DOCTOR OF PHILOSOPHY (PhD)

On

Digital Mining for Sustainable Economic Development and Employment Generation with a special reference to South Africa

By

Nathan Paul Williams

N° UNISE1050it

PhD THESIS

Submitted to the

SELINUS UNIVERSITY

In fulfilment for the award of the degree of

DOCTOR OF PHILOSOPHY

TECHNOLOGICAL MANAGEMENT

“I do hereby attest that I am the sole author of this thesis and that its contents are only the result of the readings and research I have done”.

Nathan Paul Williams

Abstract

This study will focus on the impacts that transitioning to a digital mine with digital-enabled technologies will have on the socio-economic wellbeing of broader mining communities. The study will cover how the impact of digital disruption should be managed through adopting a shared value framework, leveraging new possibilities that Digital brings to develop new mining skills, community education and supplier development which will modernize the mining sector and create more jobs. As select job categories give way to automation, reskilling and appropriation of new skills will be critical for mining companies.

Acknowledgements

My appreciation goes to my supervisor Professor Salvatore Fava the president of Selinus University and Director of Uniselinus Europe who guided me throughout this thesis work. I have learnt a lot through his supervision which has really sharpened my intellectual ability. The knowledge I gained from this thesis will guide me in my future work. I have been working for 8 years in the managing mineworkers provident and pension funds. It has been a huge challenge to write this piece of research regarding this industry, I appreciate the guidance and your contributions to make this work possible. A special thanks to the management of Selinus University of Sciences and Literature for giving me the opportunity to study at this great institution. I also would like to thank my family for sacrificing a lot to make sure I graduate. I am thanking you all for your support, prayers and your words of encouragement. May God and reward, you all richly.

Table of Contents

1. INTRODUCTION: CHAPTER ONE

1.1. Historical Background

According to Mutemeri and Petersen (2002), mining has been a significant aspect of the economy of South Africa and has led to much of the economic development of the country. Although the small-scale mining sector still has to realise its full potential. The practice of mining has drawn various negative remarks and has become a topic of controversy. Since the demand for minerals is increasing at a steady pace, and the stocks of such metals are depleting, the issues related to mining are in consideration (Tawiah & Baah, 2011).

Globally, mining companies are rapidly switching their strategies and are adopting new operating and business models in order to include new and more efficient technologies in the mining industry. Factors contributing to this shift in the working structure of the mining industry is due to the changing global demand, a search of locations for new reserves, market volatility and a commitment to operational excellence. Mining companies are left with limited resources to adjust since from the past several years, ageing workforce and cost reduction have been a constant problem for this industry.

New technologies like Digital Transformation have opened possibilities to develop accurate and agile planning, improving operating efficiencies and heighten vendor awareness.

The mining industry has its focus on digital transformation, which could help in gaining a competitive advantage within the industry (Sganzerla, Seixas & Conti, 2016).

Argentina has seen a large-scale investment by foreign investors in exploration and exploitation of the mineral resources since the liberalization of its investment regime.
However, this has been strongly opposed by many social groups including the church and local communities. The new mining projects have often raised various ethical, environmental and economic concerns.

For this purpose, the mining companies continue to develop the Corporate Social Responsibility initiatives in order to promote the sustainability and development of nation simultaneously (Mutti, Yakovleva, Brust, & Di Marco, 2012). The economy of the nation is impacted significantly by mining practices. Thus, the industry data must be available freely so that the shareholders can understand how the sector is performing in order to make sound decisions (Mineral Council South Africa, 2019).

For more than 100 years, the South African mining sector has been considered as a labor-intensive industry using physically demanding manual drilling methods with blasting and cleaning on a stop-start basis, predominantly in the narrow reef, hard-rock mining for gold, platinum and chrome (Minerals Council South Africa, 2019).
The challenges from coal mining include land subsidence, coal mine accidents, mining waste disposal, air pollution and damage to water bodies.

In order to address this problem of environmental pollution, remediation measures and clean processes have been designed.

To improve the changes in the landscape, restoration methods must be proposed (Zhengfu, Inyang, Daniels, Frank, & Struthers, 2010). Globally, the sustainability and social responsibility of the businesses has become a topic of discussion, and a high-profile issue in many industries and countries and the same was applicable for the mining industry (Jenkins & Yakovleva, 2006).

According to Limpitlaw, Aken, Lodewijks and Viljoen (2005), coal mining is a mature industry in South Africa as there are major coal fields in South Africa and a large number of closed collieries. Presently, the multinational companies in South Africa have applied scientific steps in order to control and mitigate future pollution from the mines that are closed. In order to reduce the dependency of local communities on the mines before closure, companies are undertaking various local economic development initiatives and integrated planning frameworks.

1.2. Problem Statement

This study aims to develop and suggest methods that can prove to be advantageous for the mining sector. Kamunda, Mathuthu and Madhuku (2016) conducted a study in order to examine the health risks caused by the heavy metals on the local communities inhabiting a gold mining area.

For this purpose, the researchers collected 56 soil samples from five mine tailings and 17 from two mine villages to analyze the presence of Lead, Arsenic, Cadmium, Mercury, Cobalt, Chromium, Copper, Zinc and Nickel using ICP-MS.

The concentration of these heavy metals in the soil was then measured to calculate the risks for children and adults residing in that area. The results revealed that everyone in 5882 adults might be affected and for children, one child may be affected in every 2725 individuals. The carcinogenic risk values were found to be higher than acceptable values in both cases.

Halvani, Zare and Mirmohammadi (2009) in their research study, examined the rate of tiredness and sleepiness around the shift and non-shift workers and its relationship to occupational accidents. This study was conducted on 137 shift workers and 130 non-shift workers of Iranian Industrial Mining Groups. A strategy of the multi-part questionnaire was implemented. This questionnaire included demographic characteristics and Epworth Sleepiness scale and Piper Fatigue Scale was applied to it.

The results reported that the number of accidents in both groups was not related significantly to the rate of sleepiness. The shift workers were more prone to the rate of fatigue and number of work accidents.

Further, it was revealed that fatigue had a powerful relationship with occupational accidents as compared to sleepiness.

Thus, the evaluation of fatigue is a more accurate factor in preventing accidents at the workplace rather than the rate of sleepiness.

Marshall, Bonchis, Nebot and Scheding (2016) published a research paper to comprehend the use of robotics technology in the surface and underground applications in mining.

Mining can be defined as the practice of extracting resources for various purposes. Mining business uses heavy machines that operate on electric types of equipment and diesel. These machines are subject to harsh conditions like in extreme arctic to desert climates. The applications of robotics in mining include haulage and excavation, robotic mapping and surveying, robotic dozing and robotic drilling. The study deals with the unique challenges involved in implementing robotics in the mining industry.

Further, it indicates the importance of using robots from the perspective of the miners to enhance productivity, encourages safety and reduce costs and from the perspective of companies in order to meet the increasing product demands.

Presently, the mining sector is dealing with problems like the hazardous impacts of mining on the environment, the detrimental impacts on the health of the workers who are involved in mining due to the poisonous gases that are emitted during the process, the local communities who are frequently dispersed from their native lands and the mining industries who want to implement advanced technologies which are economical.

1.3. Aims and Objectives

1.3.1. Aim: To explore the methods to modernize the South African Mining Industry while building a sustainable economy by creation of new jobs.

1.3.2. Objectives

- To determine the importance of mining Industry in South Africa.
- To determine the threats of mining on the lives of the Mine workers.
- To explore the methods to reduce the environmental problems related to mining.

1.3.3. Literature Review

According to Schueler, Kuemmerle and Schröder (2011), the use of land conflicts has become increasingly evident from the local scales to global scales. This conflict generally occurs due to surface gold mining, although the effects of mining remain unclear on local livelihoods.
The goal of this research paper was to assess the change in the land cover due to the mining of gold in Western Ghana and to study the impact of these changes on the land-use system in comparison to the practices within South Africa.
For this purpose, Landsat satellite images were obtained from 1986-2002 in order to map the change in the land cover and held interviews with the farmers to find its implications on their livelihoods.

From the results, it was revealed that surface mining led to deforestation, a significant loss of farmlands and further led to spillover effects as the farmers who were relocated and expanded their farmland into forests.

Edwards, Sloan, Weng, Dirks, Sayer, and Laurance (2014), in their research paper, assessed the environmental threats related to the African mining industry including the expansion of infrastructure, alteration of habitat, bushmeat hunting, human migration, weak governance and corruption. These threats were illustrated in Central Africa.

The results revealed that in order to protect certain wildlife habitats, mining set-asides could be used, moreover by improving the networks of transportation crop yields and the land for conservation can be increased.

Further, the study stated that research and policy measures would be needed to interpret alliance between the development activities and mining, improve assessment of environmental impacts, devise mechanisms for offsetting and mitigation and identify the choke points of the market in which lobbying can improve the environmental impacts. Moreover, rapid mining expansions will have adverse impacts on the African biodiversity and the environments without careful and effective management.

One of the major environmental concerns regarding the mining industry is the acid mine drainage.
Ochieng, Seanego and Nkwonta (2010) published a research paper in which the most severe environmental problem of acid mine drainage was discussed. Globally, the problem of acid mine drainage is recognized as a critical problem in the mining of coal and gold.

From the studies undertaken in South Africa, it was observed that highly acidic water was released from the mining companies, and this could not be released directly into water bodies.

The study revealed that some form of water treatment was necessary in order to neutralize and nullify the acidic levels of the mine water.

The primary aim of this study was to create awareness about the detrimental impacts of releasing the acidic water of the mine companies into the water bodies.

Coetzee and Staden (2011), in their study, analyzed the safety disclosure methods in the annual reports, corporate press releases and sustainability reports of South Africa. For this purpose, the mining accidents that occurred in the Goldfield mines and the Harmony Gold mines were taken into consideration.
Over the years, it is observed that significant concerns regarding the safety of employees and stakeholder's scrutiny have increased.
From the results of the study, it was clear that organizations reacted to the recognized legitimacy threats due to an increase in the safety disclosures. Furthermore, it was noticed that the organizations responded to the stakeholder scrutiny, intimidating their legitimacy after these mining incidents.

The results also revealed that there is a relationship between social performance, risk, companies' size and the number of fatalities although media attention which is devoted to the mining accidents is insignificant to the levels of safety disclosure.
According to Utembe, Faustman, Matatiele and Gulumian (2015) mining although associated with several chemical hazards, plays a significant role in the economy of South Africa.

Depending upon the duration of exposure; size, shape, level and composition of the mineral; dust due to mining can lead to various pathological effects. Mining and processing of minerals further lead to occupational exposure to toxic substances like cyanide, vanadium, platinum, mercury, diesel particulate and chromium.

The mineworkers remain at risk, although South Africa has set occupational exposure limits (OELs). The study recommended that South Africa should not blindly follow the OELs from other countries but should rather set its own standards as the hazards posed by a mineral depends solely on its own physicochemical properties. Due to large areas occupied by tailings dams and dumps the mining industry has led to the contamination of the environment at a huge level. Thus, the study suggests a need for developing guidelines for safe land-uses of contaminated lands after mine closure.

The mining industry in South Africa is an integral part of its economy. The studies conducted in the past have highlighted the importance of mining for the economy of South Africa, several environmental issues related to mining and the threats to the lives of the laborer's involved in the mining practices. However, no such study has been performed that assesses the importance of creating jobs without threatening human lives in the mining industry. The present study will try to bridge this gap in the existing literature.

1.3.4. Research Methodology

This study will adopt a qualitative research approach. Interviews will be conducted with the top managers of the mining companies to know their perspective on the concept of sustainable development of the mining industry without endangering human lives and without ceasing the job opportunities. The interview will include questions regarding the employment of robotics and other improved techniques in the field of mining. Moreover, interviews will also be held with the laborer's and the local groups to know their perspective on the same. The laborer's will be asked questions regarding the impact of mining in their lives, the diseases related to mining and their willingness to learn the operation of new techniques used in mining.

The local groups will also be interrogated to find their perception of the environmental concerns regarding the mining practices. Moreover, the research will involve an interpretivism approach to interpret the data collected from the interviews. The data will be collected using the primary sources of data collection. The analysis of data will then be done using a thematic analysis. After the interpretation and analysis of data through thematic analysis, findings will be drawn, and finally, a conclusion will be validated.

The Primary Data collection method will be used for collection of data. Interviews will be conducted with the top managers of the mining industry, mine workers and the local communities. Thematic analysis will then be applied to the data collected in order to interpret and analyze the data. In this method, the technique of purposive sampling will be used.

1.3.5. Limitations of the Study

The current study has the following limitations:

1.3.5.1. The study is limited to fewer participants due to the financial, time constraints and the current COVID19 pandemic restrictions.

1.3.5.2. Since interview is being used as a source of primary data collection; interviewers are biased, and their likes and dislikes can affect their judgement.

1.3.6. Significance of Study

Globally, mining companies are rapidly switching their strategies and are adopting new operating and business models in order to include new and more efficient technologies in the mining industry. Factors contributing to this shift in the working structure of the mining industry is due to the changing global demand, a search of locations for new reserves, market volatility and a commitment to operational excellence. This research study will be utilized to comprehend the environmental issues related to mining.
It will suggest various methods that will help in building a sustainable economy while addressing the safety of the environment and human lives.

In today's era, companies want a safe environment for their employees without affecting their business profitability and this balance is what this study will try to achieve and recommend.

This study will explore the employment of robotics technology in the mining industry. The reasons to consider robots in mining include the deteriorating conditions in the underground mines, lack of skilled workers, the limited potential of both humans and traditional mines, the rising cost of labour and the preservation of human lives.

This study will analyze the negative and positive impacts of recruiting advanced technologies in this sector in developing a sustainable economy. Further, this study will add to the existing literature and will also be utilized as a foundation by other researchers for formulating methods to contribute to the current study.

2. IMPORTANCE OF MINING: CHAPTER TWO

2.1. Introduction

Mining is the digging process or action through which natural minerals present beneath the surface of the earth is extracted. It is the fifth largest and second oldest industry in the world. The mining industry has been classified into two types such as underground mining and surface mining that contributes towards the development of the world economy (Down & Stocks, 1977). While focusing on the mining industry in South Africa, R20.3-trillion worth of mineral reserves have been recorded in the country. The mining sector contributes to the economic sector of South Africa by forming the fifth-largest part of the South African Gross Domestic Product (GDP) value.

According to the US Geological Survey, it was found that the South African reserves are formed of rich minerals such as vanadium, manganese, diamond, platinum, chromite ore, and gold. To focus on the importance of the mining industry in South Africa, a survey was conducted by the Chamber of Mines now called the Minerals Council of Southern Africa, and found that the mining industry employed more than one million individuals (directly and indirectly). The survey revealed that the mining sector contributed 18% towards the GDP through direct and indirect (8.6% and 10%) inputs. The mining sector is a critical source for foreign exchange earning with more than 50% and foreign savings with R1.9 trillion in the year 2011. Thus, it can be said that the mining industry forms an integral part of South Africa that provides economic success to the country.

The mining sector in South Africa not only contributed towards the economic development of the country but also contributed towards industrial development. The major industries that occupy the mining market are BHP Billiton Energy Coal South Africa Proprietary Limited, Harmony Gold, Rio Tinto, Kumba Iron Ore Ltd, and Sibanye-Stillwater.

The gold mining companies include Anglo Gold Ashanti, Harmony Gold Mine, Mponeng Gold mine, and Savuka Gold Mine. The different mining companies such as the platinum industry employed 164 513 workers, the gold industry employed 95 130 workers, and the coal industry included 92 230 laborers. The other industries such as chrome, iron ore, diamond, and manganese occupied 19 693, 19 092, 15 728, and 10 846 workers respectively in the year 2019.

However, due to the poor working conditions in the mining sector such as poor safety, high geothermal temperature issues, and silica dust the strength and contribution of the mining sector have decreased over the years. For example, deep level gold mining had a harmful impact on the health conditions of the workers. As a result, more than 128 575 mineworkers suffered from occupation diseases, more than 1 million workers suffered from occupational injuries and 69 000 workers died because of occupation injuries (Steen, Gyi, White, Gabosianelwe, Ludick, Mazonde, Mabongo, Ncube, Monare, Ehrlich and Schierhout, 1997).

Therefore, the governing body in South Africa introduces mitigating measures and technological reforms so that the working conditions in South Africa are improved.

The technological changes such as Digital Transformation in the South African mining industry helped the industry to grow and expand its functionaries as per the advanced changes taking place globally.

For example, the digital transformation advancements include different applications such as agile planning, analytics, intelligent sensors, and collaborative value chain that help in improving productivity (Sganzerla, Seixas and Conti, 2016).

It will help to modify the labor-intensive image of the South African mining industry and introduce technology-based production processes. The use of digital transformation tools such as the Internet of Things (IoT) will help in an adequate flow of information and mobilize the distribution and consumption process. On the other hand, the use of analytics will analyze complex market conditions, real-time data and provide relevant information for processing and execution. As a result, the efficiency of the mining industry will increase and contribute to economic growth optimally. For example, due to reforms in the Ghana mining industry, the condition of other sectors such as the environment and health also improved. As a result, Ghana became the center of mining and attracted companies like Newmont (USA) and Ashanti Goldfields and Anglo Gold (merged company) to the region.

The governing bodies in Ghana have also signed a memorandum with the Extractive Industries Transparency Initiative (EITI) to adopt global standards and ensure transparency in the administration of minerals, oil, and gas (Akabzaa, & Darimani 2001).

Thus, it can be said that digital mining could be beneficial for the South African mining industry as it provides sustainable economic development and employment generation opportunities.

2.1.1. Threats of mining on the lives of the mineworkers in South Africa

Even though the mining sector is highly contributing to the economic growth of South Africa, it is not well developed and negatively impacts the growth and expansion of the industry. Economists suggest that the high dependency of a country on its natural resources makes its international activities limited. It creates a close economy that does not allow the conduction of international commercial activities effectively.

The high dependence on the extraction of natural resources makes the country dependent on it and discourages exploration of other new economic methods of growth and development (Sachs & Warner, 1999). Additionally, high dependence on extraction or mining process does not allow balanced growth in the country, as a result it impedes sustainable development, and destructs the environment (Richards, 2002).

If the workings of the mining industry are not managed properly, it will increase the cost of production that adversely impacts the social, ecological, and financial conditions of the country (Warhurst, 1999). For example, due to intensive and improper mining in South Africa, there is the creation of surface disturbances, waste generation, and exposure of geological substances to the atmosphere which adversely affect human health conditions.

Due to mining process, there is oxidation, high temperature, and precipitation of harmful gases, pollutants (dust, fumes, and chemicals) that causes diseases and health issues in workers and individuals living in the surrounding regions (Chiaro & Joklik, 1998).

The mining industry is using chemicals and explosives for mineral extraction purposes that creates safety and health hazards to mineworkers and the environment. As a result, a high increase has been recorded in the environmental issues which have led to the imposition of additional taxes on the mining companies.

For example, 304 miners, 238 miners, 2530 miners were suffering from lung disease, autopsy, and silicosis in gold mines in Thamanga (Botswana), Eastern Cape (South Africa), Cape Town (South Africa) respectively (Murray, Davies and Rees, 2011).

