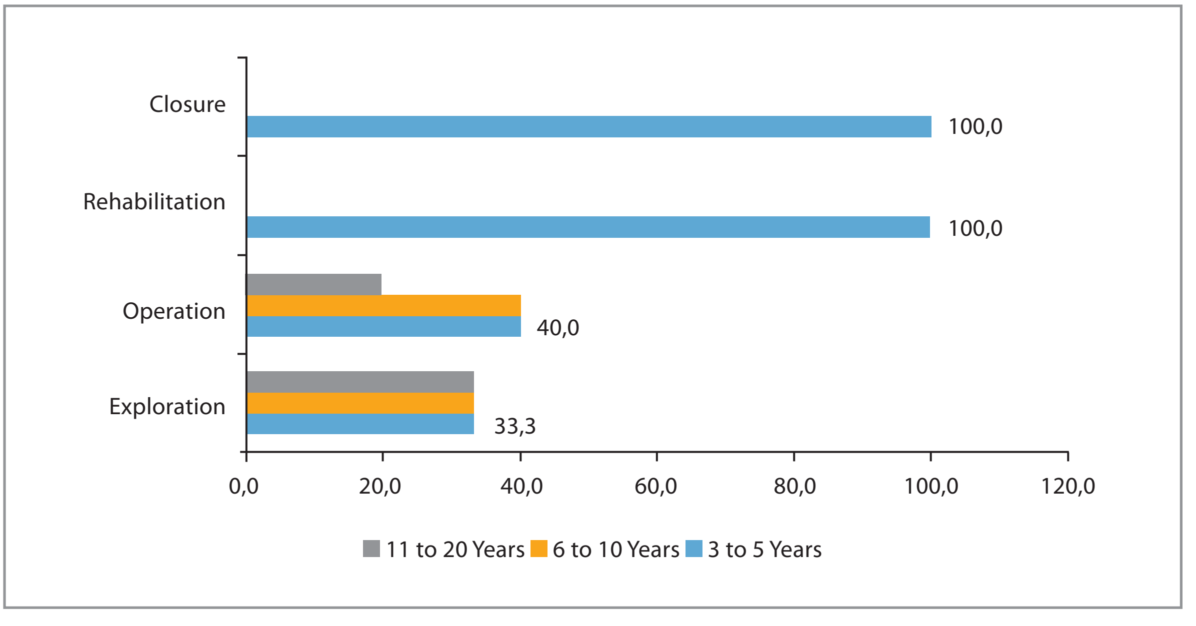


Figure 8: Period New Mining Technologies have been in use

It is emerging from the study that the new technologies applied in mining have brought a change in the processes. As Figure 9 below depicts, 80% of the respondents indicated that the new technologies have changed mining operations and 20% said no impact has been visible.

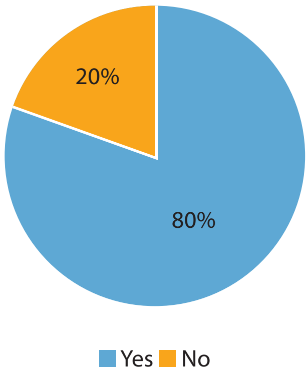


Figure 9: The Impact of New Technologies on Mining Operations

4.5 The Impact of New Technologies on Productivity

New mining technologies have brought a change in mining productivity and efficiency in Zambia. All the respondents confirm that production increased because of improved technologies (Figure 10). Although they vary in terms of the degree of increase across the mines of the respondents. Since the deployment of new technologies there is higher visibility, and granularity on what is happening in real-time has improved the precision and accuracy of responses to changing ore physio-chemical characteristics. The life of some mines in Zambia has increased because of the introduction of new technologies. Change from conventional mining, such as the use of jack hammers, has certainly enhanced efficiency at KCM. As a result of new technologies in Mopani, production costs have declined while KCM's production has increased. Although the grades are not high, the quest to adopt new technologies to enhance efficiency and the investment is huge, and the output is comparable to global output. Mines at KCM are now treating more tonnage with less footprint.

The overall mine production increased because of the deployment of new technologies. The mine deployed advanced environmentally clean technologies. In Nchanga Smelter, the new technologies achieve 99.6% sulphur capture thus reducing pollution to the environment. The three new zero-discharge concentrators have replaced older concentrators and improved efficiency (Vedanta, 2021). This advanced smelter can now produce cobalt alloy because the Konkola ore body has cobalt in the mineralogy. It emerges that there is a reduced repair fleet due to automated machines.

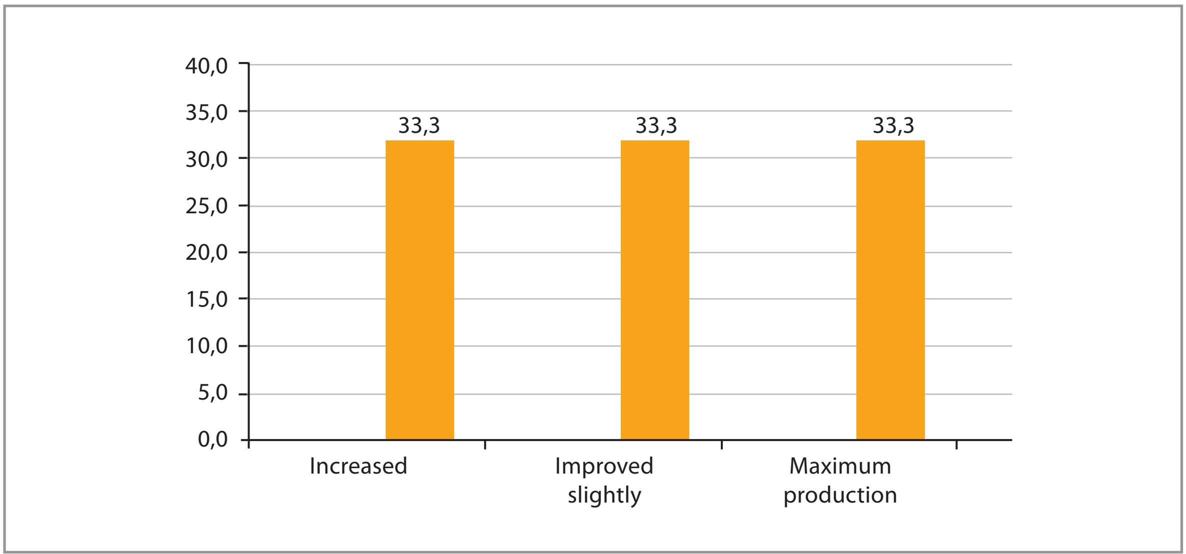


Figure 10: The Impact of New Technologies on Production

The new technologies have brought change in the way mining is done. When asked how so, 20% of respondents indicated that miners can now draw ore from the dangerous draw points. The other portion of respondents, constituting 10%, specified that technologies have led to high mineral refining, followed by 10% of respondents confirming that more tonnage is being hosted due to more than one steel rope attached to the skips and large capacity conveyances or skips. Lastly, 10% of respondents attest to the fact that there has been easier mineral processing. Process control philosophies are now being tailor-made on-site because the tools to study the behaviours and responses of the processing circuit are now accessible to mine operators, as revealed by 20% of respondents.

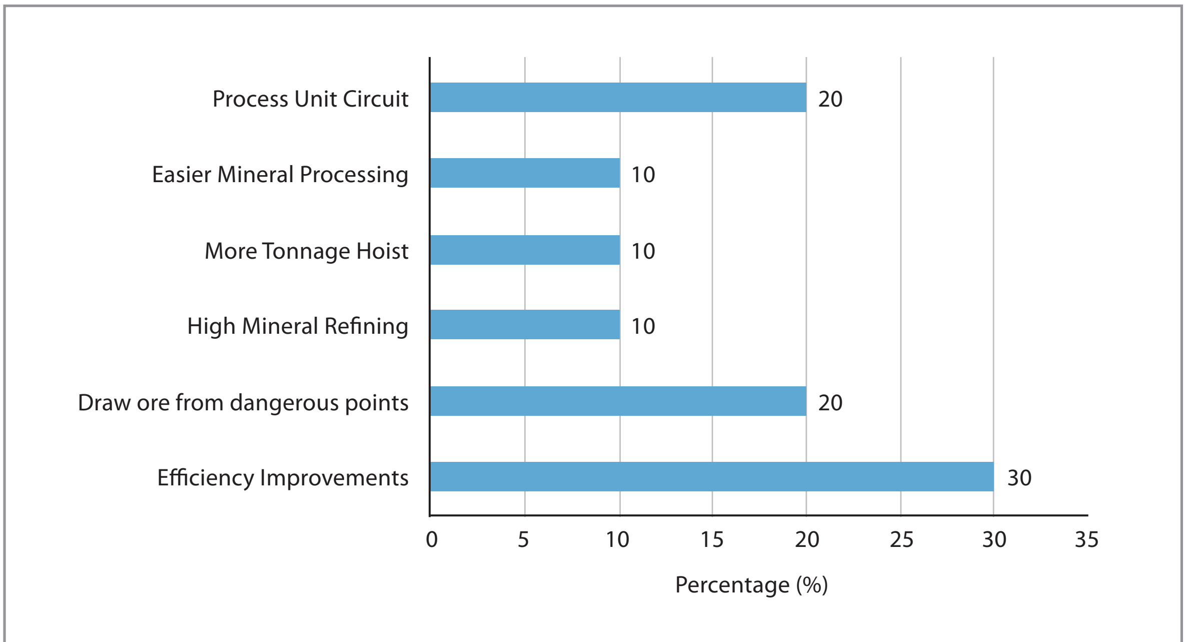


Figure 11: How Mining Technologies Changed the Way Mining Processes Operates

When asked if the new mining technologies have rendered some aspects of the mining and mining business obsolete, most respondents (80%) said in the positive, while 20% responded in the negative (Figure 12). An interview with the representative from the KCM revealed that the introduction of the new smelter in Nkana Mine had rendered the entire mining operation obsolete. The very same smelter was the best in the world during the 80s-90s. It implies that the technology evolution is moving so fast.

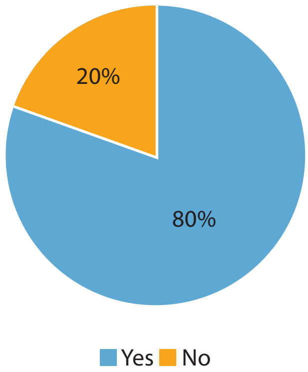


Figure 12: Respondents on Perception of New Mining Technologies

4.6 Impact of 4IR on Labour

In Zambia, there exists many factors that may limit the full potential of the 4IR to be effectively considered as beneficial to the country. Zambia, being a developing country, would have challenges with convincing its citizens of the long-term benefits of the 4IR seeing that most parts of the country are still lacking electrification and people lack access to good internet connection. Zambia faces challenges in the required skills in the 4IR due to the changing nature of jobs as a result of advances in technology and mining techniques.

Mining industry experts agree that the 4IR and new mining technologies will shake labour dynamics in the mining industry. The impact of the 4IR on labour dynamics is inevitable and will be at the expense of jobs. Thus, hundreds of miners that would have worked are replaced by the largest machinery employed - for example, in the new mines in North West Province. In 2013, KCM mines retrenched more than 1 500 mineworkers as they moved into mechanization. The reason for retrenchment was to reduce the overheads and improve grades. This was met with resistance by workers and government since the government owned the largest stake at the time. The introduction of new technology saw the retrenchment of many workers, from around 1 400 to about 800. Kalumbila Mine has the largest loader in Africa. It is easy to replace miners for the open cast mining, but for underground operations it is not easy as machinery cannot reach certain areas. The labour component needs to be managed well.

When looking at the categories of workers whose jobs are on the line as new technologies are introduced, artisans and general workers are on top of the list. Highly specialized skills are required for operating highly advanced machines, and only a few Zambian locals have the skills. Additionally, some mine reports are now being generated in a highly automated fashion; human intervention is no longer required at a data input level. With the introduction of new technologies come opportunities for workers to learn new skills. For example, commissioning of the mines in Kalumbila brought highly advanced machinery, and skills were transferred to locals. The workers are now able to compete with highly skilled workers globally. Workers from Zambia trained during the commissioning of the Kalumbila Mines were involved in the construction of one of the highly automated mines in Panama. But most Zambian workers do not possess the skills required by new 4IR technologies. Part of the agreement with the local people was that the mines would employ local people for all mining operations. However, that is not the case as most workers are unskilled. For example, an agreement with local leaders was reached wherein the mines could bring highly skilled workers if they cannot find them in Zambia.

Highly skilled workers from other countries mostly come for six weeks to service some of the machines. Low-skilled miners are now sent out to other countries to advance their skills. The mines have now partnered with the Copperbelt University of Zambia to upskill workers with the required 4IR technology skills. The mining and metallurgy curriculum has remained the same despite new technological innovations even though there is a need to fuse components of 4IR into the curriculum.

The findings indicate that more than 60% of the respondents believe that the 4IR will negatively impact mining labour dynamics. About 25% of the respondents neither agreed nor disagreed with the statement that the 4IR will have a negative impact on labour. Less than 15% of the respondents did not agree that the 4IR will have a negative impact on labour. Findings emanating from key informants' interviews highlighted that due to negative perceptions by workers on new technology and the 4IR, they might revolt or sabotage the machinery. Kansanshi Mine in Solwezi under Anglo-American is a case in point where workers reportedly sabotaged the machines.

About 43.8% of the respondents thought that the Fourth Industrial Revolution/new technology would offer the mining sector's labour component opportunities. The best way to come with the implementation of new technologies in Zambia is the involvement of mineworkers using the skills learned in other countries. Around 37.5% neither agreed nor disagreed that the 4IR will bring about opportunities to the labour component of the mining sector. About 18.8% of the respondents did not think that the 4IR will bring any opportunities into the mining sector's labour component.

To conclude, although the 4IR will bring about changes to the labour component of the mining industry, new thinking is needed on how to manage the impact on livelihoods. Creating other sources of employment to complement the mining sector is thus crucial for Zambia.

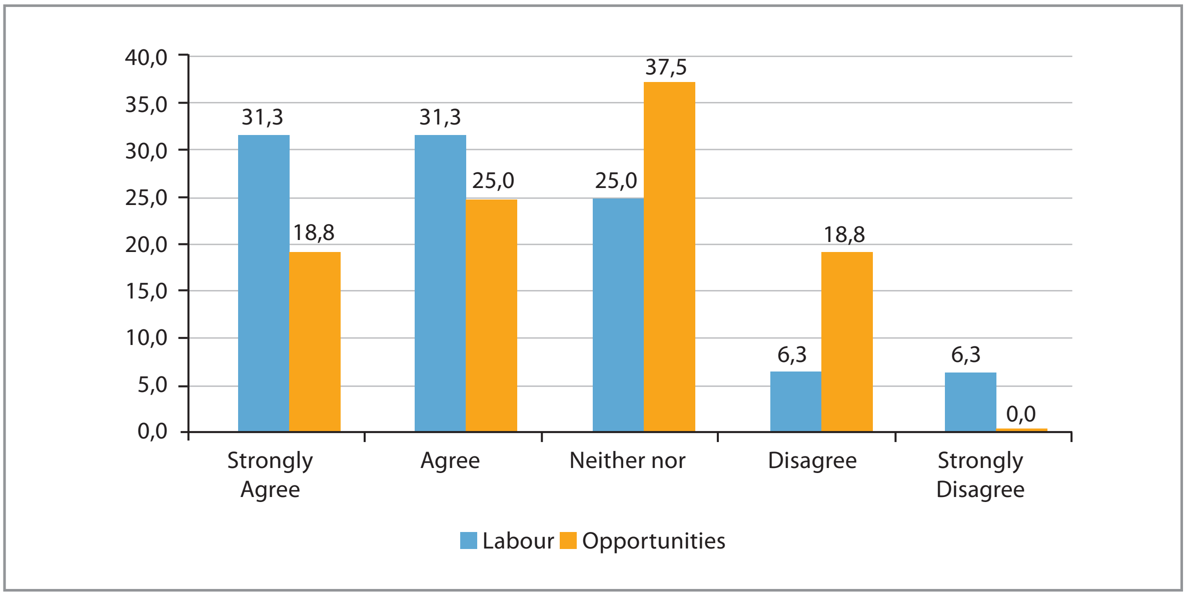


Figure 13: The Impact of 4IR and New Mining Technologies on Labour

4.7 Awareness on 4IR

Table 3 presents respondents' awareness of the 4IR. The majority of the respondents who participated in this study understand the concept of the 4IR and what it entails. Respondents are aware of how the 4IR will change the demographics of the workforce in mining and the fact that technological innovations come with life-long learning. They also understand what drives the adoption of these new technological innovations in Zambia.

Table 3: Awareness of the 4IR Technologies and their Impacts on Mining

	Responses	Percentages
Fourth Industrial Revolution	Yes	64.7
	No	35.3
Demographic shifts are in the workforce	Yes	86.7
	No	13.3
How 4IR will impact health and safety	Yes	75.0
	No	25.0
What is meant with lifelong learning	Yes	75.0
	No	25.0
What the strategic drivers are for new business models	Yes	75.0
	No	25.0

5. SOUTH AFRICA: 4IR IMPLICATIONS ON MINING

5.1 Introduction of participating mines

This section presets an introduction of all mines that participated in this study. The section will focus on these mines' relationship or lack thereof with the 4th Industrial Revolution or new technology. These two concepts will be used interchangeably as they refer to the same developments. The use of these technologies will be traced across what we have termed a 'generic mining value chain', which is exploration, operation, closure and rehabilitation.

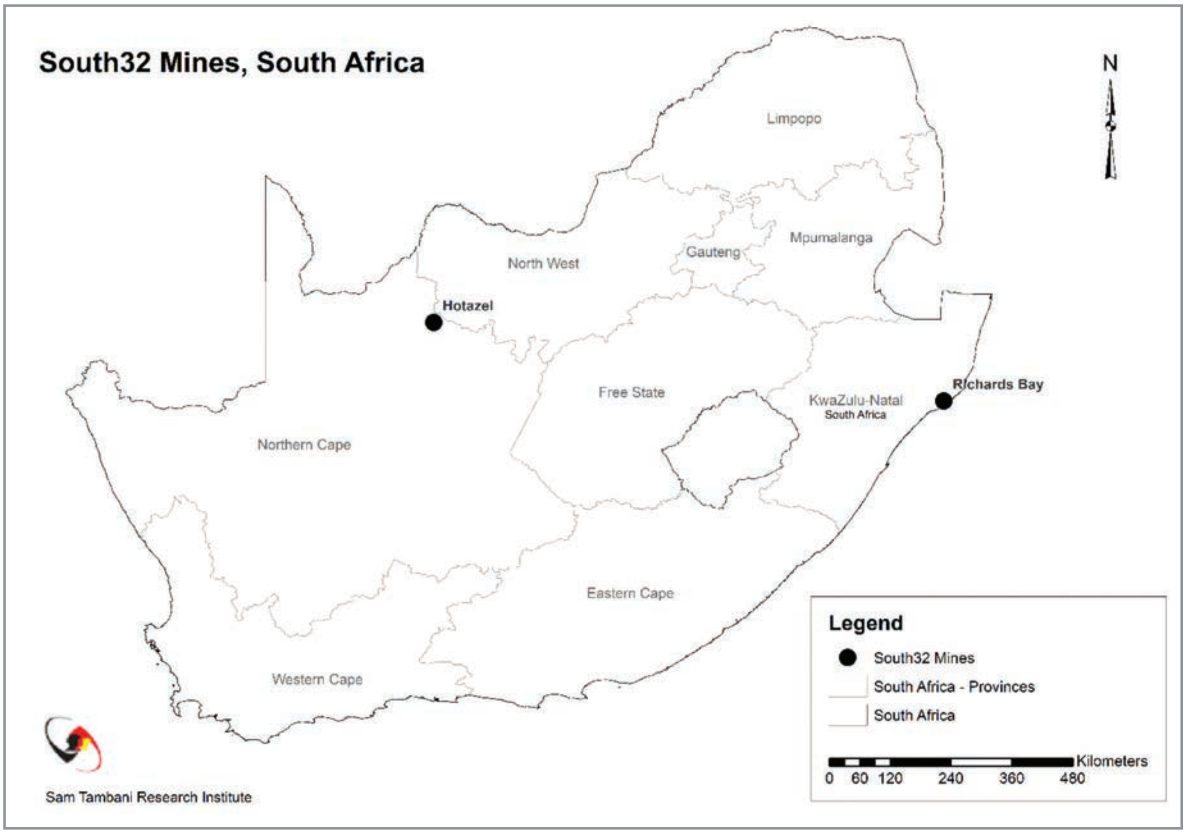


Figure 14: South32 Mining Company Foootprints in South Africa (Northern Cape- Manganese; Richards Bay- Aluminium)

- **Sasol integrated chemicals and Energy Company -** The company was formed in 1950 in Sasolburg, South Africa and built on processes that were first developed by German chemists and engineers in the early 1900s.
- **AngloGold Ashanti Limited -** is a global gold mining company. It was formed in 2004 by the merger of AngloGold and the Ashanti Goldfields Corporation. It is now a global gold producer with 21 operations on four continents.
- **South32 -** is a mining and metals company headquartered in Perth, Western Australia. It was spun out of BHP Billiton on 25 May 2015. The company has colliery mines in Gauteng Roodepoort and Mpumalnga, Emalahleni area, both in South Africa.
- **Koffiefontein Mine -** is a diamond mine situated in the Free State Province, about 80km from Kimberley, South Africa.
- **Natal Portland cement company (Pty) -** is located in Durban, KwaZulu-Natal,

South Africa and is part of the cement and concrete product manufacturing industry. The company has 465 total employees across all of its locations.