The miners faced high-temperature issues while carrying out the mining process. It requires the use of deep mining refrigerators to reduce the temperature of the underground mining regions so that the workers could work effectively. However, these facilities are not provided to the miners as the deep mining refrigerators increase costs and consume large amounts of energy. Additionally, there is a lack of adequate ventilation requirements at the mining sites. There is extensive use of inclined reefs and orebodies that restrict the movement of air and caused respiratory issues among the miners. The survey on the ventilation condition in South Africa revealed that most of the gold mines in South Africa had 6 cubic m/sec/1000-ton ventilated air circulation capacity in the rock mines each month (Geldenhuys, 2015). Thus, it can be said that the working conditions of miners in the mines in South Africa were highly degrading that caused several ailments such as lung diseases, and respiratory issues to the workers.

While focusing on the housing and other facilities such as education, healthcare, transport, and recreation that were provided to the mineworkers, it was found that the mineworkers were provided with different forms of transport such as private vehicles, and public transport such as buses to reach the mine workstation. However, the condition of vehicles and road was so poor that is caused accidents and fatalities during commutation. The healthcare facilities were present for the miners at the workstation but that only took care of the primary health conditions. The other healthcare issues that were faced by the miners were not addressed by the healthcare units.

As per the survey conducted by Department of Mineral Resources concerning mine accidents and disasters, it was found that there were more than 11000 deaths in the mining industry during 1984 to 2005. Additionally, the number of fatalities varied from 533 to 199 from 1995 to 2006. The overall fatality rate was recorded to be 0.43 against every thousand individuals in the year 2006. The survey further revealed that the fatality rate recorded a 0.71 in gold mines, 0.35 in other mines, and 0.24 in platinum mines in South Africa (Jacobs & Pienaar, 2017).

As per the survey conducted by the South African Medical Research Council, it was found that due to the prevalence of silicosis in gold mines, most of the miners suffered from tuberculosis (TB) and HIV. It is because silicosis increases the risk of TB among the miners that amplified the spread of HIV.

As a result, the number of TB patients increased from 806 against every 1000 individuals to 3821 against every 1000 individuals in the year 2004.

Additionally, inadequate treatment of TB, inaccuracy in the diagnosis of TB also increased the spread of TB among the gold miners. As per the survey reports by South African Mine Health and Safety Inspectorate, it was found that about 0.65 miners died against every 1000 workers in the year 2003 which reduced to 0.43 of miners died against every 1000 workers in the year 2005 in the mining industry. However, the mining industry still records a high mortality rate as compared to other industries that are prevalent in the South African economy.

Due to poor and degrading conditions of the mining industry in South Africa, the sector was exposed to several rebellions and strikes. For example, in 2007 the miners formed a national level group known as the National Union of Mineworkers to voice against the improper working conditions. It included 240 000 workers that worked in 60 mines (coal, platinum, and gold) and impacted the work of these respective industries.

The Lonmin strike took place in the year 2012 that enraged the country with violent confrontations. As a result, 34 mine workers were killed, and 78 miners faced serious injuries. However, there was little improvement in the working conditions and strikes kept on emerging consequently. For example, the platinum mineworkers went on a strike in the year 2014 against the poor working conditions which continued for five months (Leander, 24 October 2014).

In the current pandemic conditions due to the spread of Covid-19, the mining companies in South Africa are compelled to adhere to the safety and health conditions. It includes implementing guidelines that are provided by the Department of Mineral Resources and Energy (DMRE) to the mining companies. However, despite precautions and maintaining of safety measures, 384 miners in Impala Platinum's Marula Mine (Limpopo) were found to be virus positive. It increases the threat of spreading the disease to more than 40 000 mine workers that are working in Moab Khutsong mine (Matlosana) and AngloGold's Mponeng mine (Merafong).

The mineworkers live in poor conditions with no facilities of proper sanitation, clean drinking water, and adequate housing. The poor living conditions are further aggravated because of dumping wastes in the surroundings that cause respiratory issues like asthma, chronic cough, emphysema, pneumonia, and chronic bronchitis to the miners and surrounding inhabitants. Thus, it can be said that the workers, laborers, employees, and personnel that are working in the mining sector face a lot of difficulties due to high temperature, exhalation of silica dust, pollutants, and poor living conditions that negatively impact their health and living standards.

2.1.2. Methods to reduce the environmental problems related to mining in South Africa

While focusing on the implications of the mining industry on the environment, it had a negative impact on the environmental conditions by increasing deforestation in the country. Due to the expansion of mining, there was a significant reduction in the farmlands that created a spillover impact on the farmers. As a result, most of the farmers were forced to relocate and expand their farmlands in the forest regions. It reduced the forest land space that deteriorated the environmental conditions further.

Additionally, due to ecological threats, because of mining, there was an increase in meat hunting, migration, resettlement issues, corruption, and poor governance practices. It hampered the safety and security of forest animals and created issues for them to survive in then diminishing forest size and land cover (Edwards, Sloan, Weng, Dirks, Sayer, and Laurance 2014). Another major issue that increased alarms for the environmental concern specifically in South Africa was related to acid mine drainage that occurred because of improper handling of mining activities.

Due to improper acid mine drainage in coal and gold mines, there was a rise in the acidity levels, toxic heavy metals, and radioactive metals that degraded the quality of water. For example, the discharge of toxic materials such as radioactive wastes, heavy metals, and toxic substances by the mining companies, the toxicity levels of Witwatersrand increased manifold. The issue arose because the mining companies were allowed to release the mining waste in the open streams, dams, and groundwater. As a result, the pH levels of the water increased and reached 1500 mg/L which degraded the quality of water in the Vaal River. It negatively impacted the marine ecosystem by increasing the temperature of the water and reduced the volume of oxygen in the water.

Additionally, inadequate mining process also caused the release of greenhouse gases, fly ash, smoke, and burnouts. For example, due to underground mining practices in South Africa, there is a generation of huge amounts of wastes in the form of rock and earth. When these rocks and earth that are deep-seated in the core of the earth are exposed to the air and water, they cause toxic reactions and release toxic substances in the natural environments. Many a time, due to deep underground mining, there is a creation of disruption in the earth surfaces which increases the risks of collapses.

It results in the sinking of the buildings and causes damage to human life and safety. Underground mining lowers the water table by destructing the underground water and streams. It creates water shortages that negatively impact the survival status of humans, plants, and animals.

The other issue such as coal fire has also hampered the environmental and human conditions in South Africa. The burning of coal in the mines produces huge quantities of smoke that pollutes the natural surroundings and air. The smoke contains harmful and greenhouse gases such as carbon-dioxide (CO2), nitrous oxides (NOx), carbon-monoxide (CO), sulfur dioxide (SO2), methane (CH4), fly ash and dust.

All these negatively impact the air quality, increase the natural temperature, and pollute the soil, and water. The major cause of coal fire is mining accidents and the implementation of inadequate mining techniques. The other reasons such as thunder lightening and peat fires may also cause coal fires. For example, an incident of coal fire was recorded in the Majuba plant in South Africa which highly impacted the plant's productivity for a few months. It disrupted the working of the plant by decreasing its production capacity and destroyed the offload facility mechanisms that were developed at the plant site. Thus, it can be said that the mining industry is not only impacting human lives negatively but also adversely affecting the environment and natural surroundings. To protect the environment and humanity from improper and destructive mining practices, the mining industry must bring significant changes in its production and supply techniques.

The introduction of modern arrangements such as digital transformation in the form of agile planning, the internet of things (IoT), cloud computing, analytics, and sensors will help to revolutionize the mining working process. The penetration of digital transformation into the mining industry will help in increasing the velocity of mining operations by enhancing the flow of information between the workers and the company.

For example, the Internet of Things (IoT) implemented by the mining companies helped to develop effective communication channels and facilitate the flow of information between involved parties such as manages and miners. As a result, the exchange of information and knowledge adequately reduce the risk of accidents and mishaps at the workplace. It will not only enhance safety and security measures at the mining site but also reduce the accidents and faults related to leakage and acid drainage.

While focusing on the positive implications upon the implementation of digital safety practices in mining in South Africa, it was found that due to safety practices, there was a 10% decrease in the fatalities in the mining industry in the year 2018 as compared to the year 2017. A significant improvement was also recorded in the frequency of accidents by 12%, as it reduced to 2350 in the year 2018 from 2669 in the year 2017, especially in the gold, platinum, and coal mines. Thus, by using the digital mining process, human lives, as well as environment safety practices, could be implemented effectively that would save human lives and improve environmental conditions.

The implementation of digital transformation practices such as Operations Technology (OT) by the mining companies in South Africa will help in reducing the harmful environmental problems related to mining. The OT approach includes implementing multiple applications such as manufacturing systems, supervisory systems in the different business units. It helps in integrating the IT environment with the mining operations and systemizing the entire mining and safety procedures of the companies. For example, the installing of intelligent sensors helps in recording and live telecasting the working of the miners to the managers. It also detects the temperature, air pressure, and pollution levels at the mining sites. It further helps in easing out the sophisticated procedures of counting, recognizing, and tracking the miners and equipment in the site. Thus, by using these measures more security is ensured at the workplace and avoids the occurrence of any accidents, spillovers, or leakages.

On the other hand, the drones (Unmanned Aerial Vehicles) help in supervising the entire mining site by covering the large mining region in a short duration. As a result, it becomes easy for the supervisors to keep a vigil on the action of each worker. It helps in reducing wastes that facilitate the preservation of the environment by effective utilization of resources (Jackisch, Lorenz, Zimmermann, Möckel & Gloaguen, 2018).

The digital penetration in the South African mining industry will help in creating more job opportunities that will promote technological advancement and sustainable growth in the sector. At present, the mining industry contributes 47% towards job creation and 42% towards the collection of revenues. However, the labor-intensive industry faces competition at global levels because of high cost and pricing alterations.

The introduction of digital measures will revolutionize the entire mining procedures, enhance site working, and reduce the overall cost by 15%. The digital applications will also improve the abilities of the supervisors to handle the tough mining conditions. As a result, due to continuous monitoring, there will be an increased employee safety, information flow, less generation of wastes, proper disposal of wastes, and performance management. Due to the use of cloud computing and connected devices, there will be a transfer of real-time data and information flow that will enhance the performance of mining activities by 10%.

For instance, a thirty-year-old gold mining plant in South Africa adopted the digital mining process (applied advanced analytics) across all the processing phases. It helped in reducing cost and improving the efficacy by 2%. Thus, it can be said that digital penetration in the South African mining industry will help to improve the workings of the mining industry and contribute towards the reduction of environmental disasters.

The implementation of other procedures such as the launching of the Center of Excellence by the Mine Health and Safety Summit will also help to enhance the skills and abilities of the miners. Under the initiative, the mineworkers are provided with adequate training and education so that they work safely at the mining site. The initiative also aligns the National Development Plan to the mining working process that helps in promoting sustainable economic development and employment generation in the country. Additionally, South Africa's Mineral Policy also provides that the incentives related to the promotion of the South African mining industry. As per the policy, the under-performing mining industries are provided with incentives so that they could perform well in the competitive markets. The policy measures also include provisions related to environmental and health transformations, introducing rebalancing ownership strategies and safety modules so that the mining-related fatalities, accidents, and injuries reduce.

Thus, it can be said that introduction of digital transformations and constructive policy implementation will help to improve the poor environmental conditions and mine worker's living conditions.

2.2. PROBLEM STATEMENT

The major issues that are faced by the mining industry in South Africa are poor working conditions of the workers in which no appropriate safety and working environments are provided to the workers. As a result, the miners work in South Africa is plagiarized with work accidents and a high rate of worker fatigue. Due to long working hours, high temperature, poor safety conditions, high-stress levels, and fewer hours of sleep and the workers are more prone to accidents and injuries. Moreover, the mining process includes different processes such as excavation, haulage, and digging which includes labor skills and competencies. When digital transformation such as robotics, were included in the mining process, the unskilled laborers could not make use of advanced technology. For example, due to the implementation of robotics, there is an introduction of innovative mining activities such as robotic drilling, robotic mapping, robotic dozing, and surveying.

However, due to lack of capabilities of the workers, they could not use the robotic technology to the optimized levels (Marshall, Bonchis, Nebot and Scheding 2016).

Additionally, the mining industry in South Africa is also facing issues of negative impacts of mining on natural surroundings and the environment. When the mining process is carried out, there is a release of harmful gases and dust in the air. It causes contamination of air, water, and soil that not only hamper the sustenance of the natural environment but hampers human health conditions adversely.

The other issues such as acid mine drainage, coal fires, and illegal mining also impact the working of the mining industry in South Africa (Munnik, Hochmann, Hlabane & Law, 2010). Thus, it is essential to introduce innovative practices such as digital penetration in the form of the internet of things (IoT), agile applications, cloud computing, sensors, and drones to enhance the workings of the mining industry effectively.

The provision of education and training to the mineworkers will increase their skills and they will in a better position to make use of digital technologies that are introduced in the mining sector.

2.3. RESEARCH AIM AND OBJECTIVES

The main aim of the study is to explore the methods to modernize the South African Mining Industry while building a sustainable economy by the creation of new jobs. The other objectives of the study are mentioned below:

- To determine the importance of the mining industry in South Africa.
- To determine the threats of mining on the lives of the mineworkers in South Africa.
- To explore the methods to reduce the environmental problems related to mining in South Africa.

2.4. RESEARCH QUESTIONS

- What is the importance of the mining industry in South Africa?
- What are the threats of mining on the lives of the mineworkers in South Africa?
- What are the methods to reduce the environmental problems related to mining in South Africa?
- How do create sustainability in the preservation of jobs, while digitizing and what the risk factors to be considered.?

2.5. SIGNIFICANCE OF STUDY

The current study describes the condition of the mining industry in South Africa and its contribution to its economy. The mining industry is a prominent sector in South Africa that contributes to the economy by creating large employment opportunities. The mining sector includes different segments such as coal, gold, diamond, platinum, chromium, and uranium. These are key resources that provide high overseas and domestic trade propensities to the mining companies. The study provides facts related to threats of mining on the lives of the mineworkers in South Africa and highlights the issues that are faced by the environment due to the intensive mining process.

The study also examined that because of the high dependency on the mining industry, there is unbalanced growth in the economy that impedes sustainable development and destructs the environment. Due to intensive mining process, there is the creation of huge piles of wastes, and surface disturbances that negatively impact the human survival status and living conditions (Mhlongo, & Amponsah-Dacosta, 2016).

The study also highlights that necessary measures such as digital penetrations are necessary to be improved so that the degrading condition of the environment, industry, and miners could be improved.

Thus, it can be said that the study is beneficial as it provides relevant information about importance, ill effects, and measures of improvement for the environment and mine workers.

2.6. CONTRIBUTION OF STUDY

The current study which is necessary to be carried out so that the facts related to the mining industry and its importance in South Africa could be gained effectively. The study also provides relevant facts related to mining companies in South Africa that have introduced digital transformations into their working systems. It includes the adoption of agile functioning, the use of sensors, robotics so that the deteriorating conditions of the mining industry, environment, and mine workers could be improved. The study identified that the digital mining industry in South Africa is facing issues because of unskilled labor and rising cost. This is impacting the adoption of technological innovation in the mining industry adversely. The study also examines facts related to the positive implications of technologies in the mining industry and its wide application in the future.

The study will further provide reliable facts related to environmental issues that emerge because of improper mining. The ill-effects of improper mining on environmental and human health have also been included in the study.

Thus, it can be said that the study highly contributes towards the existing literature by providing relevant information about digital mining practices for sustainable economic development in South Africa and methods to reduce the environmental problems related to mining in South Africa, while considering the critical balance between the preservation of jobs, lack of skills and implementation of advance technologies.

2.7. SCOPE OF STUDY

The current study which is related to digital mining for sustainable economic development and employment generation with a special reference to South Africa is useful in the future as it provides valuable information about the mining companies and their rapid switching strategies, operating methods, and business models. It includes providing information about digital penetration in the mining sector and its effect on the mining industry. The study also provides relevant information about threats of mining on the lives of the mineworkers in South Africa and employment-generation opportunities created by the mining industry post-adoption of digital interfaces. The study will be highly beneficial to scholars and researchers who are researching a similar topic. It is because they could take references from the current study that are relevant for their study.

The study will also be beneficial to the policymakers and mining companies as they will get better learning about the threats of mining on the lives of the mineworkers in South Africa and explore the methods to reduce the environmental problems related to mining in South Africa.

2.8. LIMITATION OF STUDY

The major issue faced by the researcher while carrying out the research was related to a limited set of data. There have been several studies related to the mining industry in South Africa, but studies related to the use of technology in the mining industry have been limited in nature in respect the preservation of jobs and the environment.

Therefore, the present study explores the facts related to technology application in the mining industry in South Africa and fills the gap that has been prevailing between previous and current literature.

The other limitation that is faced by the researcher is the restricted use of the sample. Due to limited participants, facts related to the study topic could not be investigated properly which hindered the entire researching process. The study includes the primary data collection method in which an interview is to be used for collecting facts about the study. However, the conduction of the interview may be biased because of the different likes and dislikes of the participants. It may affect the course of the research process negatively. Additionally, time and financial constraints were faced by the researcher which impacted the researching process.

3. LITERATURE REVIEW: CHAPTER THREE

3.1. Status and importance of the mining industry in South Africa

The history of mining activities in South Africa begins before the arrival of the Europeans. Long before that event gold, copper, tin and iron were mined and smelted in the Northern Transvaal and Southern Rhodesia. According to some investigators this work was done by natives of Africa, probably under foreign supervision, a few hundred years ago. Others believe that it dates back much further, possibly to the pre-Christian era.

The immense importance of the discovery at a time when the European population was thinly scattered over the present area we will appreciate when it is considered that the diamonds mined for 60 years were sold for about £300,000.000. Fundamentally the Industry's economic structure is based upon its gold production. The insistent demands by the industry for railways, roads, power, water, processed goods and food led to the exploration for, and the exploitation of natural resources on an unprecedented scale.

The base-mineral industry was inextricably bound up with this expansion, and as demands arose, it made strenuous efforts to meet them. The efforts were, however, handicapped by the inaccessibility of the widely scattered mineral deposits with the result that little could be done, other than prospecting, until the road and rail networks were extended.

The total value of mineral products to the end of 1957 was approximately £5,600,000,000. The importance of mineral exports was stressed by the Governor of the South African Reserve Bank in a review of the economic position.

He put the mining and manufacturing industries in the correct perspective when he stated: and I quote "As far as the relative position of the manufacturing and mining industries in the country's economy are concerned, it deserves to be pointed out that the importance of the mining industry cannot be judged solely by its direct net contribution to the national income. Thus, although it produced only about 18 per cent of the national income as compared with about 24 per cent in the case of the manufacturing industry, the mineral exports accounted for more than half, and gold alone for more than 40 per cent of the total exports of South African products." Close quote.

The best examples apart from steel and cement are the smelting of tin concentrates, the manufacture of ferro-alloys, electric cables and motors, the production of liquid fuel from coal and phosphates from apatite.

These are all major undertakings associated with the mining industry and contributing considerably to the rapid industrialization of the country in addition to exerting favorable influence on the balance of payments position. The total value of imports during 1957 was £550,000.000 compared with the export figure of £669,000,000. Individual export figures include: Gold. £217,000,000; mining machinery, £5,437.000; chromite. £3,545,000; lead concentrates (re-exports), £10.651.000: manganese ore. £5.676,000: fire refined and blister copper. £7,519,000: asbestos. £10.954,000; coal £1.440.000; diamonds (including re-exports), £30.683,000 and radio-active minerals. £49.989.000. Gold is responsible for the greater part of the value of the mineral production in South Africa.