- **Bosjespruit coal mine -** is an underground mine based in Mpumalanga and it is owned by Sasol. The mine was opened in 1977 and has produced more than 250 million tons of coal in the last 40 years. Current coal production takes place at Irenedale with a 17.9km underground conveyor running past the South shaft to the Bosjesspruit main shaft. Bosjesspruit mines between 6.0 and 6.5 million Mtpa and has a life of mine to 2031.

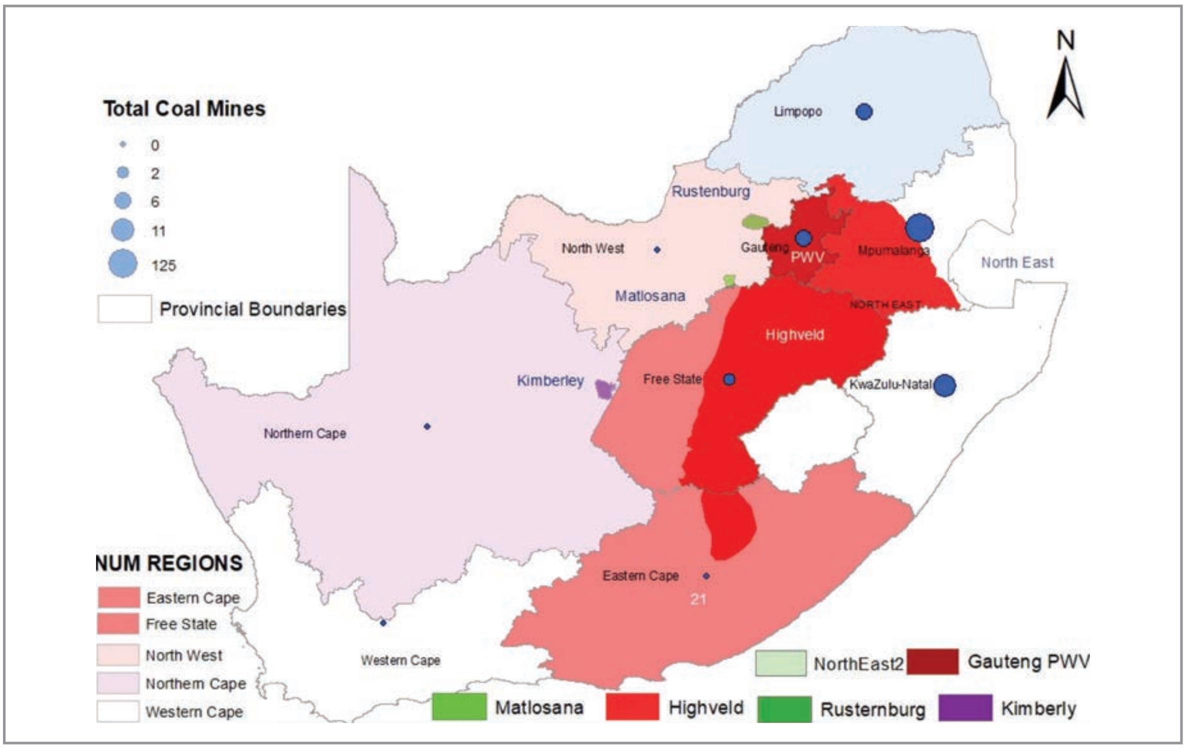


Figure 15: South African Mine Regions and Coal Mines

5.2 Mines in the Northern Cape

The following mining companies in the Northern Cape Province were selected for more in-depth assessment for this study:

- **Tshipi En Ntle -** involved in manganese mining
- **ASSMAG –** Involved in iron ore mining
- **Kokomela –** Involved in Iron ore mining
- **Finch/De Beers –** Involved in diamond mining
- **ORION –** involve in copper mining
- **Vedanta Zinc International -** involved in zinc mining.

5.3 Demographics

This section presents demographic data of respondents who took part in this study. This data does not include the data of the mines from the Northern Cape Province.

Most of this data was collected through interviews with those in managerial positions in the mines. The mines that participated in the study include: Sasol integrated, Anglo Gold Ashante, South 32, Koffiefontein Mine, Natal Portlant, and Bosjespruit Coal Mine.

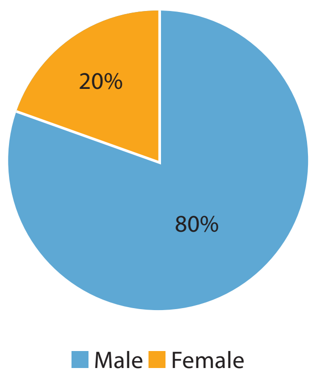


Figure 16: Gender

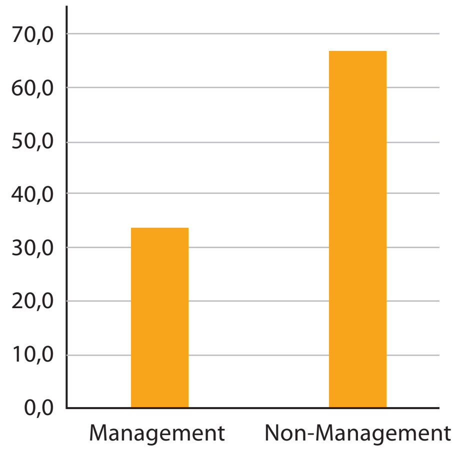


Figure 17: Position

20% of the respondents were male and 80% were female. With regards to position, only about 33% of the respondents were from management while 66% of them were non-management. This is based on the number of people who responded to the online survey.

The management from Sasol reported that with an overall workforce of 12 000 employees, only 13% of the employees are female. They further stated that one of their major goals is to hire more females in their mines.

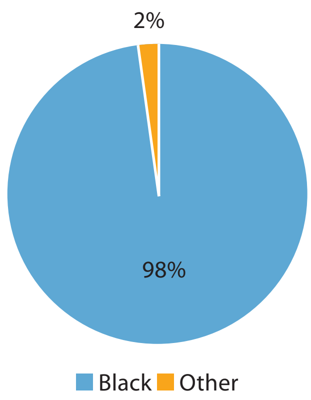


Figure 18: Race Representation in the Mines

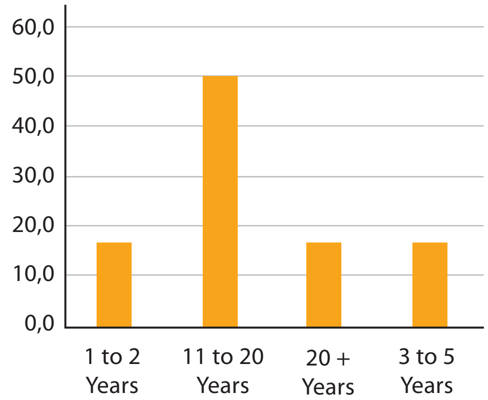


Figure 19: Years of Employment in Mine

Figure 18 indicates that 98% of the respondents were black while only 2% of the respondents were from other races. Figure 19 shows the number of years that respondents have been employed, 50% of the respondents indicated that they have worked for between 11 to 20 years. About 16% of the respondents worked for between 1 to 2 years.

5.4 Status Quo of Mining Technology

Section 3 presents the status quo of the mines that were interviewed with regards to the 4IR technologies.

Figure 20 represents new technologies being used in the mining value chain as indicated by respondents. Figure 21 shows how long mines have been using new technology. Figure 22 shows any other key attributes of new technology in mining.

The results on the status quo indicate that new technologies have been introduced and implemented in the mines that participated in the study. Respondents have to a large extent indicated a lack of knowledge in the functionality of the technology in the mining value chain. Although respondents are aware of the new technology, they were unable to report on the key attributes of the technology in the mining space.

However, mine managers have indicated that technologies have been introduced and implemented since at least 20 years ago. This has been a gradual and slow process, but with time the technology has really aided their mines in terms of productivity and efficiency - although automation definitely meant that labour would experience some shedding.

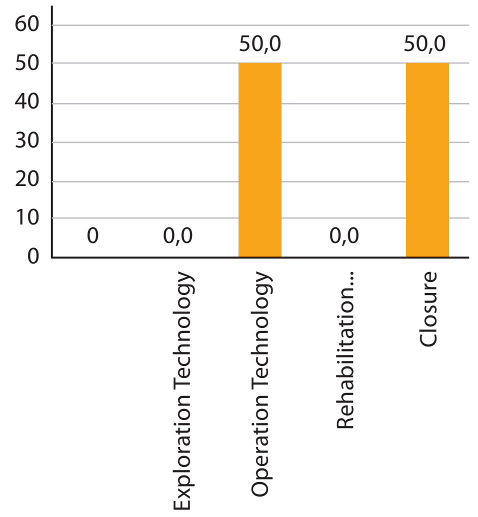


Figure 20: New Technologies being used in the Mining Value Chain

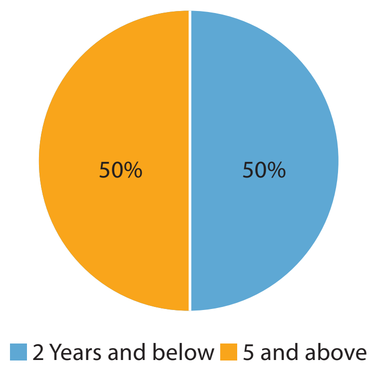


Figure 21: Period of New Technology usage

Figure 20 indicates the technology that has been used in the various mining value chain areas. About 50% of the respondents indicated that the technology that is being used is in operations and another 50% reported that there was technology being used in closure. However, respondents did not report on any technologies being used in exploration and rehabilitation.

In figure 21, 50% of the respondents indicated that they had been using new technologies for 2 years and more. Similarly, 50% of the respondents also indicated that they had been using new technologies for 5 years and more.

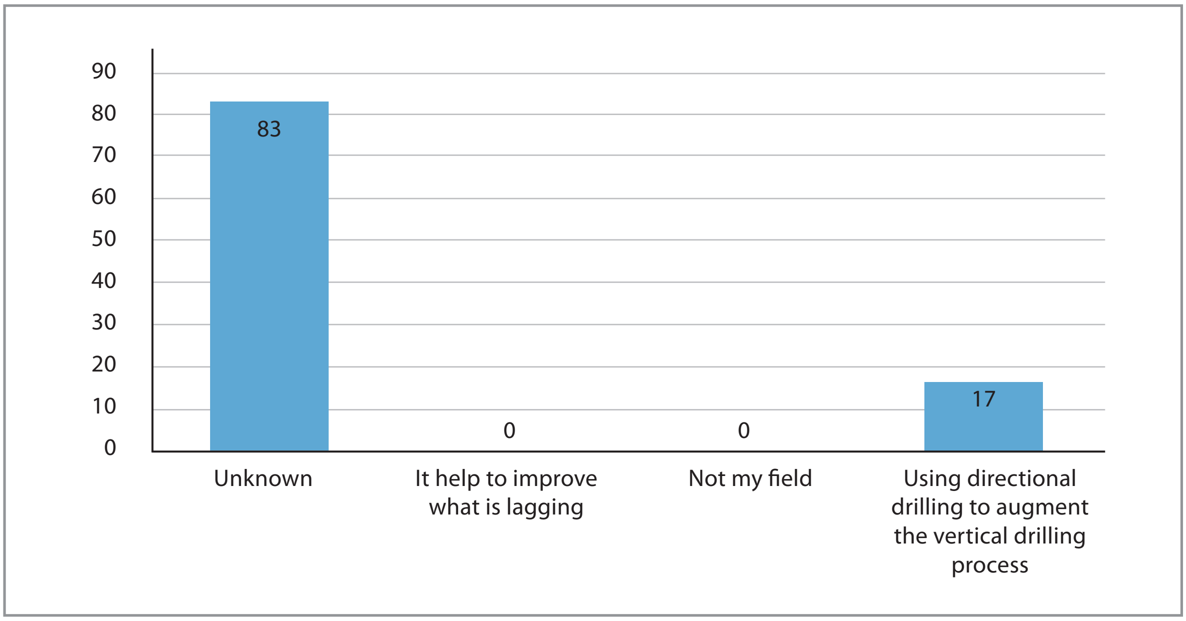


Figure 22: New Attributes of New Technology in the Mines

Figure 22 indicates that of the total respondents, 83% of them could not indicate what the attributes of new technology were. However, at least 17% of the respondents indicated that using directional drilling to augment the vertical drilling process was a key attribute for some of the technology. This indicates that the respondents who took part in the study may not have full knowledge on what the specifications of the technologies are.

However, one of the participating mines indicated that one of the key attributes of the technology was that it allowed for them to get real time information in the mine, which meant that mining activities could be more efficient.

Table 4: Period in which each Technology has been used in the Value Chain

Value chain technology	Number of years	Number of respondents
For how long have you been using these new technologies? [Exploration]	20 + Years	20%
For how long have you been using these new technologies? [Operation]	11 to 20 Years	40%
	20 + Years	10%
For how long have you been using these new technologies? [Rehabilitation]	20 + Years	10%
Closure	20 + Years	20%

Table 4 indicates how long technologies have been used across the mining value chain. Of the total respondents across the participating mines, 20% indicated that the technologies have been used for 20+ years in closure; similarly, 20% of the respondents indicated that the technologies have been used for exploration over a period of 20 + years.

In operations, technology has been used for about 20+ years. In terms of whether the technology was locally manufactured or imported, respondents indicated that the technology was all imported from European countries. This transaction was reported to have been done in such a way that different parts of the technologies would have to be imported from different countries for one machine - thus a machine does not necessarily come from one country per se.

5.5 The impact of 4IR on Productivity

Figure 23 represents the impact that the 4IR has had on productivity in the mining sector. Responses are presented as per the interviews conducted with mine mangers and an online survey that was sent out to both workers and managers.

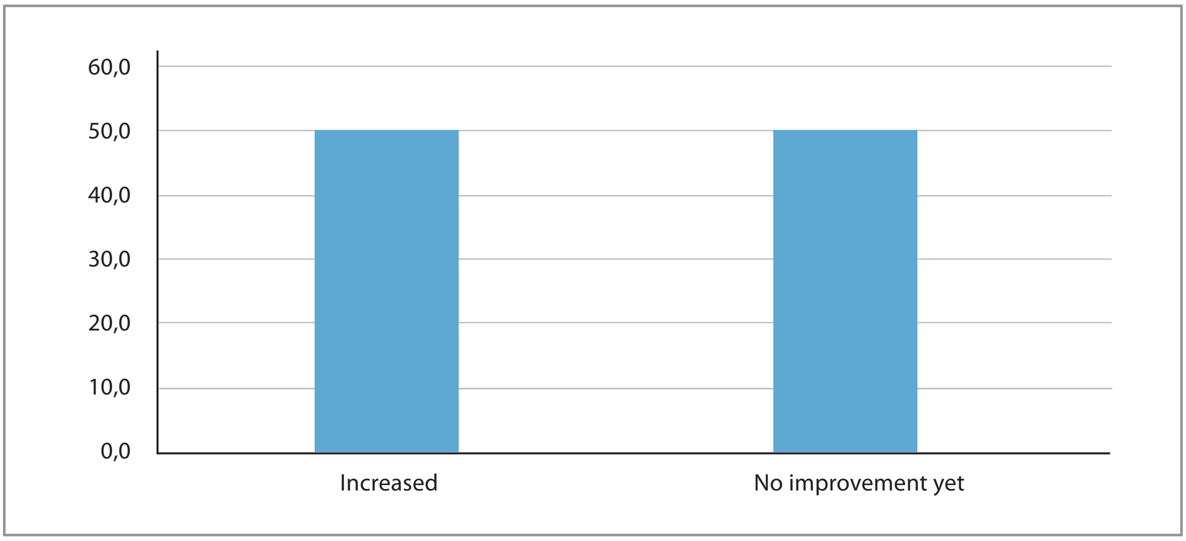


Figure 23: The Impact of Labour on Productivity

Figure 23 above is an indication of how the 4IR has impacted productivity in mining. The general outcome as indicated in the graph is that 50% of the respondents expressed that productivity has increased while 5% of them expressed that productivity had not increased yet.

One of the interviewees indicated that if they were to quantify productivity, they would say that with the new technologies, productivity has increased by 15-20%. It is also more efficient as they are able to receive more real time information and as a result are able to reach emergency situations in the mines much faster.

Another mine reported that they have a machine called 'the continuous miner' which essentially manages to conduct most of the work needed in production. In this case, most tasks and areas of mining have then been integrated which means that work is much more effective at a lower cost, taking out the manual worker expense.

5.6 Impact of 4IR on Labour

Figure 24 presents the impact of the 4IR on labour. On the one side it shows the responses of those who felt that the 4IR has a negative impact on labour; on the other side, it shows the responses of those who expressed that the 4IR has presented new opportunities in the mining sector.

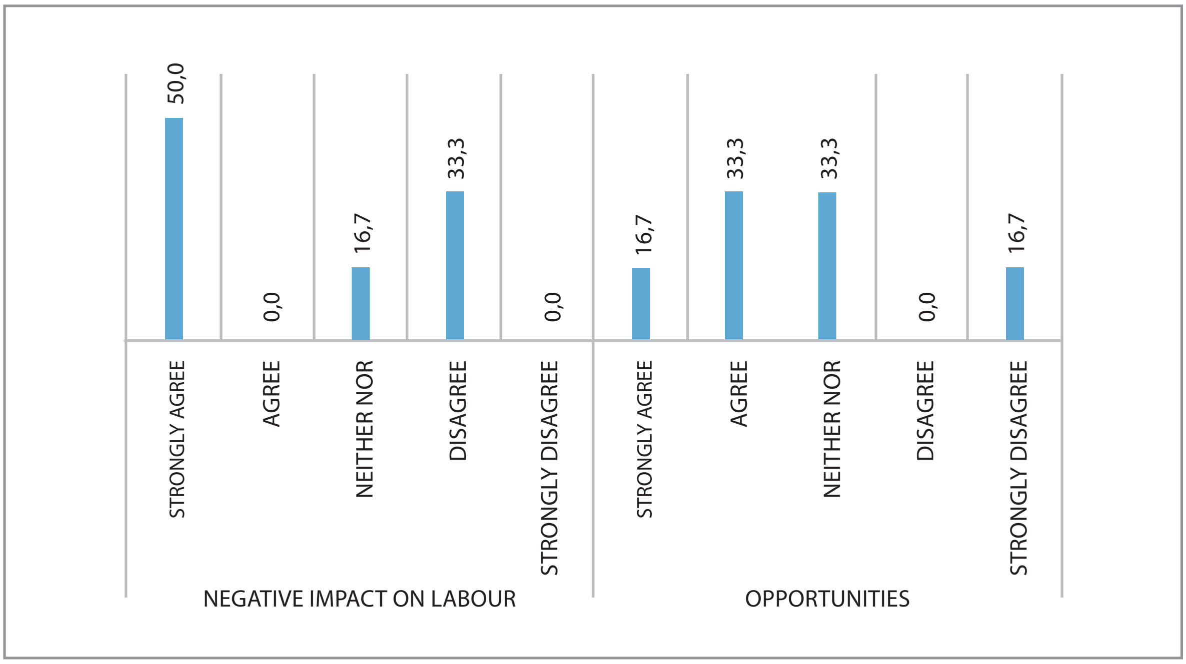


Figure 24: Change in the Way Mining is being done through the New Technology

Figure 24 is a presentation of the perceptions of respondents with regards to how technology has changed the way in which mining is done. The perceptions were divided into two groups where one group sought to answer the question of whether technologies have brought about a negative impact on labour and the second group discussed whether the new technologies brought about opportunities. About 50% of the respondents reported that they strongly agreed that the new technology had a negative impact on employment, while 33% of the respondents indicated that they disagree that the mining technology has a negative impact on labour. Only 16.7% of the respondents indicated that they neither agree nor disagree.