Since the 70 years of the discovery of the Witwatersrand approximately 580 million ounces of gold valued at over £4,000 million have been extracted and income from gold mining has accounted for four-fifths of the mining Industries total receipts from mineral sales. The gold mines have proved to be of an enormous material benefit to South Africa and are largely responsible for the acceleration of the economic development of the country and the maintenance of its economy at a level undreamed of at the beginning of the century.

The production of uranium-oxide as a by-product of the gold mines is a factor of great importance both by virtue of its own sales and the added life which it provides for those mines which produce uranium. At the end of 1958 there were 23 mines producing uranium-oxide. More than 23 million tons of ore were treated to give 6,000 tons of uranium-oxide at a value of approximately £53 million.

By agreement between the South African Government and the Governments of the United Kingdom and the United States uranium-oxide will be sold to those countries over a period of 10 years. At the end of this contract period the uranium industry will be favorably placed to compete on the free market because the capital expenditure incurred in establishing the industry will have been redeemed and a commercial market will develop concurrently with a guaranteed market, which primarily supplies a military requirement following gold and uranium in order of importance on the basis of sales value are diamonds.

The first diamonds were discovered in 1867 on the Orange River near Hopetown followed by the discovery in 1871 of volcanic diamond-bearing pipes at Kimberley and at the Premier Diamond Mine at the turn of the century. The last important find was in 1927 on the coast of Namaqualand, where after the finding of stones by a number of people, a geologist, by scientific prospecting, discovered an ancient beach line which contained an exceedingly rich deposit of diamonds which were, a better quality finer than any hitherto found in South Africa. " Alluvial" diamonds occur in widely scattered areas in many other parts of Africa.

In contrast to the average, coal seams in the United Kingdom and on the Continent coal seams in South Africa are usually much thicker and occur at shallow depths making mining much easier and less expensive. The bulk of the output is consumed locally and with the expansion of the steel industry, electric power generating, mining and the oil from coal industry, the production for internal use will continue to expand. Proved and probable coal reserves exceed 80.000 million tons.

The establishment in South Africa of an industry for the manufacture of oil from coal can be regarded as the outcome of research which began in the country more than 30 years ago. Although in 1935 a South African company engaged in the distillation of torbernite or oil-shale, it was only in 1947 that the Liquid Fuel and Oil Act was passed and two years later a license was issued to start manufacturing oil from coal plant.

The South African Gas and Oil Corporation was established in 1950 and the rights to produce oil from coal were taken over by the Government. "Sasol", the world's largest oil from coal project came into operation in 1956.

In addition to petrol, 55 million gallons per year and diesel-oil, 6-5 million gallons, the plant also produced liquid petroleum gas, ethanol, propanol, butanol, acetone, aromatic solvents, creosote, road prime, pitch, crude phenols, paraffin wax, etc. Mineral rights have been acquired over an area of about 14,000 acres and it was estimated that of the 665 million tons of coal in situ more than 300 million tons are extractable.

The plant will eventually provide one-seventh of the normal annual petrol requirements. Historically, it is of interest to recall that the mining of copper by white people in 1852 marked the beginning of exploitation of the mineral deposits, although there is evidence of mining in the northern Transvaal, probably by the ancients. Mining continued down to the water-table where possibly due to the lack of pumping equipment work was suspended. At present Messina Copper Mine produces fire-refined copper of exceptional purity, in ingot form, and at O'okiep blister copper averaging 99.03 per cent copper is produced. Electrolytic copper and nickel are produced from the platinum matte in the Rustenburg district.

The first part of a £12 million manganese ore reduction plant at Cato Ridge, near Durban, which will produce high-carbon ferro-manganese, will go into production in the near future. Chrome-ore deposits in the Eastern and Western Transvaal are probably the largest in the world and will last for centuries. The reserves are estimated at 200 million tons.

An increasing amount of high-grade concentrates, 49 per cent Cr203 is becoming available, but the bulk of exports is made up of ore of medium grade, 45 per cent Cr203. This grade is considerably cheaper than the high-grade concentrates and consequently there has been a strong demand overseas. South Africa produces about half the chrome ore supplied by Commonwealth countries. In 1957, 767.000 tons of ore was mined at a value of £3.640,000. Iron ore was extensively mined by native tribes before the advent of the European.

The deposits at Prestwick, Natal, was known to Europeans as early as 1860, but until 1913 smelting was undertaken only sporadically. In that year, however, the Steel Works erected a plant at Vereeniging, using large accumulations of scrap as raw material, most of which was from railway depots. In 1918 a blast furnace started to produce pig iron at Pretoria and in 1928 the "South African Iron and Steel Industrial Corporation" known generally as Iscor was established by Act of Parliament. The first steel ingot was rolled in April 1934. Iron ore is widely distributed in South Africa and most deposits are easily accessible. Although the reserves of high-grade ore are not extensive, those of medium and lower grade ore are practically unlimited.

The bulk of production at present is from Thabazimbi in the Rustenburg district, where hard high-grade haematite containing plus 60 per cent is found. Fe with low phosphorus and Sulphur content is mined, and also from Sishen near Postmasburg.

Only the major minerals have been included in this survey. There are about 50 base minerals which are being produced which have not been mentioned, all of importance to its economy and some of importance in the export trade. No country in the world is self-sufficient where raw materials are concerned, but South Africa possesses such a variety and quantity of minerals that its own industrial expansion can be largely provided for, and at the same time, a flourishing export business can be maintained.

The Government exercises a certain amount of supervision over the mining industry. Laws have been framed to regulate the prospecting for, and the mining of minerals in the four provinces to regulate ownership and marketing of precious stones and to safeguard the health and lives of persons employed on the mines and works connected with mines. As is only natural in view of the large revenue which the state receives from the mining industry, the Government has from time to time afforded direct and indirect aid to the mining industry.

3.2. Threats of mining on the lives of the miners in South Africa

According to Stuckler, Steele, Lurie and Basu, (2013) the mining industry in South Africa is one of the most hazardous industries in which mineworkers are at a high risk of fatalities and diseases. The gold, coal, diamond, and uranium mines produce high levels of silica dust that causes occupational lung diseases such as silicosis among the miners. The workers that are working in the South African mines are exposed to the high levels of silica which causes ailments such as tuberculosis. As a result, about 3 thousand to 7 thousand workers in every 10 thousand individuals suffer from silicosis annually. The overall incidence of silicosis has been recorded to 981 cases of silicosis in every 10 thousand individuals in South Africa and 128 cases of silicosis in every 10 thousand individuals globally.

Lurie, M.N., Williams, B.G., Zuma Mkaya-Mwamburi, Garnett, Sturm, Sweat, Fittelsohn and Karim, (2003) examined that due to the high incidence of lung diseases among the mineworkers; they also suffered from circular transmitted disease (tuberculosis) (TB) and sexually transmitted disease (HIV). The main reason behind the spread of deadly diseases such as HIV and TB is the migration issues faced by mineworkers. Due to apartheid laws in the mining industry, the male workers are separated from their wives for longer durations which encourage them to have illicit sex with women who belong to mining communities, sex trading industry or women from rural regions.

HIV spread widely among the mineworkers as they generally used to live in shabby mine colonies far from their native rural place and families. As per the survey conducted by Deloitte, it was found that HIV spread among the one-third of the mineworkers within the first eighteen months of engaging in the mine works.

Harling G, Ehrlich R, Myer, (2008) examined that HIV increases the risks of active tuberculosis among the workers which further deteriorated their health conditions. Additionally, the places where the mineworkers live are dirty with improper ventilation and sanitation.

About 16 male workers are forced to stay in a single room with little space and distance between individuals. Under such conditions, the spread of active tuberculosis increases by 27% among the mineworkers that negatively impacts their good health conditions. Due to high risks of epidemiological and social factors, the South African mining industry accounts for 760 000 cases of TB in the country and known as the head or center that increases the spread of other diseases such as HIV/AIDS. The two main factors that cause the spread of occupation diseases such as silicosis and other two ailments such as HIV and TB among the mineworkers in South Africa.

The first factor included the migrant labor system which weakens the incentive systems that are provided by the mining company.

As a result, the cost of the mining industry to provide a dust-free working environment increases as the trained working staff migrates and the new workers takes time to adjust to the new working environment.

While comparing the working condition of the mining industry of South Africa, Australia, and North America, it was found that the North American and Australian mining operations do not face secondary issues like African mining operations because of the non-migrant nature of the workers. On the other hand, the South African mining operations include workers that come from Botswana, Lesotho, Mozambique, Swaziland, and Zimbabwe. The mineworkers that come from different countries can be trained easily and cost cheaper against retaining the old local workers.

Thus, the mining companies in South Africa promote migrant work culture to increase their profits without paying much heed to the spread of diseases because of it. The second factor which is responsible for the spread of occupation and other diseases among the mineworkers, is related to the occupational health compensation packages which are provided to the workers. As per the industry survey, it was found that the occupational health compensation that is given to the mineworkers is not sufficient because of which they could avail of proper treatment facilities. The cost of the unpaid occupation compensation amounts to US $2.9 billion which is to be given to the mineworkers and pending with the lawsuits. There is a huge amount of unclaimed benefits to be paid to silicosis and TB patients within the mining sector.

The South African mines are also known for high mortality rates because of inadequate working conditions at the mining sites. Consider for example, the death of 28 gold miners and missing several mineworkers could be recorded in the Columbia mining sites. The laborers that lost their lives and went missing belonged to poor families and continued working to earn a living. They ignored the safety warnings that were given by the government body regarding the erosion and dangerous condition of the mining site and fell prey to the landslide. de Andrade et al., (1995) examined that Brazil mining sites have been plagued with malaria since the 1980s. The condition of Amazonian gold mining was worst as is situated near the deforestation region which was the center of the mosquito breed colonies. As a result, the cases of malaria increased among the mineworkers working in the Amazonian gold mine and reached 600 000 infected cases within a year.

About 99% of cases of malaria infection were recorded in the Amazon Basin region (Brazil) and 50% of cases were recorded in the Americas. Additionally, a high incidence of bacterial and viral diseases was recorded among miners in Gabon, while, lung cancer diseases were recorded among mineworkers in Zimbabwe.

The suffering associated with carbon monoxide poisoning was experienced by mineworkers in Kenya and noise-induced hearing loss issues faced by miners in Ghana.

Additionally, the mineworkers in the Republic of South Africa (RSA) which is known as the world’s largest gold manufacturer suffered from occupational mining health-related ailments such as cancer and lung diseases.

Bertherat et al., (1999) examined that the mineworkers working in the 5 gold mining operations in the rural settings of northeastern Gabon were infected by the Ebola virus and leptospirosis.

It caused hemorrhagic fever to most of the mineworkers and the rural populations. As per the village survey, it was recorded that 15.7 % of the individuals in Gabon suffered from leptospirosis in which 14.7% of individuals were mineworkers and 0% were fishermen.

The survey revealed that there was a 10.2% spread of the Ebola virus in Gabon in which 11.3% of individuals were miners and 25.0% were fishermen. Thus, it can be said that the lives of the mineworkers in Africa were in poor conditions as they suffered from ailments and were not provided with proper treatment or occupation compensation package.

Amedofu et al., (1996) examined that the other issues such as noise pollution and hearing loss issues are also faced by the mineworkers in South Africa. There are no regulations related to noise pollution in developing countries like South Africa. The gold mining companies in Ghana also did not pay heed to the noise pollution generated by it. It negatively impacted the health conditions of the workers that are working in gold mines as they are forced to work in high noise pollution conditions.

Thus, due to working under improper work practices such as loud noise, 20% of the mineworkers faced noise-induced hearing loss issues. It included 34% of individuals that worked as mine laborers, 20% of individuals that worked as equipment operators, and 0% of individuals that worked as office workers.

Boffetta et al., (1994) examined that the mineworkers that were working in Zimbabwe suffered from lung cancer as they were highly exposed to harmful substances such as arsenic and silica dust. Additionally, an example of mineworker fatalities could be recorded in the mining industry in Kenya. Due to high exposure to carbon monoxide, 7 mineworkers died because of suffocation in the year 1980.

Butchart, (1996) examined that the gold mining companies in Republic of South Africa (RSA) employed 200 000 migrant workers in the year 1920, which increased to 427 000 workers in the year 1988 and reached 500 000 in the year 1999. The workers worked under vulnerable conditions by reaching depths of 3500m beneath the earth. The majority of workers that were employed in the mining sector belonged to countries like Angola, Botswana, Zambia, Mozambique, and Zimbabwe. The working conditions in the gold mines were poor with no proper accommodation, medical, education, training, or recreation services. As a result, most of the workers suffered from ailments such as parasitic infections, tuberculosis, misery, death, injury, and pneumonia.

Thus, it can be said that the conditions of mineworkers in South Africa have been high and that the mining companies did not provide them with any growth opportunities.

The separation of mining activities with the dust is impossible as mining processes such as digging, and extraction could not be executed without producing any dust. There is a generation of dust during the crushing and extraction process in which silicate particles mix with and pollutes the atmosphere. When the polluted air is inhaled by the mineworkers, they fall ill and cause serious health implications.

Moreover, the miners are required to work underground with small openings that do not allow proper conduction of the respiration process. As a result, by performing high-risk mining tasks for longer duration many mineworkers develop respiratory health issues.

Additionally, there is no age limit to the inclusion of workers in the mining industry in Africa. The industry employs young (12-year-old boys and girls) and old individuals for different mining purposes such as ore crushing and panning. The workers that are working in the mining industry are not provided with proper protective gear, clothing, masks, or gloves which increase the risk of inhalation of silica dust in large quantities by the workers. It negatively impacts their good health conditions and causes serious health hazards to the young and old mineworkers.

Mossman, (1993) examined that exposure to silica creates chronic or nodular silicosis among the mineworkers which if not addressed properly results in respiratory and heart failure. The symptoms of acute silicosis are also found among the mineworkers when they are exposed to high frequencies of silica dust on a regular basis. Due to high exposure to silica dust, the internal linings of the airways are damaged and there is deposition of heavy metals in the lungs which makes lungs heavier and finally causes lung failure and death of the miner. The symptoms of accelerated silicosis are also found among the mine workers in South African mining industry. The symptoms increase in the miners when they are exposed to silica dust for more than 5 to 10 years. It causes lung diseases in which the miners complain of breathlessness and pain in the stomach.

If the symptoms of the accelerated silicosis are not treated appropriately, the miners suffer from cardiopulmonary failure and death in the final stages.

Harada (1997) examined that exposure to high levels of mercury also causes harmful effects to health conditions of the workers. If the mercury intake is increased in the body, it damages the central nervous system of the body. It causes feebleness, loss of hearing, loss of eyesight, loss of balance, and tiredness among the miners. Some of the miners suffer from the symptoms of numbness, loss of smell, loss of tastes, ringing in ears, and forgetfulness issues. On the other hand, the consumption of lead contaminated air, water and dust causes the mineworkers to suffer from poor health conditions. The consumption of even low levels of lead is dangerous as it adversely impacts the nervous system of the body. If it is consumed by expecting women mineworkers, the infant in the fetus of mother may also get damaged and born with disabilities and low IQ.

Uitto (1992) examined the condition of mineworkers that were working in mining companies in Migori district, Kenya. It was found that the working conditions of the miners were highly deteriorating as most of them highly consumed contaminated waters of Kuja and Migori rivers. The miners are also forced to drink waters from the contaminated waterlogged pits that act as breeding grounds for mosquitoes.

As a result, the mineworkers are prone to several diseases such as malaria, tuberculosis and lung diseases which cause high rates of mortalities among the mineworkers.

3.3. Digital technology (robotics) in the mining industry in South Africa

The mines in South Africa are some of the deepest and narrowest in the world. The mines are spread in the slender and tabular form which increases high risk to the workings of the miners and operators.

For example, due to presence of narrow steeps, long trials, cramped working sites, high temperature, dampness and high involvement of labor force, the working conditions of the mining industry are highly vulnerable and risky. It causes accidents and large number of fatalities to the mineworkers and equipment operators. Therefore, it is essential to introduce safety measures in the mining sector so that the fatality rates in the industry are reduced.

This included introducing Tripartite Action Plan on Health and Safety by the South African mining leaders so that global standards of mining are implemented in the industry that provides growth to all the types of mining operations (gold, diamond, coal, and uranium) in South Africa. The introduction of advanced technologies such as robotics in the mining industry will help to improve the workings of the mines and conditions of workers in South Africa.

The adoption of new technologies will help in establishing linkages between the human and machines which helps the miners to carry out mining activity more proficiently.

Harper, (2008) examined that the adoption of new technologies in the mining industry helps in extracting all the supplementary layers of rocks along with the desired layers so that gold could be extracted precisely. It includes cutting out the thickened reefs into smaller rocks which increases the efficacy of gold mines at low cost. Additionally, if the conception such as Nederburg miner is included in the mining process, the extraction of minerals from narrower reefs would become easy. van der Merwe, (2011) examined that the mines that are operating in South Africa indicate the possibilities of introducing deeper mining implementations in the future.

Under such conditions the use of advanced technologies such as robotics into the mining process will help in enhancing the efficacy of the mining operations by analyzing increasing cost and risks factors.

Robotic technology that is used in South African mining industry is largely based on Nederburg miner concept.

When the robots are designed and operated as per the directives provided by Nederburg miner, it provides benefits to the mining industry in terms of productivity, safe working environment and reducing cost. This robotics includes establishing association between human and machines through developing systems such as the South African Space Resources Association (SASRA). It is a system that helps in establishing communication and transmitting information between the involved parties through space mining industry. Innovations and developments in the robotics have given rise to the developments such as space mining robots.

The application of space mining robots facilitates the working of the mining industry by establishing coordination with the different systems of operation such as digging, breaking rocks, and excavation. The robotics technology provides real-time information about the activities that are taking place at the working sites and underground mines.

The implementation of robotics into the workings of the mining industry in South Africa facilitates the working of engineering students that are associated with NASA Lunabotics.

The engineering students are engaged in the development of capable robots that have the ability to enhance the working of the mining industry in a cost-effective manner. It provides opportunity to the students to compete with each other and develop best models that can be used in the mining industry to increase the mining productivity levels. One of the major achievements of the engineering students of NASA Lunabotics, is the development of innovative products under the 'Mobile Robot Competition'. As per NASA Lunabotics, the researchers are in the research and development process of a system or robot that would help in the cleaning and mucking of the gold mine. The introduction of such robotic technology will not only enhance the working of the mining industry but also enhance each production level.

The scholars and developers in South Africa have developed a working base known as International Lunar Research Park (ILRP) that functions as the replica of robotic lunar base. It promotes mining processes through robotic lunar base so that efficiency of the deep seeded narrow gold mines could be conducted effectively.

Green, J., & Plumb, S. (2011) examined that the developers in South Africa mining sector are working towards developing SANSA technologies through which the mining activities could be enhanced to optimized levels. However, the process is in the developing stage and needs in-depth study and analysis before implementing into mining applications. The use of robotics in the mining industry will allow the miner to improve the efficacy of mining by streamlining the entire work procedure. It will also help in improving the safety aspects of both underground and open mining operations and enhance the competitiveness of the companies. The use of robotics will allow the miners to reach to the narrowest mining destinations and extract minerals from the contracted sites effectively. The gold and platinum mines in South Africa exhibit similar characteristics such as narrowness (5 cm to 1.5 cm) and reaching to the depths of the earth with varying temperatures of 12 degrees to 30 degrees.

When the minerals are present at such depths at temperatures below the ground, it creates issues for the mineworkers to move underground and extract valuable minerals from such depths. Additionally, at such deep depths, varying temperatures of up to 50 degree Celsius, and humidity of up to 100%, the miners face the risks of rocks bursts and collapses. The robotic technology has the ability to identify reserves and extend the mining operations to the new sites by using safe and cost-effective means.

The robotics include the use of remote sensing application that helps automating the transport vehicles, conducting reef grading activities, and accessibility to extreme depths below the earth's surface.

While considering the mining industry in South Africa, different organizations such as Anglo American and Carnegie Mellon University have collaborated and working together develop more features of robotic application in the mining field. It includes the active involvement of Council for Scientific and Industrial Research (CSIR) who is also undertaking investigative activities towards the deployment of robotics in the mining sector.

The other research and development organization such as Mobile Intelligent Autonomous Systems Field Robotics Group is also actively involved in the field of research and investigation to develop a prototype model of robotics so that safe mining practices could be implemented appropriately.

Robotic application in the mining industry enhanced the production process by making effective use of Differential Global Positioning system (DGPS). It also includes the use of machine vision methods that provides high quality production in reduced time and safely. The robotic application includes the use of XBOX Kinect Data Set technology cost effectively. It includes the use of sensors that helps in mapping the indoor information at the underground mining site. Robotics includes Kinect technology that uses highly efficient IR projectors and cameras to capture the images of the mining conditions in the deep mining settings. It performs 3D scanning activity that provides exact and precise information about the internal mining environment remotely. It helps the mine operators and supervisors to take rightful decisions related to digging, extraction and excavation successfully.

The Mining industry is one of the riskiest industries in which the robotics technology helps in mine rescue process. It includes the use of robotics in different forms such as Unmanned Ground Vehicles (UGVs) which is applied on the examination of ground surface so that the information related to entrapped miners and victims are identified easily. UGVs venture into the dangerous and narrow mining stopes and rescue the mineworkers from critical conditions. On the other hand, Unmanned Surface Vehicles (USVs) is another type of robotic application that is placed on the surface of water.

The device helps the supervisors and the rescue teams to investigate if any mineworker is blocked under water and suggest the right equipment through which rescue could be provided to the victim. Unmanned Underwater Vehicles (UUVs) is also effectively used in the mining industry to save the lives of miners that are entrapped under water.

The device searches through the water surface and provides valuable information related to fatalities and materials beneath water surface. Unmanned Aerial Vehicles (UAVs) are specially designed robotic applications that work in both ground and air and help in transferring medical supplies to the sufferers at the time of crises.

Additionally, Sub-terranean Robot (SR) is also used in the mining industry which includes mobile technologies, camera, and motors to detect possible hazards at the mining sites. It helps in inspecting and mapping the mining site to ensure that there are no victims in the destroyed surroundings. It facilitates the rescue process by providing live video streaming facilities and rescue personnel assess systems.

Thus, it can be said that robotic technology is highly helpful for the mining industry as it helps in ensuring safety, providing rescue, and enhancing productivity.

There are certain challenges such as localization without GPS, swarming, data communication, and power related to the adoption of robotics in the South African mining industry. While focusing on the localization without GPS challenge, it included that localization is an essential requirement for the robotic application to work proficiently and establish coordination between the operations.

While considering the earth surface, the localization activities are carried out by using GPS systems. However, when the mining activities are performed beneath the earth surface, the GPS systems do not function. As a result, the robotic applications that are based on the GPS system of localization do not work beneath the earth's surface.

As per the philosophies and guidelines provided by Nederburg Miner, the technologies that are to be introduced in the mining industry must be innovative and small. It noted that the size of robots be about less than 50 stopes and must not be heavy loaded. Thus, it often becomes difficult for the research and development (R&D) technicians to develop robots based on Nederburg Miner guidelines. Additionally, as per Nederburg Miner, the structure and frame of the robot must be such that it improvises the human structure and feasible to go anywhere. It includes handling of robots remotely and working autonomously so that coordination is established between the different mining operations.

When the construction of robots is made as per Nederburg Miner, there is creation of small robots which specializes in particular functionary. Thus, there must be construction of several robots each specialized in a specific functionary so that all the robots work together. It will help in developing synchronization between the different mining activities with the help of intelligent systems and logistics. It also establishes interaction between the agents so that work is carried out collaboratively and concisely.

However, the major challenge that is faced with the use of robots is related to the breaking down of rocks. Due to small size of the robots, it becomes difficult for the robots to break the rock or carry out long drilling processes for long hours. The other limitation with the use of robots in the mining sector is the use of battery technology in the working of robots.

The mining robots could not provide power through wires and cables as it would distract the miners form working during underground mining process. Thus, the dependency on the battery power capacity of the robots increases which imposes limitations in its application in the mining industry. The robotic technology that is used by the mining industry in South Africa is AziSA which helps in collection of information from the different mining operations. However, AziSA has limited access and designed for environments that work with restricted power and limited communication facilities.

Thus, due to such limitations, there is gap in the effective utilization of robots and requires more research and development activities to enhance its capabilities.

3.4. Negative and positive impacts of recruiting advanced technologies in the mining industry in South Africa.

Mining is a high-risk industry in which the miners are required to work skillfully to accomplish the tasks error-free. The mining activities include different tasks such as digging, evacuation, tunneling, and extracting. The production of different mining activities is not easy and many a time risky which results in accidents and fatalities.

The rate of mine fatalities in the South African mines has been on the rise over the last 10 years. As per the survey conducted by the Chamber of Mines, it was found that there have been 82 fatalities in the Harmony Gold Mining Co, at its Tshepong Mining center in the year 2017. The fatality figure recorded by the mine was the highest in the last 10 years. On the other hand, 73 fatalities of mineworkers were recorded in the year 2016 which is the lowest in the last 10 years. Thus, it has become essential to introduce technological advancements so that the fatalities and deaths that are occurring in the mining sector could be reduced. Scholars of the nations like South Africa, the United States, and China are researching and investigating the possibilities of introducing advanced technologies such as Virtual reality in the mining sector.

Virtual reality (VR) based advanced technologies are included in the mining industry in South Africa to improve the working of the mining industry. For example, the VR application includes implementing VR based engines, VR software, VR input, and output devices, VR databases, and tasks. The VR input devices include two types of processes which are manual and automatic. The manual process includes the use of technical devices such as a mouse, keyboard, and joystick which are difficult for the miners to learn and use.

Thus, even though based on mature technology, because non-technical skills among the miners, the system could not produce outcomes appropriately. On the other hand, the automatic VR systems include devices such as IR sensors, gyroscope, microphone, camera, accelerometer, and magnetic sensors that adequately track the mining operations.

The VR based mining equipment has to sense abilities such as visual, auditory, smell, touch, and taste and takes charge of 70%, 20%, 5%, 4%, and 1% sensing abilities of the mine workers respectively.

The application of VR training systems such as Screen-based general VR training systems, Projector-based customized VR training systems, and HMD-based intuitive VR training systems highly benefitted the mining industry by developing standardized production and security systems. For example, the application of a Projector-based customized VR training system includes the use of visual sensors and projectors that provide a live demo of the work that is executed at the mining sites. It helps the supervisors and managers to monitor the activities of miners and provide with support or instruction in real-time. The application of an HMD-based intuitive VR training system also benefitted the miners and mine supervisors by providing them a well-coordinated and synchronized working system.

It is because the HMD-based intuitive VR training system helps the miners to interact with the managers through virtual communication and equipment. As a result, there is a movement of information between miners and supervisors in real-time.

It enables the miners to provide real-time information to the managers who guide them appropriately. Thus, it can be said that the use of VR technology in the mining sector increases the productivity levels as the miners are properly guided and communicated about their work.

Advanced technologies like robotics are also used in the mining industry to improve the working condition at the mining sites, rescue workers, and limit the exposure of miners to hazardous working conditions. Robotic vehicle surveys the mine and provides ground information to the mine supervisors. It helps the technicians and managers to plan and execute search rescue operations during emergency evacuations effectively. The robots are highly beneficial in performing risky mining tasks such as laying out explosives and to go down underground or open mining sites which are difficult for humans to enter and access. For example, robotic systems are used in open cast mines to enhance productivity levels and maintain safety at the worksite. The wide application of robotics is executed in machinery automation in the case of the open mining process. It performs complicated mining tasks, carries out controlled caving activities, and burrow machines in flooded gravels which are inaccessible by mineworkers. As a result, robotic applications enhance the working of open mining by providing robotic rock drilling rigs, robotic assistants, and driverless locomotives.

The mines in South Africa are deep and have high inclines which becomes difficult for the mineworkers to reach the mineral source and to extract it properly. The robots or co-robots that are developed by the Council for Scientific and Industrial Research (CSIR) will help to resolve the issue by providing innovative robotic solutions. The use of robotic technology in the South African mining industry will help in meeting challenges that are faced by miners while working in flooded mines.

The robots such as UNEXMin are loaded with different advanced devices like acoustic cameras, laser cameras, computers, Sound Navigation and Ranging (SONAR) devices, and rechargeable batteries that make it efficient to be used in the regions where human reach is difficult. CSIR is closely working with manufacturers and mining companies in South Africa to understand their mining challenges to provide solutions through innovative developments. The miners reported that the fall-of rocks are the major issues faced by them while carrying out mining activities.

The fall-of rock incident occurs instantly and causes a high number of fatalities in the mines. The use of robots at mines will help in the identification of loose or hanging rocks and reduce the occurrence of fatalities. Thus, it can be said that the use of technologies such as robots helps in ensuring safety by examining the site, developing underground communications, and providing mechanized drill and blast services that increase the productivity and safety at a mining site.

Technology such as the Internet of Things (IoT) is also used in the mining industry to enhance productivity levels and reduce costs by eliminating waste and machinery failure. The IoT application provides reliable information about the digging and extraction before the actual process is initiated. It helps in managing the digging process and reducing risks associated with extraction. For example, automated and driverless vehicles based on IoT technologies are used by mining operations so that optimized productivity is attained without human intervention.

It allows the mining operations to operate any time, extract, and process the minerals in the short duration that saves time and cost of human labor.

For example, RFID based Thembekile Asset Management Solutions (TAMS) systems are used by mining companies like Anglo American and Canyon Coal to enhance the IoT based application in their mining sites. TAMS collect real-time data and report the same to the authorized supervisors through fixed or mobile devices and provide customized solutions that enhance business intelligence. The IoT application also improves safety, promotes the use of other innovative applications, and reduces maintenance costs by developing an integrated and transparent system of work.

The use of IoT applications in the South African mining industry helps in estimating and monitoring the inventories. The mining operations in the South Africa mining industry are expensive and in the current pandemic (Covid-19) conditions, the use of labor has become more risky and costly than before. The use of IoT technologies will enhance the under-performing mining operations, enhance efficacy, and lower input costs by implementing IoT based solutions. For example, IoT technology could be used to monitor the working of robots, provide accurate information related to robot breakdown, and save the mining operations from machinery failure losses. Thus, the IoT will support the South African mining industry to kick-start its manufacturing process after the pandemic with few laborers and technology-based systems such as cloud networks, robots, and IoT devices. It will benefit the mining industry in terms of increased production, energy-efficient, water preservation, predictive maintenance, process automation, improved safety, and reduced time latency.

The use of automation technologies also improves the working of the mining industry. Automation is referred to as the process in which the human activity is replaced (partially or completely) in physical or mental form by the machines.

Madhavan, (2001) examined that automation technology is an amalgamation of several technologies and advanced devices. It includes communication technology, sensing technology, system processes, navigation, and imaging technology.

Lynas and Horberry, (2011a) examined that automation technology is applied in the mining industry in different phases such as supervision, control, and automatic systems to reduce human dealings in the risky mining tasks. Automation technology adoption in mining provides access to reliable information remotely with the help of tele-remote systems that help to provide instructions and guidance to mineworkers remotely.

Murphy, (2011) examined that the use of autonomous and remote-based applications in the mining industry provides it with a wide range of applications and benefits. For example, automated driverless vehicles remove variability and idling time which increases the mining efficacy levels. Moreover, automated machines make proper use of resources that saves fuel and reduces wastes. The other costs that are caused because of physical damage by human drivers like collision are avoided by the automated machines that increase the productivity and safety levels at the workplace.

Due to increased benefits provided by automated machines, its usability has increased in the mining industry.

As per the survey conducted by Statista, 2017, it was found that the use of automated devices in the metal and mining industry provided increased benefits to the sector since 2016. It is expected that the use of automated technology will reach 47 billion US dollars globally by the year 2025 and add value to the metal and mining industries globally.

The use of automated systems is in high demand in the mining industry in South Africa as it provides controlled systems, advanced mining technologies, and machine guidance. The use of an automated system helps in carrying out remote monitoring and equipment control activities. It includes automation of blasting, drilling, and transit activities so that tasks are performed accurately and safely. Automated systems enhance safety mechanisms by removing personnel from dangerous environments and placing them at a safe distance. Additionally, the use of sensor-based sorting and driverless vehicles and data analysis systems help in sorting issues related to navigation, identifying mineral resources, and separating/sorting minerals through advanced hydraulic means. Thus, it can be said that the use of automated technologies is highly beneficial for the South African mines as it helps in enhancing the efficacy levels at reduced costs.

The testing of automated mining trucks has been completed by Cisco which will be used in opencast coal mines in South Africa.

The working of mineworkers at the coal sites is not easy as they are required to transport hundred tons of loads at the mine site. It endangers the lives of the drivers as they could not control heavy vehicles and cause accidents.

The use of automated mining trucks developed by Cisco will help the coal miners to transport the heavy loads of material across the site safely. The automated trucks are loaded with connected and secured systems that will help to keep track of the workings of the trucks and provide the users to stop and movement as per usability remotely.

As a result, the work safety aspects in the coal mines in South Africa will improve which will enhance the productivity and profitability levels of the mining companies. Thus, it can be said that the use of different technologies such as robotics, internet of things, virtual reality, and automated devices are highly beneficial as they increase the safety and productivity levels at the mining sites in South Africa.

Along with the positive implications of the use of technology in the mining industry, there are some negative implications also. For example, the use of technological innovations such as automated devices in the mining industry reduces the use or deployment of labor. It negatively impacts the economy of the country by reducing the employment opportunities and lowering the Gross Domestic Product by at least 4%. The high penetration of technology into the workings of the mining industry will not only disturb the local procurement processes but also reduce their functionaries to a minimum. Though the use of technology in the mining industry will increase productivity, enhance mine safety, and reduce the cost of production, it will however create employment challenges in South Africa. For example, due to the use of automated vehicles or driverless vehicles, there will be no use of truck drivers and they will lose their jobs. As a result, there will be an increase in the unemployment of unskilled laborers in the mining sector in South Africa.

It will put a strain on the South African government to provide employment to the increased number of jobless workers in the mining sector and to provide them with proper income and earnings.

The adoption of technology in the mining sector involves huge cost. The introduction of technology-based devices in the mining sites incurs huge costs related to research and development (R&D). It increases the initial cost of the mining companies and reduces its profit earnings. For example, the mine operator is required to provide productivity and performance reports to the officials including technology costs and expenditure. It impacts the net present value (NPV) negatively and increases capital expenditure (CAPEX) on R&D activities.

It reduces the profitability levels and hampers the position of the mining companies in the local and globalized competitive markets. Nebot, (2007) examined that the use of technology-based devices and equipment are not easy and require skilled laborers to use and implement their functionaries. However, most of the workers or miners that are working in the mining industry are either unskilled or partially skilled. The miners lack the ability or competency to use technology-based devices effectively.

As a result, the technological devices are not utilized to their full capacity that adversely impacts the productivity levels. Hence, to enhance the efficacy and abilities of miners to use the technology-driven equipment, the mineworkers must be provided with training and education which increases the costs of the mining companies.

Matysek, and Fisher (2016) examined that the execution, upgrading, and installing of technology-based devices; software or hardware is a complicated process and requires expertise or technical skills to carry out the implementation process.

Moreover, the adoption of new technologies also requires upgrading, modifying, or changing the entire or partial legacy operating system. For example, the installing of virtual reality technology-based devices includes the use of modern modems, internet connectivity, sensor installing, and computing devices.

It increases the cost of the mining companies in terms of technology adoption and reduces the profit earnings significantly. The use of digital and advanced technologies such as automation and the internet of things creates cybersecurity threats and risks in the mining industry. Due to increased technology adoption in the mining sector, the South African mining industry may face issues related to cybercrimes and threats. The mining sector is a highly competitive industry and under such conditions losing confidential information to the cybercriminals may cost the mining companies adversely.

The mineral products and metals that are produced by the mining sector of South Africa account for 21% and 12% of the $111billion exports respectively. If the confidential information that is availed by the mining companies is tracked and misused by the cybercriminals, it will result in big loses to the South African mining export business. Thus, it can be said that due to challenges like the high cost of implementation, increasing unemployment, training cost, and cybersecurity threats the adoption of technology could impact the South African mining industry productivity negatively.

3.5. Methods to reduce the environmental problems related to mining

Mining is an important commercial activity that highly contributes to economic development in South Africa. However, due to the mining process, there are negative environmental implications that are degrading the soil, air, and water in South Africa.

Agyapong (1998) examined that the ecological responsiveness is commonly low among the mineworkers and the mining operations that lay less or no emphasis on the preservation or conservation of the environment. For instance, there are several technology-based methods such as the end of pipe techniques or Mercury Capture System (MCS) that can be used to reduce the emission of toxic mercury by 90% while extracting minerals from the gold mines. However, only a few mines adopt the technology to reduce the toxic mercury extraction in the mining industry in South Africa. The absence of stringent environment safety-related regulations also deters the mines from using environment-friendly mining techniques.

The legislation related to environmental security and safety is still at the infancy stage in South Africa which creates issues in the adoption of adequate environment protection laws while performing mining activities by the miners.

For example, many a time, the mines leave the excavated lands open of which there is large scale erosion of groundwater, rain, and wind.

Tráore (1994) examined that when mining processes are carried out by mines in South Africa, there is a creation of noise pollution, erosion of river, and sedimentation. There is a high accumulation of toxic mercury which pollutes the natural surroundings and negatively impacts the health conditions of birds, animals, and humans.

Hollaway, (1997) examined the high accumulation of mercury causes land degradation and environmental stress. For example, due to improper mining practices in the Liptako-Gourma region, Burkina Faso, the quality of land deteriorated. It negatively impacts the cultivation of produce in the region and reduces the yield to minimum levels.

On the other hand, due to degrading land in the Ghana mining region, 15000 hectares of land has been stripped of the vegetation propensities.

Due to improper mining practices, the topsoil of the land is eroded which makes the soil infertile and unfit for cultivation. As a result, there is an increasing pressure on the farmers and cultivators to identify new sources for the cultivation of crops and restore watercourses.

Maponga & Anderson, (1995) examined that due to improper mining in Zimbabwe, deforestation, water pollution, and acid mine drainage have increased in the region.

Shoko, Maviya, and Bachs (1993) examined that 64% of the gold mines in Zimbabwe do not adopt proper means of mining and exhibit poor chemical management practices. It gives rise to the contamination of natural resources and degrades the condition of natural surroundings.

Maponga (1997) examined that there is a lack of adequate sanitary facilities at mining working site. As a result, 98% of the miners are forced to use shallow pits for defecation, and 32% of the miners have to use unused mine pits for drinking water purposes.

Thus, due to improper sanitary provisions, the river basins get polluted which leads to habitat loss to animals. Therefore, it is essential, that these governments must intervene and introduce mitigating strategies to reduce the negative implications of the mining industry on the environment.