The other side of Figure 24 presents the perceptions of respondents on whether the 4IR has brought opportunities in labour for workers. The data corresponds quite well with the other group of data. About 16.7% of the respondents indicated that they strongly agree that mining technologies will present opportunities, which is of course a small amount. Another 16.7% of the respondents indicated that they strongly disagree that mining technologies will present opportunities. Based on the data, there might be some uncertainties among respondents on the actual impact of the 4IR on labour. About 33% of the respondents were neutral.

In the interviews, one of the mines indicated that a lot of jobs had been lost since the automation. The justification for this notion is that automation allows for safer, more effective, and more efficient mining.

5.7 Impact on Labour – Northern Cape

In the Northern Cape the new mining practices offer a promise of lifting efficiency and economic gains for mineworkers but offer new social and economic challenges. The new technologies require skilled workers with technical skills that are hard to come by in most of the province. As such the new technologies will result into significant job losses.

The socio-economic impacts of mine automation ought to be carefully considered by mining companies, local governments and other stakeholders to ensure long term sustainability of the mining sector. As a result of the increasing level of technology, the role of the worker in the technical system has changed, and so has the relationship between the mineworker and the rock. While there has always been a machine between the worker and the rock, over time the machine has tended to become bigger and more technically sophisticated - with several mining processes becoming automated or remotely controlled.

This has created new types of work where improvements to the physical work environment are obvious. In mining operations, the heavy lifting work has been eliminated as well as the hazards associated with noise and dangerous gases. For many of the mineworkers, actual contact with the rock is minimal. In the most extreme cases, the operator makes only occasional visits to the machine that they control remotely.

These changes also include requirements for changes in qualifications, knowledge, and skills. It is observable that there is a clear transformation from the use of manual skills to the more technical qualifications based on the knowledge necessary to operate the new advanced technologies. Mine workers in the new era must possess independent skills such flexibility, technical intelligence, perceptive ability, technical sensibility, a sense of responsibility, trustworthiness, and independence.

What was once the mineworkers' tacit knowledge has now been formalised and codified into automated routines and computer programs (Abrahamsson and Johansson, 2006). One effect of automation is that mining activities now seem much simpler when they have been moved out of their context, i.e., the physical place where the loading or drilling machines work.

There is a noticeable degree of 're-skilling' in the changes occurring in mining work. A lot of the activities in the new mines do not require physical strength. What the workers require is concentration and tactile ability to undertake remote tasks such as the control of the iron ore conveyor belt without being in close physical proximity with the operations.

In this context, we observe that the mineworker of today and tomorrow will be an individual able to learn and re-learn new skills with every change in the production process. Without elucidating a list of particular skills, the results indicate the following as the knowledge requirements expected of a mineworker in an era of smart machines:

- the need for generic theoretical knowledge to create flexibility in the production systems.
- the need for an understanding at the system level to deal with disruptions to production.
- the need for interpersonal skills to work in various production groups.
- the need for initiative and ability to improvise at all levels of the production system.

From the above statements, the claim can be made that the future mineworker will be one who has the ability to make their total expertise available to the total production process. This requires new curricular that contains both general knowledge and specific mining knowledge, with the help of new modern teaching methods. Presently, such a mode of technical education does not exist in the tertiary institutions of the Northern Cape. Urban Technical Vocational Education Training, the government owned institutions, continues to offer the traditional qualifications for mill wright technicians such as boiler making and blasting - work that is now being undertaken by specialised robots. The aforementioned gap in educational practice was observed earlier by Mallet and Orr (2008) who state that mines need to develop new effective methods for on-the-job learning and collaborate with educational institutions to document, contextualise, and codify new specialisations for mining operations.

The new technologies are also increasing levels of collaboration and integration between mine companies and partner organisations. In many ways, mines are transforming into service oriented enterprises. As a result, tasks are shifting to external service providers who engage with mines on short term contracts. With the lack of availability of specialist skills, the trend will be for most expert roles to be provided through niche service companies. Outsourcing to external specialist companies has been happening for many years in areas like long-term mine planning, where mine operations have found it difficult to attract and retain the expertise necessary to carry out activities that are only required once or twice a year.

5.8 Awareness of 4IR

Table 5 shows the extent to which mineworkers are aware of the 4IR. Respondents answered questions with a 'yes' or 'no'.

Table 5: Awareness of the 4IR

Area of awareness	Yes/No	%
I am aware of the Fourth Industrial Revolution	Yes	83.3
	No	16.7
I am aware of Demographic shifts are in the work force	Yes	16.7
	No	83.3
I am aware of how the 4IR will impact my health and safety	Yes	66.7
	No	33.3
I am aware of main transformative technologies	Yes	66.7
	No	33.3
I am aware of what is meant with lifelong learning	Yes	50.0
	No	50.0
I am aware of what the strategic drivers are for new business models	Yes	50.0
	No	50.0

As indicated in Table 5, mineworkers are mostly aware of the 4IR. About 83.3% of the respondents indicated that they were aware of the 4IR, while only 16.7% of the respondents reported to not have been aware of the 4IR. Although the responses vary, a large amount of respondents reported to have some knowledge of the 4IR. In terms of the demographic shifts, 16.7% of the respondents indicated that they are aware or had knowledge of 4IR. This is a very small percentage and indicates that respondents might need some education around the changes that will take place. About 50% of the respondents indicated that they are aware of what is meant by lifelong learning which means that they are aware that systems will continually change and they have to be prepared in some way.

From a management point of view, interviewees indicated that they have been aware of the technology and have been embracing it over the past 20 years. They reported that the dynamics of how operations were done definitely meant that their mines would have to undergo massive changes, which they also embraced. However, the process of adaptation has been slow for some mines.

5.9 Dynamics of Mining Technologies in Selected Mining Companies in the Northern Cape

In this section we focus on the state and changes in mining technologies used by selected mines in the Northern Cape Province. The companies were selected in a purposeful way based on the mineral they are involved in, their scale of production, and anecdotal evidence of introduction of new mining technologies.

5.9.1 Tshipi En Ntle

The mine was established in 2007 and is currently South Africa's largest exporter of manganese and is the fifth largest in the world. The company's mining field, known as Tshipi Borwa Mine, is a shallow open-cast operation.

The mine has established an 8 km private rail line which gives them direct access to Transnet's rail link. However, due to high demand for the rail network as other mines also use the same link to the export hubs. The mine also makes use of road haulage.

The mine uses drill-and-blast and load-and-haul mining techniques to conduct its activities. This is an elaborate process that involves removing the top soil and storing it in a separate area for later use during the rehabilitation phase. The various layers of the Kalahari formation are removed, followed by the dolomite. Once exposed, the manganese ore is drilled, blasted, and hauled into a crusher.

The ore is processed in primary and secondary crushers and screened to produce lumpy and fine products. The Tshipi Mine is operated as a conventional open-pit drill-and-blast facility. The mine's operations are contracted to another company, Aveng Moolmans. Aveng is responsible for all the mining operations on a contractor operator fixed cost per bank cubic metre ("BCM") basis. Aveng Moolmans has installed a mobile equipment fleet which consists of 51 trucks, 6 drills, and 3 excavators. The management at the mine observes that their capacity is constrained by low crushing capacity and rail allocation with Transnet.

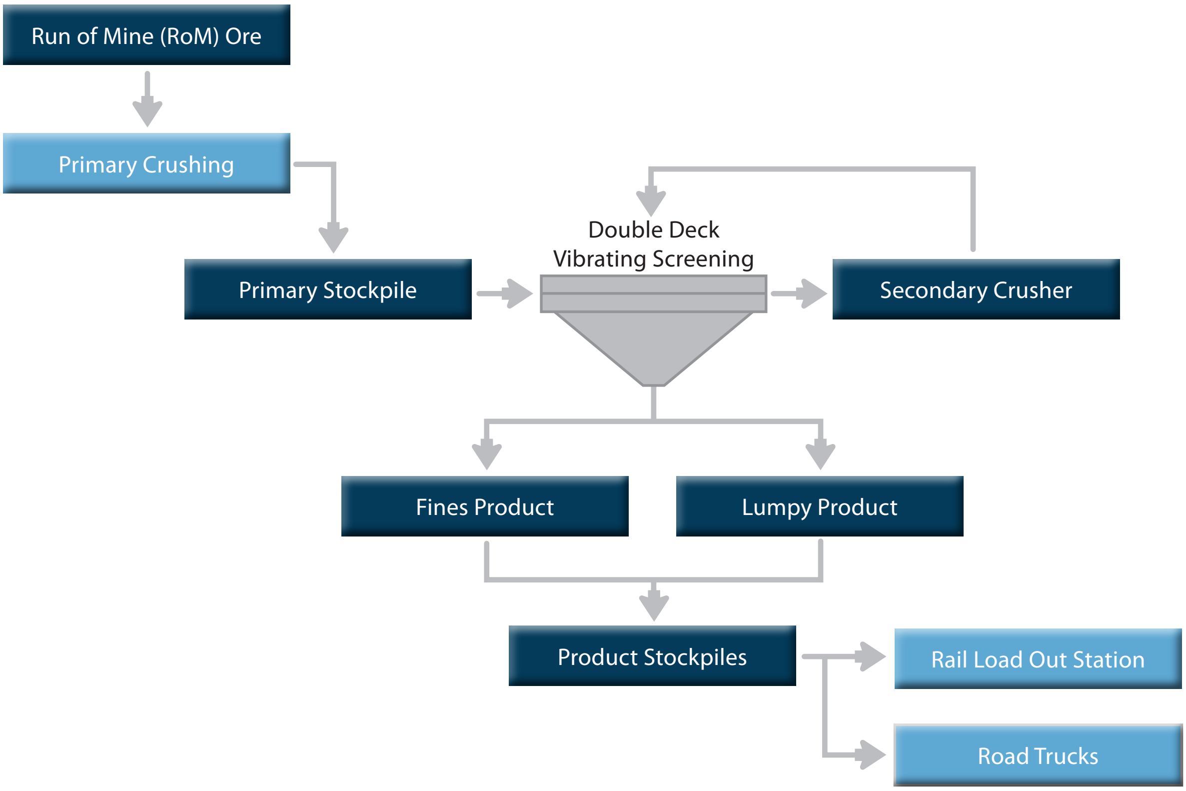


Figure 25: Run of the Mine Process at Tshipi Borwa Iron Ore Mine

The onsite processing facilities are contracted to another provider: African Mining and Crushing. The firm has personnel at the mine who conduct its contracted responsibilities. The mine is currently installing a new conveyor system to increase the pace of material evacuation. Presently the mine sources its electricity from own generation capacity, using generators and solar.