Nöetstaller, (1994) examined that to reduce the negative impact of mining on the environment; necessary modifications are to be introduced in the regulatory system of South Africa. It includes stopping illegal mining activities and introducing registration and compulsory licensing procedures. It will increase the responsibility of the mines to use standard methods for the mining process by ensuring that less or no damage is caused to the environment.

For example, in Ghana, the miners are not allowed to work without registration. The registered miners are required to produce voluntary feedback to the governing authority stating the methodology, technology, and environmentally friendly measure production techniques adopted by them.

If the miners do not follow the directives that are provided by the governing authorities, the officials possess the right to cancel the registration of the mining company and penalize them for the destruction caused to the environment.

de Nava, (1996) examined that the governing body in South Africa have introduced new licensing procedures in the country according which the mining companies is required to include environment-friendly technology and methods so that ecological conservation and mining production activities are performed simultaneously.

Bugnosen, Twigg, & Scott, (1999) examined that the South African governing body has introduced a regulatory strategy based on environmental issue in countries like Zambia, Zimbabwe, Ghana, and Ethiopia. As per the regulation of the Government, the mining companies in Zambia, Ghana, Zimbabwe, and Ethiopia are required to execute the instructions that are provided under generic mining legislation.

For example, the Mining (Alluvial Gold) (Public Stream) Regulations have been imposed in Zimbabwe to regulate the working of gold mines in the country. As per the Regulation, the gold mining companies are not allowed to conduct mining activities near the riverbanks. There are restrictions related to undercutting and pitting in riverbeds after 1.5 meters of depth. Hilson, (2000) examined that environmental impact assessment (EIA) measures have been included by the governing body in South Africa to protect the natural environment from mining ill-effects.

EIA evaluates the performance of technologies and analyzes the leaching processes that are implemented by the mining operations. Additionally, the Environmental Protection Agency Act of 1994 has been introduced that provides directives to the small-scale mining operations regarding the execution of environment-friendly ways of production in mining.

Iddirisu & Tsikata, (1998) examined that provision of support services by establishing national and international agencies will help in reducing the environmental ill-effects caused because of mining.

For example, seven District support centers have been established in Ghana to provide support and assistance to the mining companies in Ghana. Shamva Mining Centre has been established in Zimbabwe to support the mines and resolve the issues faced by them while performing environment-friendly mining practices.

Walsh (1999) examined that the involvement of universities and colleges in the mining industry will help in promoting ecological awareness. It includes initiating environmental-friendly mining programs through which the learners will be instructed about the application of environmental-friendly mining techniques. For example, the School of Mines in Bulawayo in Zimbabwe has introduced undergraduate courses and training modules through which the future mining employees, associates, or workers are taught to use environmental-friendly mining techniques.

The introduction of environmental-friendly mining programs in the South African universities will help to strengthen the base of the workers so that they would deploy the training and learning instructions in real-life mining working conditions.

It will help in large scale implementation of environmental-friendly mining techniques and conservation of natural surroundings.

Hollaway, (1993) examined that introduction of advanced technology and provision of training to the workers will also help in reducing the ill-effects of mining on the environment. For example, the use of advanced technologies like robotics, internet of things, and automation will help to reduce improper mining practices.

The technology will systemize the entire production process that will ensure to optimize the utilization of resources and the elimination of wastes. Hosford, (1993) examined that there is widespread illiteracy in the mining industry in South Africa.

Additionally, lack of (education and training) illiteracy rates account for 36%, 15%, and 32% of mines in Ghana, Zimbabwe, and Tanzania respectively which sums up to 44% in the whole of Africa. Therefore, it is essential to introduce the appropriate training and education program for the miners so that their skills and competencies will be increased. It will help the miners to use their skills appropriately and perform mining activities by using environmental-friendly mining techniques.

The mines in South Africa have established autonomous acid mine drainage treatment plants so that harmful effects of acid mine drainage could be reduced. For example, Western Areas Gold Mine has introduced the GYP-CIX process to control the acid mine drainage negative implications. Mining laws such as South Africa Minerals and Mining Act (MMA) - Act 703 of 2006 has been introduced by the Governing body of South Africa so that the illegal mining practices are reduced in the country.

Additionally, reforms have been brought in the workings and earnings of Artisans and small-scale mining (ASM) workers so that their living conditions get improved. For example, the ASM laborers that are working in Tanzania mines are provided with 10 times more salaries in comparison to the farmers.

The high earning propensities by the mineworkers enable them to improve their living standards and health status. The ‘Action Plan’ initiative has been introduced by the South African Government by considering the African Mining Vision and tailored the policies in such a way that it provides benefits to both the mining as well as the environment sustenance practices.

The ‘Action Plan’ includes regularizing the sub-mining operations that are working in the mining sector, recognizing and implementing the best practices through which the ecological administration code of practice could be implemented. The adoption of all these strategies such as stringent regulative measures, support centers, educative plans, and ‘Action Plan’ will help to improve the mining process and safeguard the environment from its ill-effects.

3.6. Methods that will help in building a sustainable economy in South Africa

The sustainable role of mining industry towards the economic development in South Africa is still under scrutiny. The mining industry in South Africa has been criticized for unlawful mining practices, causing harm to the environment and poor working conditions of the mineworkers.

Therefore, it is essential to introduce corporate social responsibility (CSR) practices into the workings of the mining industry so that it could contribute towards sustainable economic development. Hamann et al, (2000) examined that the CSR activities include implementing corporate citizenship attributes through which the positive aspects of mining are optimized, and negative aspects are reduced.

It promotes the mining production process, reduces adverse environmental aspects, and helps in maintaining profits of the organization.

O'Riordan et al, (2000) examined that CSR helps in meeting the needs and demands of all the stakeholders such as shareholders, clients, customers, suppliers, common public, and associated communities. Thus, by adopting CSR, the mining companies in South Africa will be able to provide integrated, self-sustained, and uniform social-economic growth in the country.

Pinney (2001) examined that the adoption of CSR agenda into the business planning by the mining companies will provide a constructive change towards the sustainable development process.

CSR helps to meet both civil society and commercial aspects of the companies. It induces philanthropy and mitigation approaches by including the participation of Non-Profit Organizations (NGOs). NGOs play a significant role in establishing a balance between corporate commercial activities and community development activities. The mining industry in South Africa is known to be one of the most destructive industries and CSR initiatives performed by the mining companies helps in eliminating the socially destructive image of the industry.

Due to the adoption of CSR, the mining companies were able to establish themselves in the international markets. It helped the mining companies to improve its image and enlist itself in the global stock markets such as the London Stock Exchange. Moreover, to maintain its position and stand in the international market, the companies ensured that it performed CSR activities systematically and regularly so that more investors are attracted to the company.

For example, Sibanye-Stillwater which is one of the mining houses in South Africa has adopted high standards of CSR practices. It includes adopting principles of government practices, ethical conduct, and performing work by using CARE values (loyalty, responsibility, admiration, enabling, and wellbeing).

The company has also introduced mitigating measures such as water footprint management, environment footprint administration, and risks administration so that the commercial business activities, welfare worker, and environmental protection initiatives are introduced simultaneously. Thus, by promoting adequate CSR activities, the mining company contributes towards sustainable development in South Africa.

The introduction of company and community development policies such as the Global Environment Facility (GEF) along with the Africa Mining Vision (AMV) will help in promoting sustainable development in the country. The policy highlights the use of partnership strategies so that the collaborative efforts of the mining companies will reduce the ill-effects of the mining industry.

For example, the "El Dorado" project has been introduced by the governing body of Guyana to enhance the working of the mining industry. It includes the 2013 Minamata Convention on Mercury initiative according to which the use of mercury that is produced by the gold mines is reduced to a minimum.

Additionally, to move ahead in the path of sustainable development, the South African mines are adopting partnership policies with other mining companies of countries like the Philippines, Mongolia, Peru, and Kenya under the GOLD Program. The establishment of the partnership includes the active involvement of the UN Industrial Development Organization (UNIDO) and the UN Development Programme (UNDP) so that uniform trade practices are adopted by the participating companies.

The South African mining industry also adopted cleaner production (CP) and Environmental management accounting (EMA) to promote sustainable development practices. The mining industry in South Africa highly contributes towards exporting activities so that the country produces higher revenues in the form of foreign direct investment. However, there are limitations in the workings of the mining industry because of poor infrastructure, erratic power cuts, and water shortages. It negatively impacts the functioning of the mining industry by reducing the capacities of the machines and laborers. Thus, the adoption of cleaner technologies will help in meeting the challenges that are faced by the mining operations and provides sustainable growth opportunities.

On the other hand, the use of environmental management accounting (EMA) tools helps in enhancing the commercial workings of the mining operations along with environmental protection and conservation initiatives. As a result, there is the attainment of commercial as well as environmental goals that promotes sustainable development.

Initiatives such as ‘Sustainable Development Day’ has been introduced by the governing body in South Africa to promote sustainable development practices in the country. The ‘Sustainable Development Day’ initiative has been introduced to promote sustainability in the core business activities in the mining industry. It provides an appealing and interactive medium to the mining companies through which they establish open communications with the other industry leaders to propose ideas related to the reduction of socioeconomic disparities.

The ‘Sustainable Development Day’ provides a participative platform to all the commercial units in the mining or non-mining industry in South Africa to come forward and work together towards the community development activities.

It includes the active involvement of NGOs, government agencies, scholars, and entrepreneurs so that all the intellectuals could meet and discuss sustainable development initiatives collaboratively.

It includes introducing technological advancements such as Climate-Smart Mining, Community Voices, and Innovative Tech and Data management solutions so that the mining activities of the mining industry could be improved and do not cause harm to natural surroundings. It also includes creating job opportunities so that skilled and semi-skilled laborers could be employed effectively. Hence, it can be said that by adopting CSR initiatives, partnerships, the introduction of company and community development policy, and environmental management accounting (EMA), sustainable development could be achieved in South Africa.

3.7. Research gap

As per the above-discussed literature review, it was found that mining is a high-risk industry in which the mines are required to work skillfully to accomplish the tasks error-free. The use of advanced technologies such as robotics in mining will improve the working condition in mine sites, rescue workers, and limit the exposure of miners to hazardous working conditions). The current study which is related to the digital mining for sustainable economic development and employment generation with a special reference to South Africa included facts related to the status and importance of the mining industry in South Africa which have not been covered by scholars earlier. The comparative analysis of African mining industries and practices and how it relates to South Africa in particular. It was examined that there have been studies related to technologies and its application in the South African industry before, but its critical analysis has been missing in the previous literature.

The current study identified a gap and filled it by providing relevant information related to the negative and positive impacts of recruiting advanced technologies in the mining industry in South Africa. The study examined that the facts related to methods to reduce the environmental problems related to mining in South Africa and found that the adoption of strategies such as stringent regulative measure, support centers, educative plans, and 'Action Plan' will help to improve the mining process and safeguard the environment from its ill-effects. However, facts related to it were limited in the previous literature which is adequately filed by the current study.

4. RESEARCH METHODOLOGY: CHAPTER FOUR

4.1. Introduction

The present study is related to digital mining for sustainable economic development and employment generation with a special reference to South Africa and has been considered as an important source of information regarding the mining companies along with their strategies of rapid switching, business models and operating methods. The main aim of the study is to explore the methods to modernize the South African Mining Industry while building a sustainable economy by the creation of new jobs. Also, it has been revealed from the previous chapters that the introduction of the digital transformations and other constructive policies have enhanced the living standards of the mine workers and improved the poor environmental conditions.

The major issue of the mining industries in South Africa is the poor working scenarios of the workers with no safety environment. Hence, the introduction of innovative practices such as digital penetration in the form of the internet of things (IoT), agile applications, cloud computing, sensors, and drones will help to enhance the workings of the mining industry effectively. Thus, the researcher in this research has focused on the facts related to threats of mining on the lives of the mineworkers in South Africa and highlights the issues that are faced by the environment due to the intensive mining process.

The understanding of the ideas and the theories being adopted for conducting a research study has been found to be mandatory along with the other motivational concepts and their implementation in the research study (Shank, 2002). The research methodology has been considered as one of the most relevant sections in the entire research study. Hence, research methodology has been defined as the protocol by which the scholar or the researcher can refine the information as per the topic of concern (Bazeley & Jackson, 2013).

The present chapter deals with the various research methods that have been implemented in the given study to fulfil the major aims and objectives of the research study. The evaluation of the results is dependent on the research methods that have been used in the study.
Also, the research methodology has been considered an appropriate way for analysing the accurate interpretation of the research study being conducted (Bernard, 2011). Therefore, the following research methods have been followed for exploring the methods to modernize the South African Mining Industry while building a sustainable economy by the creation of new jobs.

This chapter consists of the description regarding the other sections related to the research methodology that involves research design, research paradigm, the implementation of the sampling technique, data collection methods, tools that have been used for data interpretation and also the ethical consideration involved in the given research study.

4.2. Research process

Any research study goes through the protocol of following some major steps that need to be performed for appropriate completion of the research work (Bryman, 2015). Following are some of the major steps that needs to be followed for conduction of any research study.

- Identification of the research problem
- The appropriate execution of the literature review
- Formulation of the research variables
- Developing the research design
- Focus on the research design that is selected for the research work and the research paradigm
- Data collection methods (Cohen, Manion & Morrison, 2013)
- Analysis of the collected data
- Data interpretation of the analysed data
- Discussion on the result obtained from the analysed data

The previous chapters of the present research study have evolved the problem statement for the given research that gives direction for the implementation of research methodology.

The literature review has been elaborated in another section of the research study by utilizing the secondary resources involving the books, articles, journals and further conducted the review literature (Creswell, 2013).

Also, the elaboration of the research design, research paradigm, research approaches and data collection methods have been implicated in this chapter.
Further the data analysis and data interpretation have been elaborated in the next chapter. Later, the findings and discussions have been illustrated which have been considered as the last section of the research study.

4.3. Research strategies

The implementation of research strategies has evolved to analyse the complete planning of the research work so that the research work can be carried out efficiently. The research strategies have helped the researcher in the formulation and development of the research plans and further execution and monitoring of the research plans by following a systematic process. The research plan helps in supporting high status of the research work so that implementation of research methods can be done with appropriate guidance in the research work (Creswell & Poth, 2016). Also, the utilization of research methods in the research study has evolved different processes for collecting and interpreting the evidence. These may be present in the form of questionnaires, interviews, or statistical methods. Various research strategies have been discussed in the study, but the research has to choose only the specific tool that is appropriate as per the suggested topic so that appropriate data can be collected concerning the digital mining for sustainable economic development and employment generation in South Africa.

The basic implementation procedure of the research strategy is dependent upon the major goal of the study which further helped the researcher in obtaining the appropriate strategy that fulfils the aims and objectives of the given research study. Also, was important for the researcher to choose a specific research strategy ensuring the maintenance of the ethics of the study (Denzin & Lincoln, 2011). It has been strictly implicated in the ethical study that no harm should be caused to anyone during the implementation of the research work. The research strategies involve the methods, paradigms, designs, data collection techniques, sampling, approaches and data analysing tools.

Chosen Strategy

The present research study has been conducted choosing the adequate research components that have been required to perform the research work efficiently. The researcher has opted for the research design, research approaches, research methods, data collection methods, data analysing tools, sampling techniques and ethical consideration.

Also, the researcher has selected the survey conduction method by distributing questionnaires among the participants for the collection and interpretation of data along with appropriate interrogation of the participants according to the concerned topic.

4.4. Research design

The conduction of research design has been considered as the complete set or plan carried out for the research work that have been combined together for performing the research in logical manner (De Vaus, 2001). The research design has been also considered as a blueprint in the research that involves the collected data, data evaluation and data analysis. It is an integrated and comprehensive strategy that has been frequently used by the researcher by combining the various aspects that have been associated with the research study in a coherent and logical manner which further ensures the appropriate use of the research problem. It has been also used for the collection and measurement of the data that has been utilized in the research study. The research design has been efficient in analysing the data that are involved in obtaining appropriate results for the research study. The research designs have been developed in different forms that include descriptive, explanatory, exploratory, and experimental (Salkind, 2010). These have been elaborated below:

4.4.1. Descriptive research design

The descriptive research design has been considered for providing an overview on the research process as being independent. This type of research design has been evolved in justifying the current practices along with the formulation and development of new theories accordingly (Yeboah-Fofie, 2017). The researchers have also termed this design as an outcome evolved from social aspects (McNabb, 2012).
This type of research design involves the formulation of hypotheses after the data has been collected.
The theories developed from this type of research design evolve interconnection among the existing variables involved in the research study and also acquire a descriptive method for the acceptance and rejection of the formulated hypothesis.

4.4.2. Explanatory research design

The explanatory research design has been defined as the development of casual relationship among the variables present in the research study. This type of research design first formulates the hypothesis and later the research methods such as data collection and all are carried on. Hence, here the collected data is completely dependent upon the developed hypothesis (Creswell & Clark, 2007).

4.4.3. Exploratory research design

This type of research design has evolved in exploring the matter for understanding the concept of the matter related to the research in a better way (Ariga, Hill & Ji, 2007). It has been also revealed that the primary objective of this research design aims in identifying the issues and variables for the research being studied. Also, the social perspectives of the research are focussed when this type of research design is implicated in the research study. This type of research design involves the research study with background of literature review and group interviews being conducted. Its theme has supported the research study in finding out the solution to the research problem.

4.4.4. Experimental research design

The experimental research design has evolved for defining the formulated hypothesis and supports the development of valid inference that eventually considers the interrelation among the dependent and independent variables in the research study. It further involves the development conceptual framework from which any experiment is processed for conduction (Flick, 2015).

In this type of research design, the problem statement is first analysed and depending on this, the hypothesis is further formulated. After the analysis of the data is done to obtain the final result which determines experimental design in the research work for representing the relationship among the different variables involved in the research study.

Chosen design

In the present study, descriptive research designs have been selected as the current practices have been used for developing new theories accordingly. Also, the process of data collected is initiated first and may be the formulation of research hypotheses is implicated later.

4.5. Research Paradigm

Research Paradigm has been considered to be the combination of different concepts, variables and all other issues concerned with the methodology approaches and all other related tools in the research study. It consists of the structure or framework of the scientific ideas in the research study along with the values and assumptions being used in this study. Morgan (2007) has given the concept of different versions of paradigm. The versions of paradigm have been explained by the researcher in terms of sharing beliefs that have been responsible for influencing the variety of knowledge gained by the researcher and the methods of interpreting collected information (Morgan, 2007).

Also, the researcher has revealed that paradigm is none other than the belief of different members with the same specification for determining the basic aspects of the mentioned research questions along with the methodology of the research.

Hence, the previous studies have proved the fact that the research paradigm is the collective process that involves some of the discussion processes such as positivism, interpretivism, constructivism, etc (Chilisa & Kawulich, 2012). The researchers have implicated that the mentioned components of the research paradigm have been associated with the assumption regarding the perceptions of the existing reality.
The researchers have also implicated the explanation of some of the paradigms for better understanding of the research paradigm. The basic concepts of Ontology have been revealed by the researchers that clearly implicates the paradigm types that evolve the determination of the reality and has been classified as positivism and interpretivism.

4.5.1. Positivism

Positivism has been considered as one of the most primary forms of research paradigm that has been evolved by analysing the result through the scientific methods (Chilisa & Kawulich, 2012). This research paradigm was initially used during the 19th century when one of the researchers rejected the metaphysics in terms of research that may follow the scientific and logical reasoning for analysing the research hypothesis. The basic aspects and concepts of positivism have been laid down by the Associates of the Vienna Circle which is now considered as one of the most common principles of research paradigms.