5.9.2 Assmag Iron Ore

The company is active in the iron ore and manganese hub of Kathu where they operate two iron ore mines, Khumani and Beeshoek mines. The company started operation in 1935 and is currently controlled jointly by Assore Limited and African Rainbow Minerals. In total the two mines employ 6 567 permanent employees and operate as three divisions, namely: iron ore, manganese, and chrome.

The principal mining method being used by the mine is what is commonly referred to as the truck, shovel and loader. The iron ore is mined from a series of open pits by means of conventional drilling, blasting, and loading onto trucks followed by hauling to the crushing facilities. From there, it is transferred by means of overland conveyors and stockpiled onto blending beds that divide the material into two categories, on- and off-grade material, before reaching the beneficiation plant.

Run-of-mine ore is crushed and stored as 'on-grade' or 'off-grade' on blending stockpiles. Ore from the stockpiles is sent to the wash-and-screen plants. The washing and screening plants consist primarily of tertiary crushing, washing, screening, conveying, and stacking equipment. If the ore is categorised as low grade, it is sent to the beneficiation plants for its quality to be improved.

5.9.3 Orion Mineral Resources - Prieska Copper Zinc Mine

The Prieska Copper-Zinc Project is the centrepiece of Orion's asset portfolio. Historically mined between the 1970s and 1990s, Prieska is one of the world's top-30 volcanogenic massive sulphide (VMS) base metal deposits, with a recorded historical production of over 430k tonnes of copper . The company expects mining to start in January 2022. Presently they are still re-establishing the old mine. Both open pit and underground mining are planned for the duration of the foundation phase. Underground mining is planned to commence on completion of mine dewatering, shaft refurbishment, and underground infrastructure establishment, some 24 months from site mobilisation. Underground mining is then scheduled to build up over 14 months to a steady-state run-of-mine production rate of 200ktpm (kilo tonnes per month) or 2.4Mtpa (million tonnes per annum).

Tunnel development remaining from the previous mining operations allows for early access to underground production mining areas. A combination of Lonhole Open Stoping with Fill (LHOSF) and Drift-and-Fill (D&F) mining methods will be used, supported with paste back-filling.

Ore processing is planned to involve conventional differential froth flotation to produce separate copper and zinc concentrates at average grades of 24% Cu and 50% Zn from underground mined material. Minor modifications to the processing plant will allow the open-pit material to be treated at the end of the mine life, on a campaign basis, to produce separate copper and zinc concentrates at average grades of 26% copper and 36% zinc.

The flowsheet for processing underground material is similar to the flowsheet used during previous mining operations. Life-of-mine metal recoveries into concentrates are anticipated to be 84.4% for Cu and 83.9% for Zn from treating underground mined material, and 66.7% and 59.4% for Cu and Zn respectively for open-pit mined material. The concentrates will be trucked to Groveput, 50km from site, and then railed to the port.

5.9.4 Finsch Mine - Diamonds

Finch Mine uses the new block caving mining method. Block caving is a new alternative method of developing new mines or extending the operation of open pits.

Block caving is an underground hard rock mining method that involves undermining an ore body, allowing it to progressively collapse under its own weight. It is the underground version of open pit mining. In block caving, a large section of rock is undercut, creating an artificial cavern that fills with its own rubble as it collapses. This broken ore falls into a pre-constructed series of funnels and access tunnels underneath the broken ore mass. These mineworks are sheltered from the collapsing ore inside bunker-like mass of rock, and miners extract it continuously from here. The collapse progresses upward through the ore body, eventually causing large areas of the surface to subside into sinkholes.

The cost of block cave mining is about 1/10 of the correspondent cost of conventional methods. The production rates can reach 30 000 to 100 000 tons per day. Moreover, drilling and blasting costs are far less, and there are no backfilling costs. Another benefit of block caving is the large reduction in surface waste disposal needs. As open pits get deeper, their ratios of waste rock to ore often gets higher and the waste must be placed in surface storage areas. The amount of waste rock generated from underground methods like block caving is a fraction of this, reducing superficial land impacts.

All of Petra's operations are mining 'hard rock' kimberlite pipe diamond orebodies, as opposed to alluvial deposits (i.e., deposits of diamonds which have been removed from the primary kimberlite source by natural erosive action over millions of years, and eventually deposited in a new environment such as a riverbed, an ocean floor, or a shoreline).

Mining of a diamond-bearing kimberlite generally starts with the excavation of a pit into the kimberlite pipe. In this process, called 'open-pit' or 'open-cast' mining, the initially weathered ore material is removed with large hydraulic shovels and ore trucks. Hard rock is drilled and blasted with explosives so the broken material can be removed. Open pits are excavated until the strip ratio (the amount of host rock that must be stripped away in order to access new ore) becomes prohibitive to the mine's operating cost. At this point, the operator will evaluate making the transition to underground mining.

5.9.5 Sishen Mine

The Sishen Mine is located 30 km away from the town of Kathu in Northern Cape. The company is operated by Anglo-America and it mines hematite iron ore, through an open pit mine. It is one of the largest open-pit mines producing iron ore in the world.

More than 900 million tonnes (Mt) of iron ore has been produced during 60 years of the mine's operations (Mining Technology , 2019). Although the company as a whole has been in mining for a long period, it has had a new mining project that it has embarked on in the last 10 years and it has introduced some new mining technologies.

The Sishen Mine employs the open-pit mining method involving drill and blast. The mined ore is trucked to the nearby beneficiation plant. The mine uses a fleet of P101-4100 shovels and 960 trucks. Strong performance of the 2 800 shovel fleet in 2019 allowed the mine to exceed equipment efficiency targets. The owner fleet efficiency of the mining operation increased from 65% in 2018 to 68% in 2019.

The ore undergoes dense media separation (DMS) and the jig processes at the beneficiation plant. It is crushed, washed, and separated into coarse, medium, and fine materials by wet screening. The Sishen Jig Plant is the largest facility of its kind in the world.

A joint venture development agreement was signed between Kumba and Exxaro in April 2012 to utilise the latter's ultra-high dense-medium separation (UHDMS) technology in Kumba operations. Tenova Bateman has been awarded a contract to supply a 50tph modular beneficiation plant based on UHDMS technology for the Sishen Mine as part of this initiative. The Sishen Jig Plant was officially opened in November 2008, while the UHDMS pilot plant at the mine became operational in the fourth quarter of 2013.

5.9.6 Kolomela Mine

Kolomela Iron Ore Mine is part of the Sishen Iron Ore Company controlled by Anglo-American. The company also uses the truck & shovel / loader mining system. Kolomela Mine is an open pit iron ore mine with a production capacity of 9 million tonnes of iron ore per annum (Mtpa). The existing processing facilities at the mine involve a direct shipping ore operation which includes crushing and screening of the recovered ore material into stockpiles of 'lump' and 'fines' for transportation by rail to Saldanha Bay.

Kolomela mine is primarily a direct shipping ore operation where ore reserves are crushed and screened for quality. The company is presently implementing an intelligent mine initiative. This includes implementing infrastructure and machinery that is digitised through sensors and other instrumentation, and artificial intelligence is being used to accelerate a range of processes, beginning with ore body characterisation.

Both Kolomela and Sishen Mine have installed 28 rigs blasting rigs that do not require physical human operation. At Kumba's Kolomela Mine, the lives of drill operators have, through technology, been transformed. Drill operators no longer need to descend into the sometimes dangerous iron ore pit; rather they work in a safe, air-conditioned command centre to oversee the drills at work. Their equipment now consists of state-of-the-art computers and screens and they are able to remotely operate the drill. The autonomous drilling project is one of the first in South Africa and the all-female drilling crew is believed to be unique as jobs for drilling operators were historically reserved for men. "There is no requirement for physical strength as the drill rigs use motors and sensors to perform the heavy drilling," says an operational supervisor at the mine.

The company has also implemented autonomous mining technologies to increase the ore recovery rate. They have incorporated technologies such as driverless haul trucks, autonomous rail systems, robotic mining, and autonomous drilling systems.

The company has retrofitted their mobile equipment with sensors that collect data and concentrates them into servers where analytical software provides the mine with information such as functional up or down times, navigation information, and maintenance.

The company is also implementing wearable Personal Protective Equipment (PPE) that is embedded with sensors. The system in real time reports on the location and health of the mineworkers. Returning essential data on elements such as body temperature, blood pressure, and fatigue and it serves as an early disaster warning system.

The management of the mine argues that the introduction of these technologies is necessary for their company's operating efficiency and long term sustainability. While these technologies have the potential to secure the future of the company, the expected gains for the company may be community losses in terms of fewer mineworker jobs.

5.9.7 Vedanta Zinc International

This is one of the province's latest mining projects as operations commenced in 2015. It is said to be South Africa's most technologically advanced mine. The company has installed a battery of digital technologies to enable key operations such as the ones below:

- Mine planning and operations are designed by algorithms that determine processes as informed by the ore-body information which is gathered from a number of sources such as drill-hole data and rock face inspections. This is combined with geological data to design mining plans.
- The company undertakes predictive maintenance of their equipment and movables. A smart plant management system applies predictive analytics on data which is collected from the sensors installed on the key equipment. The system is capable of predicting possible failures in advance and proactively schedule maintenance work orders, and automatically order replacement parts.
- It has automated SHEQ processes and predictive safety management. Employees are required to move with electronic safety monitors that report data such as position tracking within the mining area, as well as health indicators.

From the company's headquarters in India, Vedanta Resources executives have real time access to activities taking place at the mine site in Aggeneys. The company's digital nerve centre complements planning, control, and decision-making. The nerve centre brings together real time data across the company's entire mining operations throughout the world enabling control and decision making. Vedanta Zinc International (VZI) has collaborated with GE South Africa to unveil a greenfields digitalisation initiative at the Gamsberg project in the Northern Cape.

Under the initiative, VZI intends to build a 'Smart Ore Movement' system into the $400m project. The company noted that advanced systems will be implemented during the development phase of the project. The project is currently under development, with production expected to commence in mid-next year.

Under the 'Smart Ore Movement' concept, VZI aims to ensure that all available information regarding the state of the mine, the quality of ore, the conditions of the processing plant and the value of the output product are made available to the mine management team in real-time. The information is also presented in such a way that it assists in arriving at real-time decision-making.

Apart from addressing VZI's application and digital infrastructure needs, the partnership will focus on providing a foundation for the agile co-creation of mining solutions to be deployed across the company. The digital transformation project is aimed at eliminating inefficiencies through the application of a new culture, combined with digital technology and a customised delivery approach.

5.9.8 Synthetic Diamonds by De Beers

The diamond industry is also being affected by the growth in the production and use of synthetic diamonds. These are lab grown imitations of the sparkling gem, offering a similar aesthetic allure at a lower price. De Beers, the world leading diamond company, is driving this through their Element Six venture.

5.10 Impact of the Changing Mining Practices on the Communities in the Northern Cape

This section contains a discussion on how the changing mining practices are impacting the communities in the Northern Cape. Mining operations significantly alter a communities social and economic infrastructure. Therefore, various stakeholders have expectations about the roles they should play in the communities where they operate.

The Mineral and Petroleum Resources Development Act, 2002, (Act 28 of 2002 as amended) requires mining companies to apply for mining rights from the state by submitting inter alia Social and Labour Plans (SLP's) for approval by the Department of Mineral Resources (DMR) as a condition to operate. In compliance with the legislation, the mines that have been included in this survey are implementing Social and Labour Plans that have been approved by DMR. The plans prioritise projects that are featured in the district and local municipality's Integrated Development Plans.

Host local governments, local communities and other stakeholders hold general expectations about mines providing jobs and encouraging local economic development. Generally, within communities there is knowledge that mines spend a good part of the revenues they generate on salaries and wages of their staff and on procuring goods and services from their suppliers. Research by the African Development Bank indicates that mining companies use between 50% and 65% of their gross project revenue on paying workers and professionals, procuring goods and services, and building infrastructure. Within this spend is the argument that if a larger share of these capital outlays is used locally, it would stimulate local economic activities and give rise to positive social and economic impacts.

However, Roe and Round (2018) warn that multiplier effects are never quite straightforward. What really matters is where, how, and on what the earned incomes are spent on. In summary, multiplier effects cannot be taken for granted as has been witnessed in the Northern Cape where the proliferation of mining has not impacted the province's high levels of unemployment and poverty.

The Mining Charter is broad in its expectations as it focuses on enabling local content development and economic down streaming. The people who live in the areas where the mines are located often expect direct benefits in terms of jobs and supplier opportunities. Today there are mixed results in terms of meeting these expectations. In Kathu, the rising price of iron ore in the early 2010s, resulted into a boom for that town as Anglo-American invested in the local infrastructure and offered well-paying jobs. However, in De Aar, the copper mine owned by Orion Metals has faced community closures, some of them violent in nature as the mine has not offered large employment opportunities.

The automated and mechanised nature of the mines at Orion and Vedanta means that these mines have a lower requirement for human hands. The nerve centres in India and Australia have shifted labour demand towards workers and professionals with higher cognitive, social, and technological skills, reducing the number of physical and manual jobs that require only basic cognitive skills.

This development has decreased the opportunities for locally recruited labour and for induced employment through the spending of incomes on locally produced goods and services from surrounding communities.

6. THE VOICE OF THE UNIONS IN ZAMBIA ON THE 4IR

6.1 Introduction

This section focuses on the unions' response to 4IR and examines awareness of the 4IR concept by the unions. A note is made on the future of work. Unions' arguments to adapt to the technological and environmental changes need to be heard and be part of policy responses for mining management and the state as well as the other stakeholders such as universities. Thus, this section takes a look at the disruptions on labour dynamics and how unions are preparing for the future of work in the 4IR era.

6.2 The Trade Union Movement in Zambia

Zambia's trade unions were formed to fight for the interest of the working class. In Zambia, the earliest piece of legislation to regulate the activities of trade unions was the Trade Unions and Trade Disputes Act of 1964 (Zambia Daily Mail Limited, 2015). The Mineworkers Union of Zambia structure was opened in 1974. The MUZ union comprises of 10 board members: 4 members are full time, and the rest are part time. The union is the largest mine workers union with 80 branches across the country. Other unions include the National Union of Mine and Allied Workers (NUMAU), the United Mine Workers Union (UMUZ), Mine Contractors, ZUNO, Consolidated Mine Workers, and TAU. The concentration of unions is in the north west Zambia, where the two biggest mining unions - the Mineworkers Union of Zambia (MUZ) and the National Union of Mine and Allied Workers (NUMAW) - organise. These two unions are headquartered in Kitwe, where union leadership and professional staff are housed (Kapesea & McNamara, 2020).

Trade unions are a distinctive voice in society meant to highlight the plight of workers and also to raise awareness on various ills. MUZ is the biggest mining union though it has witnessed a drop in membership. The number of unionized miners fell to below 20 000 in the early and mid-2000s (from a peak of 65 000 before privatization (McNamara & Musonds, 2019).

6.3 Zambia Mining Unions Evolution

Zambia has come through a serious transition - from state owned mines to privatisation. During the time when the mines were state-owned, government provided free accommodation, basic services such as water, electricity, housing, and sporting services. Organized labour has been a significant factor in progressive social, political, cultural, and constitutional change in Zambia (Wild, 2012).

Privatisation was a game changer which saw most of the benefits for workers being eroded. This brought up social despondency in most mining towns. Investors have been more on the path of profiteering than on ploughing back into the community. Trade unions are noting that the world of work is undergoing rapid changes due to the 4IR. The overall membership of trade unions is on the decline. This a point of concern for organised labour.

6.4 Unions Awareness of 4IR

The 4IR or new mining technologies is an emerging concern for trade unions in Zambia and it has transformed the workplace remarkably. Trade unions are aware that the new venture mines in the North West Province have been employing new technologies and new methods of mining to enhance productivity as output is the major goal. The new technologies have created the need to lay off some workers as their positions get redundant. Unions are aware that in other areas, new technologies have contributed to the safety of workers in the mines and increased the lifespan of the mines. There is a consensus that workers will also have to improve their skills to match the needs automation.

Trade unions are keeping an eye on the ongoing trend towards modernization of mining. However, the impact of these technologies and machinery on labour and local communities has not been clearly defined. This gives rise to antagonism between labour and the mining companies.

6.5 Unions' Perception of Technology Innovation

Organised labour in Zambia has a perception that mechanisation and automation is replacing labour. Members are being forced to move from mining to agriculture. This has had serious effects particularly on the workers and also on the labour movements. A case in point is the shutting down of Mopani Copper Mine under the guise of investigative exploration. Specific technologies such as the concentrators and smelter saw the scaling down in the number of mineworkers from 1 500 to 150 employees. This has had a serious impact on the mineworkers and this remains a threat.

6.6 Impact of the 4IR on Labour Dynamics

The Zambian mining industry is undergoing rapid shifts with companies focusing on increased productivity, efficient mineral processing, and cost-efficient methods (OGAnalysis, 2019). The use of these advanced machines threatens the labour force. Unions argue that in some countries the largescale application of technologies in mines has led to destruction of livelihoods. Kansanshi Mine in Solwezi is a case in point where workers reportedly sabotaged the machines and revolted. Introduction of new technology saw the retrenchment of many workers, from around 1 400 to only about 800.

The trade unions generally understand the significance of technology and its role in increasing productivity in mining. To reach ore at deeper levels, automation needs to be applied to ensure occupational health and the safety of workers. Under the privatisation era, the new mine owners invested massively in the mines and there was a sudden economic upturn due to advanced productivity. Investments went into new machinery, new mining methods, and new mineral processing and metal extraction technologies. The massive greenfield projects at Kansanshi and Lumwana, both in the North West Province of Zambia, brought newer technologies into the industry and mines remained operational and jobs were saved (Sikamo, Mwanza, and Mweemba, 2016)

Occupational health and the safety of workers has also been a bone of contention. Amongst the reasons for primary technological innovations were the two factors: occupational health and safety, and production. Mining today is faced depth with extreme geo-stress uncertainties, geomechanics and cost, demanding sophisticated design and site-specific planning (Ali et.al, 2021). With global emphasis on decent work and zero harm mining, mines are now obliged to install automated digital systems to monitor the real-time well-being of the workforce. The introduction of smart mines, digital systems, real time ground behaviour monitoring, and proximity detectors has enhanced safety in mining operations.

6.7 Casualization of labour

Mining companies in Zambia are increasingly employing workers through contractors, instead of offering direct employment. It was discovered through a study that the new jobs have tended to be fixed-term contracts, or are outsourced to independent contractors (LIZ, 2016). Unions are recruiting and organizing to fight back this promotion of precarious work (IndustriAll, 2019). This casualization of labour is regarded as a new slavery that subjects workers to poverty as it denies them their full benefits. Chief among the major concerns is that of the country's 65 000 mineworkers, nearly half are employed through contracting (IndustriAll, 2019). The Mineworkers Union of Zambia (MUZ) has been opposing plans by Konkola Copper Mines (KCM) to outsource operations and transfer workers to contractors. Unions argue that some mine companies continue to disregard the health and safety standards yet when injuries and death occur, employers shift the responsibility to the contractors.

6.8 Trends and Challenges envisaged

What is emerging from the union's voice in Zambia is that technological applications and new mining methods pose a threat to the sustainability of jobs. It is highlighted that some existing jobs are becoming redundant. The levels of remuneration are also very poor. Koyi (2016) emphasizes that the current wages for lowly paid unionised workers in the Zambian mining sector are insufficient to cover the minimum requirement for decent living in Zambia. Given the changes, particularly regarding modern machinery and technology and lack of clarity, this may cause revolt by labour. There has to be the political will to enforce the laws and regulations which safeguard the interests of the mineworkers.