The approach of positivism has also involved the interlinking of various independent events with the reality through recognition of valid cognition (Clarke, 2009). It has been considered as an agreement that constitutes a well-defined relation among all other events that already exist.

The productive approach of positivism has been determined by analysing the experiments, collection, observations, data analysis that involves quantitative estimation. It has been effective in inferring the connection among the variables along with the collection of the desired information and testing of the hypothesis. The researchers following the positivism concept eventually adopt the statistical method for data analysis (Yakow & Schwartz-Shea, 2015).
It has also been analysed that positivism is evolved from the concepts of science. Hence, it all involves the scientific fact for studying human activities.

4.5.2. Interpretivism

Interpretivism has been considered to have little variance with positivism that considers the beliefs and ideas. Many of the research studies have revealed the fact that interpretivism has been adapted by the researchers and has evolved the identification of the problems along with their solutions by observations collected from the ideas and meanings of humans.

Also, it has been proven that interpretivism is correlated with the reality which has been already discovered to be complex and multi-layered (Dammak, 2015). The researcher also concluded that the reality has been framed by the people by their assumptions and creativity. It has been further stated that the world full of social values should be analysed by the thoughts and views of the natural world while analysing the mindset of the participants along with mediation of the researchers.

It has also analysed that interpretive methods have been used for analysing any qualitative type of research which can be done in a better way by determining the natural world (Denzin & Lincoln, 2011). Therefore, the analysis through interpretivism has evolved the conclusion with effective results and better understanding of the concept and facts related to the research. It has been reported by many researchers that interpretivism helps in analysing the result by determining the social world and taking opinion of the individuals through the individual's actions analysis.
The interrogative methods have been used by the participants who are responsible for the collection of opinions and information for interpretivism methods.

Chosen Paradigm

The present research study has been conducted with the aim of exploring the methods to modernize the South African Mining Industry while building a sustainable economy by the creation of new jobs. Hence, the research paradigm helps in analysing the different parameters for fulfilling the major objectives of this research study. In this study, interpretivism research paradigm has been followed for interpretation of the appropriate results.

4.6. Research Approach

Usually the research methodology is considered wrongly as only the process involving collection of information, documentation, etc. but this is not true. Rather a research comprises methods of data collection along with data analysis, data interpretation which leads towards the better understanding of the research study (Hennink, Hutter & Bailey, 2010). Hence, the research process follows a systematic protocol for fulfilling the major objectives by appropriate management of data procession and obtaining appropriate results accordingly.
Also, it has been illustrated that the research process is only initiated when a certain question arises in the current process regarding the basic concepts and existence of the study. Hence, these questions evolve the initiation for conducting the research and identifying the solution to the research questions leading to adapting the research approaches. The research approaches are of three types which includes quantitative, qualitative, and mixed approaches. Hence, the adoption of the desired research approach is dependent upon the demand of the research (Williams, 2007).

Therefore, it has been revealed that the basic aim of any research approach is to implement an appropriate strategy involving the methods of data collection, analysis of the collected data and its interpretation. A research approach is further divided into different categories represented below as:

- Data collection approach
- Data analysis or reasoning approach

4.6.1. Data collection approach

This type of research approach is further divided into three types which includes quantitative, qualitative, and mixed approach.

- **Quantitative research approach:** This type of research approach has been basically, evolved for quantifying the collected data in the research study. This research approach initially evolved during the era of 1250 A.D.

In this type of research approach, numerical and statistical research approach has been utilized along with the implementation of the data collection that requires conduction of survey process for analysing the results (Williams, 2007). Other studies have revealed that the quantitative research approach has been considered as the perspective of defining science in a more relatable manner (Taylor, 2011). This research approach has been mainly implemented for establishing correlation among the different variables being used in the research study mainly involving the elements grouping, numbering, and their conversion into the measurable models.

- **Qualitative research approach:** This type of research approach has been considered as the subjective one that involves comprehensive research with some sort of new theories (Jackson, 2015). It has been also explained in terms of social considerations which is represented from the participants' point of view. This approach also involves the description, explanation and data interpretation that further involved some new concepts and theories relating real experiences.

This type of research approach has been usually implemented in different modes such as through case studies, analysing the content and determining the root theories (Williams, 2007). One of the studies revealed that this research approach has been considered best for exploring the research aiming towards the discovery of basic information and data concerning the topic and situations of implementation (Richardson, 2003).

- **Mixed research approach:** The researcher has found issues regarding the implementation of any of the above-mentioned research approaches and this led towards difficulty in deciding the best suitable approach to be implicated that justifies the major objectives. This condition led towards the implementation of a mixed research approach in the research study. It was initially evolved during the 1990s.

This approach has involved the implication of different data collection in the research analysis with quantitative or qualitative data.
Hence, this approach involves the compilation of both the methods on an individual basis with the objective of eliminating the drawbacks and enhances the qualitative and quantitative research approach (Williams, 2007).

Chosen research approach

The present research study has followed a qualitative research approach. This research study has aimed for finding new methods of data mining in South Africa while maintaining the economy by providing new job opportunities and determining the threats caused by mining on the living standard of the workers. The qualitative research approach helps in analysing the result from the participants' point of view and determining their actual experience. Hence, this research approach involves new theories and concepts by analysing the collected data and discussing its interpretation by collaborating with the participants involved in the research work.

4.6.2. Data analysis or reasoning approach

This type of research approach has further different types which includes inductive, deductive, and mixed approach. Following are the different types of reasoning approaches:

- **Inductive approach:** The inductive approach is usually not concerned with the research hypothesis and mainly holds on with the major aims and objectives of the paper which will further support in analysing the research study (Lewis, 2015). In this type of reasoning approach, the researchers are responsible for collecting the information as per the selected topic which helps in developing a theory coning the observations for further discussion of the patterns related to research. This eventually involves the adoption of qualitative data.

- **Deductive approach:** The Deductive approach of reasoning is being used for the research hypothesis which must be analysed and tested through the observatory tests that eventually should be either continued or get rejected. The researchers organize their observations and data collection by moving from the general selection towards the specific selection completely dependent on the variables (Lindlof & Taylor, 2010).

  The research studies mainly involve the analysis of all the scientific observations that are further correlated with the deductive approach. In this type of reasoning approach, the researcher is responsible for determining the study through the surviving theories that lead towards the testing of research hypotheses that have been evolved from the existing theories.

- **Mixed approach:** The mixed approach has been evolved from the compilation of inductive and deductive approach that leads towards the successful implementation of the study (Mackey & Gass, 2015). The data interpretation is done by analysing this type reasoning approach in the research study.

Chosen reasoning approach

The present study has chosen an inductive approach as the reasoning approach because this approach focuses on the objective of the research study and helps in analysing the appropriate result. The qualitative data is involved which helps in developing theories based on the concerned topic for further consideration of the observation in the study.

4.7. Data Collection Method

The research methods of the study are completely dependent upon the type of data being collected. Hence, it is considered as one of the most important parts in facilitating any research study. Two main sources of data collection have been involved in a research study that is primary data collection and secondary data collection that fulfils the major objectives of the research study (Maxwell, 2012).

4.7.1. Primary Data Collection

Primary data collection method has been considered as one of the most major types of data collection techniques that aims in gathering important information by using different methods. In this type of data collection, raw data is collected that is further used in analysing the research objectives (Miller et al., 2012). It has been used preferably in descriptive or experimental research design where relatable experiments are being performed and the observations are done with analysis of communication sources such as conduction of survey process accordingly. Qualitative and quantitative research methods are involved in primary data collection.

Quantitative data has been collected by conducting interviews through online survey or face-to-face interviews by using a set of questionnaires (Neuman & Robson, 2012). Also, the chosen respondents help in data collection by conducting face-to-face interviews in the form of qualitative data collection. Therefore, primary data collection has been considered to be the most relevant and reliable data for analysing the selected research study.

4.7.2. Secondary Data Collection

The secondary data collection method is the type of data collection method that utilizes secondary sources for collecting data for conducting the research study. It involves the data with collected information from the previous studies that has been already performed by the researchers.
Hence, this type of data collection majorly involves the accumulation of important data that helps in formulating a detailed knowledge regarding the study (Padgett, 2016). It is usually conducted by using resources such as articles, journals, websites, books, etc. that already exist as per the selected research study.

Chosen data collection method

The present research study uses primary data collection methods for exploring the methods to modernize the South African Mining Industry and determine the threats of mining on the lives of the mineworkers along with reduction of the environmental problems related to mining in South Africa (Mhlongo & Amponsah-Dacosta, 2016).

The primary data collection method involves the collection of data by conducting interviews with the top managers of the mining companies, mine workers, and the local communities. The interviews are conducted by distributing the online questionnaires through the HR offices of the mining houses. The Covid-19 pandemic laid certain restrictions and therefore, only few groups were focussed on which involved union representatives, mineworkers, mining officials and mining communities.

The interviews have been guided by setting themes according to the main objective of the study. The theme of this study consists of the mining automation and socio-economic impact on the mining communities. The questionnaires distributed among the participants contain open-ended questions which help the researcher in analysing the depth of each question involving the problems but being eliminated at the time of interview. The questions involved the employment of robotics and other improved techniques in the field of mining.

Five different groups were surveyed for the interview conduction which has been already selected in terms of mining communities. The gender representation has evolved while the conduction of the interview. Small number of participants have been preferred in the interview as their management during the conduction has been found to be easy and moderate. Also, it has been analysed that the focus groups have been considered as the controlled groups involving only selected participants that are led by the moderators (Litosseliti, 2003). These evolve the setting of exploring the topics and views of the individuals and their experiences by organizing group interaction. The strict control has been set during the mining operations, therefore granting permission for interview has been majorly involved.

The major objective to conduct the interviews with the focus group was to represent the views of the community regarding the socio-economic impact in mining.

Also, the perspectives of the participants have been analysed concerning the mining activities along with the perspectives of the labours concerning their job preservation and their safety. Also, the permission to run these groups has been evolved from the unions and chiefs that represent the different constituencies.

4.8. Population and Sampling

The sampling method refers to the process of collecting the required sample that depends on the study area. It further involves the rapid data collection process along with enhancing the data accuracy in the research study (Sarantakos, 2012). The sampling method has been further divided as probability and non-probability sampling which have been illustrated below:

4.8.1. Probability sampling

This type of sampling method involves the selection of individuals who are familiar and are usually selected on a random basis from a specific sampling structure. The participants are chosen accordingly, and this helps the researcher in deciding the sample size. This type of sampling method has been correlated with the research approach of positivism along with the selection of quantitative methods of data collection (Yin, 2013).

Following are some other types of probability sampling:

- **Random:** It involves the selection of the sample in a random manner as per the requirement of the study.
- **Systematic:** The samples are selected on the basis of periodic intervals.
- **Stratified:** The samples here are further divided into different layers according to the specific domain that has been selected for the study (Zikmund et al., 2013).
- **Cluster:** in this type of sampling, the subgroup is selected in a random manner that completely depends on specific geographical areas from the selected sample.

4.8.2. Non-probability sampling

This type of sampling method involves the qualitative research method and the respondents selected who are not from the desired area. This sampling method gives opportunity to the researchers for collaborating with the participants during the interview and understanding their viewpoints on the relatable questions.

Following are the types of non-probability sampling:

- **Convenience or accidental:** the participants are selected only for a specific period according to the convenience of the study (Saunders, 2011).
- **Purposive:** It involves the selection of samples according to the opinions on the concerned issues.

- **Quota:** The sub-groups are selected in this that further affects the specific diversity.

Chosen population

The present study uses simple random sampling design that involves a small number of units selected randomly in order to determine the actual situation. Also, non-probability sampling (purposive sampling) is used in the given research study by understanding the relevant facts related to mining companies in South Africa that have introduced digital transformations into their working systems. The expectations and experiences of the mine workers have been determined from the mining companies in South Africa.

4.8.3. Sample size

The sample size often involves the identification of the process of selecting the respondents and involving them in the form statistical samples. It helps in analysing an empirical study and further inferences are concluded from the participants (Silverman, 2016).
It involves the quantitative and qualitative data collection as quantitative method involves random selection of sample and qualitative data involves the selection of less sample from specific group.

Chosen sample size

The present research study involves the selection of those participants who belong to the focus groups.

The focus group included 20 members of union representatives, 50 mineworkers,15 mining officials and mining communities involving 35 adults belonging to the age group of 40-55 years and 30 teenagers belonging to the age group of 18-35 years. The total number of participants in the research has been estimated to be 150 in number.

4.9. Data Analysis and Management

Data analysis has been considered as one of the most important processes that helps in analysing the result of the research study. The collected data is analysed for obtaining results and reaching the objective of the research study quite clear. The data analysis tools are used according to the type of collected data. The qualitative data analysis uses the interpretations of the humans with the application of thematic analysis and content analysis techniques for interpreting the data by a survey process through conduction of interviews (Panneerselvam, 2014).

On the other hand, quantitative data has been analysed by using statistical tools because the information or data of quantitative research has been collected in the form of numerical values and have to be represented in the form of graphs and charts for better understanding among the readers.

Also, some software-based tools such as SPSS, MS excel, graph pads, etc have been used for analysing the quantitative data and evaluating the results.
Thematic analysis has been also used in some of the studies that involve data coding according to the themes. Some of the statistical data analysis tools are illustrated below:

- **Chi-square test:** It is the type of statistical analysis tools that determines the correlation among the categorical variables according to the research study.
- **Correlation:** This type of data analysing tools has been used for identifying the linear relationship among the distributing interval variables (Punch, 2013).
- **ANOVA:** This type of data analysis tools has been used for determining the variations and testing the hypothesis being developed in the research study. It involves a meaning that two people or more are equal to each other.
- **Factor analysis:** This type data analysing tools have been used for exploratory analysis and often obtains relationships among the different variables being used in the research study (Ritchie et al., 2013).
- **Descriptive analysis:** It is the type of data analysis tool that involves the statistics and description of the common characteristics of the collected data. It basically involves the simple graphical representation of the data while summarizing the samples and measures.
- **Linear regression:** This type of data analysis tools has been helped in determining the interval outcomes and predictors.
- **Multiple regression:** This type of data analysing tools has been used for predicting only one variable in terms of an equation and has been found similar to simple regression.
- **Thematic analysis:** This type of data analysis has been used to analyse the qualitative data. It has been mainly involved in the data collected in the form of interview transcripts. In this analysis, the most common themes are identified such as topic, pattern and ideas that are frequently being repeated.

Data management is referred to as the process of managing data in a coherent and systematic manner for the collection, storage, and retrieval of the data (Denzin & Lincoln, 1995). These processes of managing the data follow major objectives of ensuring high quality with accessible data, documentation of the data that has been analysed and retaining the data along with its analysis after the research work is completed.

Chosen data analysis

In the present research study, the data analysis has been done by choosing the transcription method. After the completion of the questionnaires and storage of the collected data, data has been analysed using a transcription process. The questions in the questionnaire have been converted into readable transcripts.

This process has been carried out for obtaining the appropriate result without causing any effect to the quality of the data being analysed. These transcripts after completion are further analysed by thematic analysis.

In thematic analysis, the substantive sections in the transcripts regarding the research questions and topics are coded and classified according to the themes. These themes have been used for analysis and interpretation of the collected data.

4.10. Considerations

The ethical consideration in any research study has been considered to be an important process while implementing a research work. This process involves a set of rules and regulations that have been used in the completion of the research work in an ethical manner. It has further involved an appropriate standard while carrying any research work. The ethical consideration in any research work involves the permission and will of the participants and the participants are not supposed to be forced to attempt the questionnaires (Tashakkori & Teddlie, 2010).

It is the participants' choice whether they want to continue or withdraw their participation at any time while implementing the research work. Hence, the participants should be made clear with the understanding of the research study and then move forward for granting their permission to answer the questionnaire in the survey process. Also, the security and privacy of the data should be ensured so that no third party should not be able to access the data. Thus, ethical consideration has evolved maintaining data privacy. The collected data concerning the research study has been used for academic purposes rather than utilizing it at commercial level (Taylor, Bogdan & DeVault, 2015).

Hence the present study has involved the clear concept of the ethical consideration by maintaining the privacy of data and protecting it by eliminating the data access to the third parties. Also, the participants who actively responded to the survey have not been forced to participate and have shown their willingness to cooperate in the research study.

In this research study, informed consent forms have been given to all the respondents so that they all are aware of the process of the ethical research. The consent of the respondents is an important factor while proceeding with the research study as it gives them the option to the participate in the research work willingly and have the option to not participate in the research study (Somekh & Lewin, 2005). Also, the confidentiality and privacy of the participants have been preserved along with a clear explanation of the main aim and objectives of the research study to participate. The digital recordings that involved the field notes have been securely stored throughout the research study.

4.11. Conclusion

The present research study is concerned with digital mining for sustainable economic development and employment generation in South Africa. This paper explored the methods to modernize the South African Mining Industry while building a sustainable economy by the creation of new jobs and the preservation life of the mineworkers in South Africa.

In order to fulfil these objectives, a qualitative research methodology have been carried out as it provides a better understanding of the experiences and attitudes of the people belonging to the mining communities and their concerns with the impact of Digital mining. The interviews were conducted with the using the thematic analysis where the focus groups have been involved for collecting the data. The data have been transcribed and analysed by arranging the data according to the themes and substantive patterns through classifying and grouping them in codes according to the research questions.

5. FINDINGS AND DISCUSSION: CHAPTER FIVE

5.1. Introduction

Mining is an important commercial practice that highly contributes to the economic growth and Gross Domestic Product (GDP) value. While focusing on the mining industry in South Africa in particular, it shows that mining contributes 18% towards the GDP through direct and indirect (8.6% and 10%) inputs. The mining industry is known as an important sector that contributes to South African industrial development and the progress of human civilizations.

When there is the introduction of digital technologies such as the Internet of Things (IoT) in the mining process, there is the automation of distribution and consumption process (Down & Stocks, 1977).

The study examined that the South African mining industry is majorly based on the Nederburg miner concept. The use of the robotics technology based on the Nederburg mining concept helps in increasing productivity, providing a safe working environment, and reducing cost. It also provides real-time information about the activities that are taking place at the working sites and underground mines. The study analyzed the use and the implementation of the digital mining process in the conventional mining process in South Africa and it will help in reducing accident and fatality rates by enhancing the working condition at the mining sites.

For example, the use of robots at mines will help in identifying loose or hanging rocks, developing underground communications, ensuring safety by examining the site, and reducing the fatalities to minimum levels and or eliminating them all together.

5.2. Finding and Discussion

To analyze the different facts related to the current research, the researcher had adopted descriptive research designs so that there is the development of new theories accordingly.

A descriptive research design helped in the collection of data and formulation of research hypotheses. The study included an interpretivism research paradigm for the interpretation of the appropriate results. It also helped in exploring the methods to modernize the South African Mining Industry while building a sustainable economy by the creation of new jobs.

Additionally, there has been the implementation of a qualitative research approach as it helped in analyzing the result from the participants' point of view in determining their experience. The research also included an inductive approach as its reasoning approach as it helped in developing theories based on the concerned topic for further consideration of the observation in the study.

For the effective collection of data the primary data collection method has been used for exploring the methods to modernize the South African Mining Industry and increase the preservation life of the mineworkers along with a reduction of the environmental problems related to mining in South Africa (Mhlongo & Amponsah-Dacosta, 2016).

The primary data collection included interviews and distributing online questionnaires through the HR offices of the mining companies to the union representatives, mineworkers, mining officials, and mining communities. The study included a simple random sampling design and purposive sampling for the selection of the sample.

The total number of participants in the research were 150 in which 20 members were union representatives, 50 participants were mineworkers, 15 were mining officials and mining communities.

About 35 participants were adults belonging to the age group of 40-55 years and 30 were teenagers belonging to the age group of 18-35 years. Additionally, the transcription method had been chosen for the data analysis purpose in which the facts that were collected with the help of the questionnaire were analyzed by using thematic analysis.

While analyzing the facts related to the current research which is digital mining for sustainable economic development and employment generation with a special reference to South Africa, data collection methodology had been included in the study. In the data collection methodology, online questionnaires were circulated to 150 participants via the mines utilizing the HR offices for the collection of data.

The interviews were divided into different themes such as mining automation and the socio-economic impact on the mining communities related to the study. The researcher ensured that the questions were open-ended in nature so that there was the attainment of in-depth learning about the research topic along with the identification of issues.

The participants were also grouped in five sets with each group having a minimum of 15 members and a maximum of 30 members. The groups represented both genders equally with less female participation. Thus, the focus group formed controlled groups in which the selected participants were included and led by a moderator. The selected participants were set up to explore specific topics and individual views and experiences, through group interaction. The implementation of focus groups helped in acquiring perceptions of the participants with regards to mining activities in general in their areas in detail as well as the organized labor perception in terms of job preservation and safety.

The study included data management and analysis processes for the collection and examination of facts related to the research topic. While focusing on data management, it was defined as the processes needed for a systematic, coherent process of data collection, storage and retrieval (Denzin and Lincoln, 1995).

The data management process helped in attaining high-quality accessible data, retention of data, and documentation of analysis. On the other hand, the data analysis method included different processes such as transcription, classification into themes, and coding so that the facts are gathered precisely.

It was found that once the questionnaires were completed by the respondents, they were collected and stored securely. After that, the recorded responses were transcript into readable formats cautiously so that no detail is left out and all the information is captured effectively. The transcript is then classified into different themes and coded accordingly.

The study included geographical characteristics of respondents and analyzed the facts related to the degree of mining companies' influence on local development in the study area.

The study examined the facts related to locality development as a result of mining activities and found that 75% of the respondents (112) that were mostly adults and teenagers mentioned that the mining companies in the area are not interested in the development of the area and its people, while 25% of respondents (38) that were mostly Union Reps claimed that as much as some development exist, many of the activities are not in favor of the communities.

However, there was some consensus regarding the mining companies' development of certain communities namely in the Rustenburg area. It was also identified that 60% of all respondents reported that no significant infrastructural projects had been witnessed in their areas since some of the mining companies moved or shutdown.

The study examined that 40% of respondents claimed a dysfunctional relationship with the mining companies with 20% from organized labor and 20% from the communities (adults).

While comparing the above with the literature review, it was found that due to high exposure to silica many mineworkers suffer from chronic or nodular silicosis which causes respiratory and heart failure. It was found that when the human tissues are exposed to silica dust, it damages the internal linings of the airway resulting in lung failure and death of the mineworker. It causes breathlessness (also known as dyspnoea) issues and pain in the stomach of the mineworkers which reduce their physical capacity to work and perform mining activities (Mossman, 1993).

It was also found that high levels of mercury exposure also harm the physical abilities of the mineworkers by damaging the central nervous system of the body. It also causes feebleness, loss of hearing, loss of eyesight, loss of balance, and tiredness among the mineworkers (Harada 1997).

It was also found that few respondents believed that the mine has done nothing tangible in their communities thus far. The research also included the responses that were provided by Unionists (Organized Labour).

The results provided from organized labour mentioned that fact that the engagement with government is still continuing in regarding the mining issues raised. It was noted that the mining communities in the Northwest province had some infrastructural projects. As per the Unionists, it was found that the people in mining towns in the Northwest province where the Marikana Massacre happened was still living the aftereffects of the 16 August 2012 where 38 miners were killed tragically.

It was found that 69% of these respondents were female and widows as a direct effect of the massacre and believed that mines promised to compensate them for their loss.

The respondents provided that even though the widows were compensated they felt that the mining industry was not doing enough for the mining communities as they faced issues such as bad roads, unclean water, and poverty.

While comparing the above with the literature review, it was found that working conditions of mineworkers in mining communities in South Africa were poor and deteriorating day by day. As a result, due to poor economic conditions, low wages, poor healthcare facilities, lack of sanitation and clean drinking water, the mineworkers are also forced to drink waters from the contaminated waterlogged pits. Thus, the majority of the mineworkers were prone to several diseases such as malaria, tuberculosis, and lung diseases. This in turn reduced the working capacity and increased mortality rates in the mining sites in South Africa (Uitto 1992).

The study examined the facts that were related to beneficiation and community upliftment due to mining activities in the area and found that most of the Union Representatives respondents mentioned that mining companies have not done enough to ensure that the communities benefit from their presence in their localities.

The respondents provided that the mining production activities hardly helped the local communities as it employed workers from neighboring countries like Mozambique, Lesotho, and Swaziland with a small portion from the Eastern Cape. Thus, the respondents mentioned that being neighbors they should be given first preference and provided with better work opportunities.

About 70% of the respondents (adults and teenagers) provided that the mines did not look after their well-being and had a poor relationship with the mine. The study also included the responses that were given by the community leaders. While comparing the above with literature review, it was found that due to poor economic condition and low living standards, there is increasing risks of deadly diseases such as tuberculosis and HIV among the vulnerable communities of South African mineworkers.
It was found that the places that are habituated by the mineworkers are dirty with no proper sanitation or clean drinking water facilities.

As a result, most of the mineworkers' face healthcare issues and are prone to diseases. Additionally, it was examined that the lack of occupational health compensation packages causes poor health conditions among the mineworkers. Due to low healthcare packages, the mineworkers could not access adequate medical facilities, and this negatively impact the good health conditions of the mineworkers (Harling G, Ehrlich R, Myer, 2008).

As per responses provided by the community leaders, it was found that they experienced skill shortages and the current state of the economy which dither them from investing more in the communities.

About 90% of the participants provided that they were highly sensitive to the economic climate and blamed the governing body of the country for environmental mess and lack of provision of working opportunities. Additionally, 100% of the Unionists provided that they were unhappy with the fact that the mines were employing people coming from neighboring countries and the locals were being overlooked. It has a major impact on their membership numbers.

The study further examined the responses that were given by organized labor. It was found that organized labor acknowledged that the mining communities experience significant skills shortages, which limited the majority of the populace from competing with other people for gainful employment. As a result, there was poverty across generations because of a lack of projects. The organized labor also mentioned that they had requested the mines for skill development training, but no initiative was taken by the mining companies.

While comparing the above with the literature review, it was found that several issues such as noise pollution and hearing loss issues are also faced by the mineworkers in South Africa. It was examined that there are no regulations related to noise and pollution control in South African mining sector that adversely impacts the healthy living conditions of the mineworkers (Amedofu et al., 1996).

The migrant labor issue is also faced by the workers in the South African mining sector as several workers come from neighboring countries such as Angola, Botswana, Zambia, and Zimbabwe. As a result, there is a reduction in employment opportunity for the locals and they have to face competition from foreign intruders (Butchart, 1996).

The study examined the facts related to the integration of the mining companies with existing community structures and found that there was a lack of sufficient information about the integration of the mining companies with existing community structures.

About 98% of respondents mentioned that mining companies hardly visited the regions in which they operated, as they felt that there were no reasons for visiting these mining communities.

Additionally, 70% of respondents also confirmed that the mining companies did not visit communities and mainly paid attention on earnings and profit margins.
The research analyzed the facts related to perceptions about the mining activities in the community and found that there was a lack of co-operation from the mines to engage.

The respondents provided that they contacted the mine officials regarding the cracks as result of the mine blasting. On account of this, the mine officials acknowledged the fact and provided that they were working with the government to manage these issues more effectively. The respondents also mentioned that housing in South Africa was a scarce commodity and repairing these houses is costing them heavily.
As a result, most of the houses that are occupied by the communities were having cracks, but no attention was given by the mining companies to address the situation. Thus, the communities did not see the mining companies as partners or positive contributors, but as adversaries, which was detrimental to their relationships. It also limited the developmental agenda for the locality because of the strained relationships.

While comparing the above with the literature review, it was found that due to poor working conditions at the mining sites, many mineworkers suffered from severe health issues such as lung cancer.

The mineworkers are not provided with adequate protective gear, clothing, masks, or gloves which increase the risk of inhalation of silica dust in large quantities by the workers. As a result, the mineworkers are highly exposed to harmful substances such as arsenic that has negative implications for their health conditions (Boffetta et al., 1994). Thus, it can be said that there is an emergent need to improve the working condition of mineworkers and provide them better living and medical facilities so that their poor health condition improves.

The facts related to perceptions about the reliability of services delivered were examined and found that dissatisfactory services provided by the mining companies. As per most of the respondents, there was a strained relationship between the communities and mining companies because the mining companies did not fulfill their promises. The structures that are occupied by the communities were damaged. When the companies closed the mines, the communities were left in a state of despair. Some of the respondents expressed that the condition of structures was so poor that they might fall and kill all of them someday.

The respondents expressed that the mine companies did not provide transportation to the mine employees that were using local service providers. The facts related to the impact of new technological enhancements were included in the study. It was found that almost every respondent that belonged to the organized labor was anti-mining automation. The respondents provided that if automation is introduced in the mining sector, it will result in huge job losses and an increase in the unemployment rate.

However, 60% of respondents that belonged to the young individual category were positive and expressed that they were looking forward to new sustainable and eco-friendly mining developments.
It was found that the mine officials were also very optimistic about mining automation. The mine officials believed that the introduction of automation technology would help in changing the gender divide as the new technological changes would be more inclusive of women.

While comparing the above with the literature review, it was found that the introduction of digital technologies such as automation and robotics will increase the efficacy and production capacity of the mining industry. The use of robotics will facilitate the working of the mining industry by establishing coordination with the different operating systems such as digging, breaking rocks, and excavation. Additionally, by adopting the Nederburg miner concept, there will be extraction of minerals from narrower reefs easily (Harper 2008) (Harper, G. (2008). Nederburg Miner. Narrow Vein and Reef. SAIMM).

It was found that deeper mining technologies are also into implementing procedures in the South African mining industry that will help to enhance the efficacy of the mining unit by analyzing increasing cost and risk factors (van der Merwe, 2011).

The facts related to the new mining automation and sustainability of the workforce were examined and found that 99% of respondents belonging to organized labor were not in favor of digital mining automation. However, the respondents expressed that the introduction of digital mining automation will help in enhancing their skills and create new Job opportunities.

It was found that 80% of the female respondents in the communities were very optimistic regarding the introduction of digital mining automation. The female respondents expressed that their children may have a future in mining with these new inventions and were positive about implementing digital mining automation. The study examined the facts related to perceptions of the Socio-economic impact of rapid technological change on sustainable development in the South African mining industry by including Mine officials, Union Representatives, miners, ex-miners, and beneficiaries.

It was found that organized labor was majorly impacted by the new mining automation. The organized labor expressed that it would impact their job propositions and put an end to the labor movements within the mining industry. The other challenges that were faced by the organized laborers were related to payment of low wages.

The organization argued that the mining companies could not pay their workers sufficient pay but invested large amounts of money in the digital mining automation processes. However, some of the respondents expressed that the introduction of digital mining process is essential for the mining industry as mining has become very dangerous due to the levels of risks which are associated with underground mining.

Thus, it can be said that the respondents were in between a rock and a hard place as some respondents were against automation, and some in favor of automation.

While comparing the above with the literature review, it was found that the introduction of robotic technology will help in improving the efficacy of the mineworkers by streamlining the entire work procedure. It will help the mineworkers to reach the narrowest mining destinations and extract minerals from the contracted sites effectively. As a result, the safe working culture will be promoted at the workplace which helps in reducing accident and fatality rates (Green, J., & Plumb, S. 2011.

It was also found that automation technology is a combination of several technologies such as communication technology, sensing technology, system process, navigation, and imaging. It helps in increasing the efficacy of the workers and systems by synchronizing all the operational process (Madhavan, 2001)**.**

The study examined the responses provided by the mining officials and found that mine officials from all the representing mines expressed the same sentiments and views regarding automation. The mine officials responded that automation is the future of the South African mining industry which will help it achieve sustainable growth. The officials were also concerned about the job losses but felt that automated mining will create new working opportunities and increased opportunities for skilled workers.

The facts related to mineworkers and conflicting challenges were included in the study and found that the mineworkers were conflicted as they were worried about their future in the mining industry. The young mineworkers were worried about their future in mining if they were not skilled in technology. The older mineworkers were more concerned about the safety aspects and considered that the sustainability of mining is very crucial to their livelihood. The mineworkers also expressed that automation is essential as it will help to sustain human life, promote economic progress, and ensure sustainable development in South Africa.

It was found that the majority (50%) of the mineworkers would be retiring in the coming five years. As a result, the old and experienced generation will be leaving the mining sector and the young generation would be handling and managing work at the site. Thus, under such conditions, when the older generation will be leaving the workspace and the younger generation will be handing mining work, it is essential to train and equip the younger generation so that they will resolve the workplace challenges.

While comparing the above with the literature review, it was found that the introduction of autonomous and remote-based applications in the mining industry will standardize the mining working procedures. The study examined that with the help of automated driverless vehicles; there will be the elimination of variability and idle time.
It will ensure that there is an effective utilization of resources that helps in saving valuable resources and reducing waste generation.

The use of automated technology will also help in reducing the cost associated with human error and improper utilization of resources. As a result, there will be a reduction of risky activities and the workers will be provided a safe environment to work in (Murphy, 2011).

The study examined that to enhance the skills of the young generation social networking chat groups can be created between the young and retiring generation. It would help to manage mining situations in guidance from the seniors. Therefore, the senior mineworkers can assist as senior consultants or advisors who would continue to work after retirement but with a flexible schedule.

It was found that mining communities mainly included women who had lost their husbands in the mine fatalities. These women expressed that automation would be beneficial as it would provide a safe working environment to the mineworkers. It was found that these communities lived in poor economic conditions and had very little infrastructure development. While examining the facts related to mining accidents and women employees in South African mining, it was found that most of the women employees received their jobs as their husbands had lost their lives in mining accidents.

The mining companies provided job opportunities because of the women by considering their poor economic conditions which were highly appreciated by the communities. It was ascertained that to increase the engagement level of women in the mining industry in South Africa, suitable policies, procedures, and active engagement programs have been created. The policies will also help in enhancing industrial outlook and achieving country vision 2030.

While comparing the above with the literature review, it was found that the adoption of new technology by the mining companies in South Africa is a complicated process as it involves upgrading, modifying, or changing the entire or partial older operating systems. It was also ascertained that installing new technology in the mining operations will increase the cost of the firm. It includes that the mining firm may have to face issues related to a lack of efficient labor support and security risks. The study examined that the use of automation and the internet of things may also create cybersecurity threats and risks in the mining industry (Matysek, and Fisher 2016). Therefore, it is can be said that the decision to adopt the technology within the mining process is very crucial and all the aspects of technology must be analyzed considered carefully before engaging g in the mining digital process.

The facts were related to the younger generation and their perceptions have been included in the study. It was found that most of the young individuals had left the mining communities looking for better work opportunities in Johannesburg city center. The major reason behind leaving the mining communities is that they feel that the mining management is not interested to employ young people from the mining communities.

However, some of the young individuals felt that the introduction of the 4th industrial revolution in the mining sector will help them to get highly skilled jobs and decent wages.

The communities and their perceptions have been included in the study and found that when mines closed down, the communities are left in desperate conditions with contaminated waters and bad infrastructure.
As a result, the socio-economic conditions of the communities were poor and deteriorating each day. Therefore, the communities were willing to work with the mine management to build cohesive and collaborative partnerships so that there will be the development of mutually beneficial outcomes for both parties.

While comparing the above with the literature review, it was found that the mining process degrades soil, air, and water. It was found that the ecological responsiveness is commonly low among the mineworkers. As a result, the mining operations that are carried out by the mining workers do not include environment-friendly methods of production and extraction. The study ascertained that the absence of stringent environment safety-related regulations also dithers the miners from using environment-friendly mining techniques. Therefore, the governing body and mining industry in South Africa must introduce measures that can help reduce the environmental problems related to mining (Agyapong 1998).

5.3. Conclusion

All the natural minerals present beneath the surface of the earth are extracted by the digging process is called Mining. It is the second oldest and fifth largest industry in the world. Mining plays a major role towards the contribution of the world economy.

The Mining industry is classified into two types of process such as surface mining and underground mining (Down & Stocks, 1977). South Africa has recorded R20.3 trillion worth of mineral reserve from the mining industry. This sector contributes the fifth largest part of Gross Domestic Product (GDP) value of the South Africa's economic sector. According to the survey conducted by the US Geology, it was observed that reserves of South Africa are formed by the rich minerals like diamond, manganese, vanadium, platinum, chromite ore and gold.

The Chamber of Mines now called the Minerals Council of South Africa also conducted a survey to focus the importance of the mining industry in South Africa found that, this industry employs more than one million individuals (directly and indirectly). The survey also revealed the contribution of 18% towards the GDP through direct and indirect (8.6% and 10%) inputs of the mining industry. It also acts as an important source to earn foreign investments of more than 50% and foreign savings with R1.9 trillion in the year 2011, which resulted in forming the integral part of economic success in South Africa by mining sector.

The South African mining sector not only contributed in the economic development but also in the industrial development. BHP Billiton Energy Coal South Africa Proprietary Limited, Rio Tinto, Sibanye-Stillwater, Harmony Gold Mine, Kumba Iron Ore Ltd are the major key players of the mining market. Mponeng Gold mine, Savuka Gold Mine and Asanko Gold are the main gold mining companies. These various mining industries like the gold industry employed 95130 workers, the platinum industry employed 164513 workers, and the coal industry included 92230 laborers. Other industries such as manganese, chrome, diamond, and iron ore occupied 10846, 19693, 15728 and 190092 workers respectively in the year 2019.
However, contribution of the mining sector has decreased over the years due to poor working conditions in the mining sector such as high geothermal temperature issues, poor safety, and silica dust. For instance, more than128575 mineworkers suffered from occupation diseases, 69000 workers died because of occupation injuries and more than 1 million workers suffered from occupational injuries due to the harmful impact of the deep level gold mining on the health of the workers (Steen, Gyi, White, Gabosianelwe, Ludick, Mazonde, Mabongo, Ncube, Monare, Ehrlich and Schierhout, 1997). This forced South African government to lay technological reforms to improve the working condition of the workers.

Global technological changes and new digital transformation helped the South African mining industry to grow and expand its functionaries in an exponential manner. This included the use of digital advanced applications like analytics, agile planning, collaborative value chain and intelligent sensors to enhance productivity (Sganzerla, Seixas and Conti, 2016).

With the tools such as Internet of Things (IoT) an adequate flow of information and mobilize the distribution and consumption process was made possible. The use of analytics helped in analyzing real time complex market conditions and provided relevant information of execution and processing. This enabled efficient mining process which resulted in the optimal economic growth.

For instance, reforms implemented, improved the health and environmental condition in Ghana mining industry, this attracted many companies such as Ashanti Goldfields, Anglo Gold (merged company) and Newmont (USA) to the region which resulted Ghana to become the center of the mining industry. The governing bodies of Ghana, to adopt global standards and ensure transparency in the administration of minerals, oil, and gas, they signed a memorandum with the Extractive Industries Transparency Initiative (EITI) (Akabzaa, & Darimani 2001). Thus, with the digitalization South African mining industry benefited by the sustainable economic development and employment opportunities.