6.9 The Future for Mineworkers Union of Zambia and Other Trade Unions

MUZ has experienced a dip in membership. However, the union believes that there are opportunities in these developments as well. The youth have great potential to adapt to these changes. Thus, skills transfer is much easier to a young workforce. Training and re-training are key, and educated young people can fit into this space to lead research and development (R&D). The trade unions call for the government to enact compelling laws and policies to enhance value addition in the sector. This resonates with international labour calls for preparation for the future of work (ILO, 2019).

6.10 General Reflection

Trade unions in Zambia concede that data and information from cutting edge research is critical for informed decision making in building a transformative society. This research in particular is important as it feeds into the Strategic vision and mission of MUZ. Unions call for compact and collaborative planning and research to ensure that workers are not the casualties of new 4IR technologies. At the centre of the 4IR is the extensive use of artificial intelligence and other technologies, and these technologies will have an impact on the relevancy of trade unions (Kaggwa, 2018).

It is further opined that what is not contestable is that the 4IR will reduce the number of people employed in workplaces. At the extreme, it will eliminate the human element in many production systems across the African continent at large (Kaggwa, 2018). With low trade union membership it will be difficult for workers to organise, and that will weaken their voice in fighting for their interests. Organized labour can help ensure that these marginalized voices are heard at the policy-making table. The voice of trade unions should not be subdued. Unions further argue that research on economically viable new technologies needs to be commissioned by the stakeholders. There has to be a clear plan to safeguard livelihoods.

The attitude of organised labour in Zambia towards technological change is not well documented. Nevertheless, the evidence suggests that trade unions are not fully opposed to new technological innovations at mines, they are only concerned about workers' welfare. They insist technologies should not destroy livelihoods. Cooperation and consensus are what is needed between mining management and organised labour to reduce the negative effects on workers. Unions are calling for the up-skilling of workers to help them cope with the technological changes. For the foreseeable future, the 4IR will indeed bring disruptions in the mining sector in Zambia, and labour must be ready to adapt. The new technologies have a disruptive effect, and trade unions must work on strategies to counter this and ensure that the negative impact on workers is minimal.

7. THE VOICE OF THE UNIONS IN SOUTH AFRICA

7.1 Introduction

Trade unions are mainly concerned about protecting the interests of workers and ensuring that workers do not lose their jobs. The 4IR will bring about massive changes in numerous economic sectors, including the mining sector. With these changes comes threats of job losses to workers, but on the other hand there is safer and more effective production on the side of mining companies (Mpafa, 2018). Thus, the 4IR can in many ways benefit the employer more than it benefits the employee. As a result, trade unions only have one major concern: How will the role of trade unions be affected in the 4IR? This was discussed by (Kaggwa, 2018) in his article which sought to bring forth a response for organised labour on 4IR related issues. The lifeblood of trade unions is in fact employees - who are trade union members. In his study (Mpafa, 2018) argues that the 4IR is most likely going to undermine the bargaining power of trade unions. This notion immediately births a lot of uncertainty and anxiety among trade unions, particularly around the topic of their sustainability in the 4IR era.

There are three main unions that organise in the mining space, namely: The National Union of Mineworkers (NUM), Association of Mineworkers and Construction Union (AMCU), and the National Union of Metalworkers of South Africa (NUMSA). All these unions have voiced their concerns pertaining to how they will bargain for workers with the 4IR in place. Further issues raised in this regard have been regarding the skilling and re-skilling of workers with the purpose of avoiding retrenchments and, instead, keeping workers relevant and secure. Additionally, unions have indicated their concern around how they can retain workers after skilling them for the use of technology (Mpafa, 2018). This is especially relevant because trade unions are more likely to attract unskilled workers.

This section, therefore, seeks to answer questions around the relevance and role of the trade unions in the 4IR era. What does atomisation mean for workers in the mining sector? Will the unions still be sustained post mechanisation?

7.2 Awareness of the 4IR

The topic of whether workers are aware of the 4IR is only the tip of an iceberg. The unions should be concerned about whether workers are knowledgeable; especially about the implications of the 4IR on their jobs and how they can still not be left behind. Moreover, as much as workers must be informed, it is imperative that they are constantly educated about new job roles in the 4IR era. In a study conducted by (Koziol, et al., 2018), it was highlighted that lifelong education could be the key to ensuring 4IR awareness among employers and employees. The same applies for trade unions, and this could be a service for members.

More awareness can be created for workers in the following ways:

- Educating workers and potential workers on how to perceive the 4IR based on its possible opportunities and not only as a threat to jobs.
- What changes must take place and how they should take place to ensure that companies, unions, and workers are aligning with the 4IR.
- How to ensure that the youth is included in the 4IR.

These are questions that can be answered through initiatives of intentionally pushing educational programmes that could possibly instil hope for workers, employers, and trade unions.

7.3 Impact of the 4IR on labour

This section discusses the impact that the 4IR is most likely to have on various factors from the perspective of a trade union. In essence, whatever the impact, it will directly affect the union in one way or another. As evidenced through research, the 4IR is very likely to bring about huge losses in employment.

Labour has been such a large area of concern with regards with the 4IR, especially in countries such as South Africa which are highly dependent on the mining sector. The mining sector contributes enormously to employment of individuals. The concern then becomes what happens when all these individuals are out of employment?

South Africa has a population of 59.62 million, and a total workforce of 451 427 employees in the mining sector (StatsSA, 2020). The 4IR is likely to have a different kind of impact on the three major stakeholders involved, which are: **employees, employers** and **trade unions**.

In terms of employment, jobs will definitely be lost. A study on the impact of 4IR on the mining sector by (NSTF, 2019) indicated that the 4IR will bring about massive changes in the mining industry, and it listed out the following future technologies in the mining sector:

- Digital capturing of information
- Autonomous equipment such as driverless trucks
- Wearables for capturing real time data
- Drones for surveying temperatures
- Diverse mobile workforce with integrated remote operations
- A digital mine nerve centre with controlled, safe, and healthy conditions.

Source: (NSTF, 2019)

All these changes that are highly likely to be brought forward by the 4IR are a clear indication of a total wipe-out of the workforce. From a trade union's perspective, this is a complete threat to sustainability and even existence. Employers, on the other hand, are more concerned about running efficient and effective production and not so much the lives of employees. Those who will be negatively affected are mostly employees and trade unions.

It is also highly important to note what level of development South Africa lies in. There is need to ask questions such as:

- Is South Africa ready for the 4IR? If so, in which particular compartments of the mining sector?
- In which provinces? Which mines in particular?
- And lastly, which mines are still able to provide employment for all their manual workers?

The NUM, NUMSA and AMCU have indicated how they would keep trade unions relevant in the 4IR. In so doing, they kept in mind that some mines are still stuck in the second revolution. Further, they indicated that for some mines, they would not need to defend the interests of workers but respond to the technological changes instead (Mpafa, 2018). In responding to these changes, the unions have highlighted the following:

- Skilling and re-skilling workers with the aim of retaining them in the union as members;
- Coming up with approaches on how they can source more skilled workers into the union;
- Unions diligently providing quality services.

Source: (Mpafa, 2018).

7.4 Conclusion

In summary, the 4IR might not be ideal for trade unions, but this is how systems work. Systems evolve and institutions must adapt, the trade unions will have to adapt in this case as well. Trade unions have to make sure that the right measures are taken in order for them not to be left behind. Continuous research and development must be invested just as trade unions must invest in their members as a means to retain them.

8. CONCLUSION: CROSS-CUTTING ISSUES

The impact of the 4IR in the mining sector both in terms of its scope and severity is dependent on many factors which may vary or be similar across countries. The study of the two countries provides useful insights into what is common and what is different between them.

8.1 Awareness

The study showed that the general level of awareness across the mines respondents in both countries is well over 60% although South Africa had more respondents (83%) conversant with the 4IR (Table 1). Most of the mine workers in both countries acknowledge the impact on health and safety across the mines, with more respondents from Zambia indicating that latest technologies have improved health and safety in the mines.

Table 6: Awareness and Perception on 4IR

Awareness	South African Respondents (Excludes Northern Cape)	Zambian Respondents
4IR awareness	83	64
Impact on Health and Safety	66	86
Demographic Shifts in Workforce	57%	87%

Evidence also shows that there is a huge demographic shift in the workforce, particularly in the Zambian case where 87% of the respondents have reported such. This corroborates the labour decline in mines such as KCM of Zambia which shed nearly 1 500 workers - particularly the artisans and general workers. Similarly, as the NUM leader in South Africa confirmed, retrenchments are the order of the day. While no specific numbers could be provided the situation seems more dire in Zambia than in South Africa. Important to note is that apart from 4IR deployment, other mines are shedding off employees primarily due to inherent factors such as liquidation, privatisation, or change of ownership of the mines as is the case in Zambia.

8.2 COVID-19

Both Zambia and South Africa could not be spared from COVID-19. This heavily impacted the research activities and outputs thereof. Travel restrictions have stalled research activities. Access to mines and obtaining authorisation and consent for information gathering has been a huge set back. Equally, the mining sector has been affected by the travel restrictions particularly regarding the transfer or transportation of goods in the two respective countries.

Coupled with COVID challenges has been the reluctance of most mining companies to share or disclose information. The mining sector is a very sensitive sector and mines try to protect their privacy. Contrary to the profiteering allegations, since March the mining industry has been declared 'essential' in many countries worldwide (including the two case countries in this study) enabling them to operate amid government lockdowns.

8.3 Technology Deployment

Application of new technologies is being experienced in both countries in mining processes including exploration, operation, closure, and rehabilitation for both open and underground mine ventures. The sources of these technologies vary but indications are that the advanced technologies in sync with the 4IR are imported from countries such as China, Europe, India, Australia, and USA.

8.4 Production

Increased productivity and efficiency due to the new 4IR technology has been reported in both countries. While production costs are said to have declined in some cases, they have increased in some of the mines. It has also been observed that some of the operations and sections of the mining value chain have been rendered obsolete following the introduction of mining technologies as discussed in the preceding chapters.

8.5 The voice of the union

The unions are key players in the 4IR. Unions' voices in both Zambia and South Africa attest that technological applications and new mining methods pause a threat to the sustainability of jobs. According to MUZ of Zambia, continued decline in members is primarily due to retrenchments in the mining sector as a result of new technology deployment. In South Africa NUM, NUMSA, and AMCU have also indicated how retrenchments pose a huge threat and remain an unjust phenomenon in the country. For both countries' unions, skilling and re-skilling workers with the aim of retaining them in the union as members remains a key priority.

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