In-spite of economic growth observed in South Africa through mining industry many other negative factors were hampering the growth and expansion of this industry. According to the economist, they suggested that the dependency of the country on its natural resource made their international commercial activities limiting, it restricted international commercial activities due to its closed economic condition.

This also hampered the balanced growth in the country due to its high dependency on mining sector which impedes on sustainable development, and destructs the environment (Richards, 2002).

According to the Warhust, 1999 suggested that the poor management and working of the mining industry will adversely impact the cost of production which will directly impact ecological, financial and social conditions of the country.

The mining process accelerated oxidation, precipitation of harmful gases, high temperature, pollutants (chemicals, fumes and dust) which impacted health issues in workers and individuals (Chiaro & Joklik, 1998). The use of explosives and chemicals for the mineral extraction impacted dangerously on the health and safety of the mineworkers and the environment. As a result, the imposition of additional taxes on the mining companies was levied due to the excessive environmental issues.

For instance, In Thamanga (Botswana), Eastern Cape (South Africa), Cape Town (South Africa) there were 304, 238, and 2530 miners respectively suffered from lung diseases, autopsy and silicosis in gold mines (Murray, Davies and Rees, 2011). The working condition of miners working in these mines was degrading severely causing several ailments like respiratory and lung disease due to the high temperature and lack of proper ventilation requirements in South Africa.

While focusing on the living facilities and other amenities such as healthcare, transport, recreation and education of the mineworkers, it was observed that they were provided with the public and private transportation facilities for easy access to the mine workstation but the condition of vehicle and roads were so pathetic which caused fatalities and accidents during commutation. Healthcare issues were also overlooked by the healthcare units. According to the Department of Mineral Resources, who conducted a survey stating that more than 11000 deaths were recorded during 1984 to 2005 which was due to mine accidents and can be considered as a disastrous condition in South Africa. In the year 2006 the overall fatality rate was evaluated 0.43 against every thousand individuals. In gold mines the fatality rate was 0.71, in platinum mines it was 0.24 and 0.35 in other mines was recorded in South Africa (Jacobs & Pienaar, 2017).

The South African Medical Research Council conducted a survey and, found that due to the prevalence of silicosis in gold mines it caused' tuberculosis (TB) and HIV to the mine workers. As a result, 806 TB patients were recorded for every 1000 individuals which increased to 3821 against every 1 000 people in 2004. Due to these critical health conditions the mortality rate as compared to other industries was observed as too high in South Africa. The degrading and pathetic condition of the mining industry gave birth to several rebellious and strikes. This resulted in the formation of the National Union of Mineworkers. This group included 240000 mine workers from 60 different mines (gold, platinum and coal) that impacted the production cycles. These strikes resulted in huge distress, strike and violation which forced the management to consider some up-gradation in the working conditions.

Considering the current situation due to the spread of COVID-19 pandemic, various mining companies are compelled to follow health and safety measures which are prescribed by the guidelines of the Department of Mineral Resources and Energy (DMRE) to the mining companies. Despite the guidelines and precautions 384 workers were found positive at Impala Platinum's Marula Mine (Limpopo).

However, this increased the threat of spreading the virus to more than 40000 workers working in Anglogold's Mponeng mine (Merafong) and Moab Khutsong mine (Matlosana). The poor living condition and facilities further aggravated the conditions due to the dumping waste in the surrounding areas, and created the reason causing respiratory issues such as chronic cough, chronic bronchitis, asthma, emphysema, and pneumonia to the inhabitants living in such surroundings.

Thus it is observed that the laborers, workers and other working professional who are associated with the mining sector faces enormous difficulties and decrease in their health and living standards due to pollutants, high temperature, exhalation of silica dust, all these elements impact negatively on these miners and people living in such surroundings.

The expansion and up-gradation of mining industry laid a negative impact on environmental situation. This condition also increased deforestation due to the expansion of mining. Farmers and farmworkers were forced to relocate; hence the farmers expanded their farmlands in the forest. This further impacted on the environmental condition to reduce the landscapes due to which the wildlife survival also came into danger (Edwards, Sloan, Weng, Dirks, Sayer, and Laurance 2014).

These ecological threats that arouse in the mining sector increased migration, meat hunting, corruption, resettlement issues and poor governance practices.

Another major issue that is very alarming to the environmental concerns in South Africa and was related to acid mine drainage.

There was a rise in the acidity levels, radioactive metals and toxic heavy metals that degraded the quality of water due to acid mine drainage because of improper mining in coal and gold mines. This happened because the mining companies were allowed to release the mining waste in the open streams, dams, and groundwater. This resulted in the rise of pH level of water to 1500mg/L which reduced the water quality of Vaal River.

It also impacted negatively on the marine life ecosystem. Additionally, the improper mining processes leads to release of fly ash, smoke, greenhouse gases and burnouts. Underground mining also lowered the water tables; it created shortage of water supply and on a larger perspective, negatively impacted the survival of humans, animals and plants.

Coal fire was another factor that hampered the environmental and human conditions in South Africa. The natural surroundings and air got polluted by the burning of the coal in the mines producing huge quantities of smoke which consist of harmful and greenhouse gases like carbon-monoxide (CO), carbon-dioxide (CO2), nitrous oxides (NOx), methane (CH4), sulfur dioxide (SO2), dust and fly ash.

These gases negatively impacted the quality of the air and increased the temperature and polluted water and soil. It was evident that the mining industry is heavily impacting the human lives, the environment and the natural surroundings. There were reformatory changes needed to bring significant changes in the supply and production techniques.

The digitalization transformed various modern arrangements in the form of cloud computing, analytics, agile planning, internet of things (IoT) and sensors which revolutionize mining process. These digitalized techniques facilitate the flow of information and knowledge adequately reduced the risk of accidents and mishaps at the workplace. It also enhanced security and safely measures by identifying faults and leakage and acid drainage. This resulted in 10% of reduction in the mining fatalities in the year 2018 in comparison with 2017. Similar improvements were recorded in the accidents with 12% of reduction from 2669 in 2017 to 2350 in 2018, in other mines like platinum, gold and coal.

The impact on environmental problems due to the mining process was now controlled with Operations Technology (OT) in South Africa. The advance technological usage ensured and avoided the occurrence of any accidents, spillovers, or leakages. This also helped in speeding up the work in short span of time. Overall, it reduced the wastage and facilitated the preservation of the environment by optimum utilization of resources (Jackisch, Lorenz, Zimmermann, Möckel & Gloaguen, 2018).

The digitalization also ensured job opportunities which lead to sustainable growth. Thus, the digital penetration in the mining industry helped in improvising quality of work and contributed in the reduction of environmental disaster by enhancing the overall health, living conditions and safety among the mine workers and the surrounding people in South Africa.

Therefore it can be concluded, that with the introduction of digital mining in the mining sector, it must be coupled with the creation of new job opportunities, environmentally friendly mining operations, preservation of human life and the sustainability of the mining sector to create a Sustainable Economic Development and Employment Generation framework for mining in South Africa to remain competitive.

6. REFERENCES:

Amponsah-Tawiah, K., & Dartey-Baah, K. (2011). The mining industry in Ghana: a blessing or a curse. *International Journal of Business and Social Science*, *2*(12).

Campbell, B. (2012). Corporate Social Responsibility and development in Africa: Redefining the roles and responsibilities of public and private actors in the mining sector. *Resources Policy*, *37*(2), 138-143.

Edwards, D. P., Sloan, S., Weng, L., Dirks, P., Sayer, J., & Laurance, W. F. (2014). Mining and the African environment. *Conservation Letters*, *7*(3), 302-311.

Halvani, G. H., Zare, M., & Mirmohammadi, S. J. (2009). The relation between shift work, sleepiness, fatigue and accidents in Iranian Industrial Mining Group workers. *Industrial Health*, *47*(2), 134-138.

Jenkins, H., & Yakovleva, N. (2006). Corporate social responsibility in the mining industry: Exploring trends in social and environmental disclosure. *Journal of cleaner production*, *14*(3-4), 271-284.

Kamunda, C., Mathuthu, M., & Madhuku, M. (2016). Health risk assessment of heavy metals in soils from Witwatersrand gold mining basin, South Africa. *International journal of environmental research and public health*, *13*(7), 663.

Limpitlaw, D., Aken, M., Lodewijks, H., & Viljoen, J. (2005, July). Post-mining rehabilitation, land use and pollution at collieries in South Africa. In *Colloquium: Sustainable Development in the Life of Coal Mining, South African Institute of Mining and Metallurgy, Boksburg* (Vol. 13).

Marshall, J. A., Bonchis, A., Nebot, E., & Scheding, S. (2016). Robotics in mining. In *Springer handbook of robotics* (pp. 1549-1576). Springer, Cham.

Mineral Council South Africa, 2019. Facts and Figures, 2018.

Mineral Council South Africa, 2019. Modernization: Towards the Mine of Tomorrow.

Mutemeri, N., & Petersen, F. W. (2002, November). Small–scale mining in South Africa: Past, present and future. In *Natural resources forum* (Vol. 26, No. 4, pp. 286-292). Oxford, UK and Boston, USA: Blackwell Publishing Ltd.

Mutti, D., Yakovleva, N., Vazquez-Brust, D., & Di Marco, M. H. (2012). Corporate social responsibility in the mining industry: Perspectives from stakeholder groups in Argentina. *Resources Policy*, *37*(2), 212-222.

Ochieng, G. M., Seanego, E. S., & Nkwonta, O. I. (2010). Impacts of mining on water resources in South Africa: A review. *Scientific Research and Essays*, *5*(22), 3351-3357.

Schueler, V., Kuemmerle, T., & Schröder, H. (2011). Impacts of surface gold mining on land use systems in Western Ghana. *Ambio*, *40*(5), 528-539.

Sganzerla, C., Seixas, C., & Conti, A. (2016). Disruptive innovation in digital mining. *Procedia Engineering*, *138*, 64-71.

Utembe, W., Faustman, E. M., Matatiele, P., & Gulumian, M. (2015). Hazards identified and the need for health risk assessment in the South African mining industry. *Human & experimental toxicology*, *34*(12), 1212-1221.

Zhengfu, B. I. A. N., Inyang, H. I., Daniels, J. L., Frank, O. T. T. O., & Struthers, S. (2010). Environmental issues from coal mining and their solutions. *Mining Science and Technology (China)*, *20*(2), 215-223.

Agyapong, E. (1998). Streamlining artisanal gold mining activities and the promotion of cleaner production in the mining sector in sub-Saharan Africa: Ghana as a case study. Unpublished master's thesis, International Institute for Industrial Environmental Economics, Lund University, Sweden.

Akabzaa, T., & Darimani, A. (2001). „Impact of Mining Sector Investment in Ghana: A Study of the Tarkwa Mining Region", Draft Report Prepared for SAPRI

Amedofu, G.K., Brobby, G.W., and Ocansey, G.A.: 1996, Occupational hearing loss among workers at a large gold mining company in Ghana (West Africa), Australian Journal of Audiology 18, 47–48.

Bertherat, E., Renault, A., Nabias, R., Dubreuil, G. and Georges-Courbet, M.C.: 1999, Leptospirosis and ebolavirus infection in five gold-panning villages in northeastern Gabon, American Journal of Tropical Medicine and Hygiene 60, 610–615.

Boffetta, P., Kogevinas, M., Pearce, N. and Matos, E.: 1994, Cancer, in Occupational Cancer in Developing Countries, International Agency for Research on Cancer, IARC Scientific Publication 129, Oxford University Press, New York, pp. 111–126

Bugnosen, E., Twigg, J., & Scott, A. (1999). Small-scale mining legislation and regulatory frameworks. Minerals and Energy: Raw Materials Report, 14(2), 35-38

Butchart, A.: 1996, The industrial panopticon: mining and the medical construction of migrant African labor in South Africa, 1900–1950, Social Science and Medicine 42, 185–197

Chiaro, P.S., & Joklik, G.F. (1998). The extractive industries. In D.J. Richards & G. Pearson (Eds.). The Ecology of Industry: Sectors and Linkages, Washington, D.C. National Academy of Engineering, 13–26

de Andrade, A.L.S.S., Martelli, C.M.T., Oliveira, R.M., Arias, J.R., Zicker, F. and Pang, L.: 1995, High prevalence of asymptomatic malaria in gold mining areas in Brazil, Clinical Infectious Diseases 20, 475

de Nava, C. C. (1996). Cleaner production perspectives in Latin America and the Caribbean. Industry & Environment, 19(3), 57-62

Down, C.G., & Stocks, J. (1977). Environmental Impact of Mining. London: Applied Science Publishers.

Edwards, D. P., Sloan, S., Weng, L., Dirks, P., Sayer, J., & Laurance, W. F. (2014). Mining and the African environment. Conservation Letters, 7(3), 302-311.

Geldenhuys, G. L. (2015). Characterization of diesel emissions concerning semi-volatile organic compounds in South African platinum mines and other confined environments (Doctoral dissertation, University of Pretoria).

Green, J., & Plumb, S. (2011). Mobile Robotics Competition: A Challenging Application in Mobile Robotics. AFRICON'11 - Special Sessino on robotics and Artificial Intelligence in Africa. Livingstone: IEE Xplore

HAMANN, R, BOOTH, L& O'RIORDAN, T, 2000. South Africa's environmental policy on the move. South African Geographical Journal, 82(2): 11–22.

Harada, M.: 1997, Neurotoxicity of Methyl-mercury: Minamata and the Amazon, in: M. Yasui, M.J. Strong, K. Ota and M.A. Verity (eds), Mineral and Metal Neurotoxicology, CRC Press, Tokyo, pp. 177–188.

Harling G, Ehrlich R, Myer L. The social epidemiology of tuberculosis in South Africa: a multilevel analysis. Social Science & Medicine. 2008;66(2):492–505.

Harper, G. (2008). Nederburg Miner. Narrow Vein and Reef. SAIMM

Hilson, G. (2000). Barriers to implementing cleaner technologies and cleaner production (CP) practices in the mining industry: A case study of the Americas. Minerals Engineering, 13(7), 699-717.

Hollaway, J. (1993). Review of technology for the successful development of small-scale mining. Chamber of Mines Journal, 35(3), 19-25

Hollaway, J. (1997, December). Small-scale mining: How to combine development with low environmental impact. Industry and Environment, pp. 44-48

Hosford, P.A.J. (1993). Innovations in mineral processing technology for small scale mining. Chamber of Mines Journal, 35(3), 26-29, 35, 41.

Iddirisu, A. Y., & Tsikata, F. S. (1998). Mining sector development and environment project (Regulatory framework study to assist small scale miners). Unpublished report prepared for the Minerals Commission, Accra, Ghana

Jackisch, R., Lorenz, S., Zimmermann, R., Möckel, R., & Gloaguen, R. (2018). Drone-borne hyperspectral monitoring of acid mine drainage: an example from the Sokolov Lignite District. Remote Sensing, 10(3), 385.

Jacobs, M., & Pienaar, J. (2017). Stress, coping and safety compliance in a multinational gold mining company. International journal of occupational safety and ergonomics, 23(2), 152-161.

Leander (24 October 2014). "2014 South African platinum strike: longest wage strike in South Africa". SAHistory.org.za. Retrieved 4 January 2018.

Lurie, M.N., Williams, B.G., Zuma, K., Mkaya-Mwamburi, D., Garnett, G.P., Sturm, A.W., Sweat, M.D., Gittelsohn, J. and Karim, S.S.A., 2003. The impact of migration on HIV-1 transmission in South Africa: a study of migrant and nonmigrant men and their partners. *Sexually transmitted diseases*, *30*(2), pp.149-156.

Lynas, D, and Horberry, T 2011a, Literature review: emerging human factors trends regarding automated mining equipment, prepared for CSIRO Minerals Down Under Flagship, Minerals Futures Cluster Collaboration, by the Minerals Industry Safety and Health Centre, Sustainable Minerals Institute, The University of Queensland, Brisbane

Madhavan, R 2001, Terrain aided localization of autonomous vehicles in unstructured environments, Ph.D. thesis, School of Aeronautical, Mechanical and Mechatronic Engineering, The University of Sydney

Maponga, O. (1997). Small scale mining and the environment in Zimbabwe: The case of alluvial gold panning and chromite mining. In A. K. Ghose (Ed.), Small/medium scale mining (pp. 186-211). Calcutta, India: Oxford & IBH Publishing Co. PVT Ltd.)

Maponga, O., & Anderson, M. (1995). Management of natural resources and the environment in Zimbabwe: The case of gold. Unpublished report of the United Nations Conference on Trade and Development, prepared at the Institution of Mining Research, University of Zimbabwe

Marshall, J. A., Bonchis, A., Nebot, E., & Scheding, S. (2016). Robotics in mining. In Springer handbook of robotics (pp. 1549-1576). Springer, Cham

Matysek, A L and Fisher, BS, 2016. Productivity and innovation in the mining industry, BAE research report 2016.1 (BAEconomics: Kingston

Mhlongo, S. E., & Amponsah-Dacosta, F. (2016). A review of problems and solutions of abandoned mines in South Africa. International Journal of Mining, Reclamation, and Environment, 30(4), 279-294.

Mossman, B.T.: 1993, Cellular and Molecular Mechanisms of Disease, in: D. George, Jr. Guthrie and B.T. Mossman (eds), Review in Mineralogy, Vol. 28, Mineralogical Society of America, pp. 513–553.

Munnik, V., Hochmann, G., Hlabane, M., & Law, S. (2010). The social and environmental consequences of coal mining in South Africa. Environmental Monitoring Group, 24.

Murphy, M 2011 in 'Haulage goes autonomous', Net Resources International, 28 July, viewed 13 October 2011, http://www.mining-technology.com/features/feature125450/.

Murray, J., Davies, T. and Rees, D., 2011. Occupational lung disease in the South African mining industry: research and policy implementation. *Journal of Public Health Policy*, *32*(1), pp. S65-S79.

Nebot, E M, 2007. Surface mining: main research issues for autonomous operations, Robotics Research, Results in 12th International Symposium ISRR (eds: S Thrun, R Brooks, and H Durrant-Whyte), 28:268–280.

Nöetstaller, R. (1994). Small-scale mining: Practices, policies, and perspectives. In A. K. Ghose (Ed.), Small-scale mining: A global overview. Rotterdam, the Netherlands: A. A. Balkema

PINNEY, C, 2001. More than charity: towards a new agenda for Canadian corporate citizenship. Paper presented at the 4th Annual Warwick Corporate Citizenship Unit Conference, 9–10 July

Richards, J.P. (2002). Sustainable development and the minerals industry, SEG Newsletter, 48, April 2002, Soc. Econ. Geology, Littleton Colorado

Sachs, J.D., & Warner, A.M. (1999). The big push, natural resource booms, and growth. Journal of Development Economics, 59, 43-76

Sganzerla, C., Seixas, C. and Conti, A., 2016. Disruptive innovation in digital mining. *Procedia Engineering*, *138*, pp.64-71.https://www.researchgate.net/publication/299371185_Disruptive_Innovation_in_Digital_Mining/link/570ac7d508ae2eb9421fe246/download

Shoko, M., Maviya, J., & Bachs, A. (1993). Mines and environment in Zimbabwe. Gweru, Zimbabwe: Department of Natural Resources.

Steen, T.W., Gyi, K.M., White, N.W., Gabosianelwe, T., Ludick, S., Mazonde, G.N., Mabongo, N., Ncube, M., Monare, N., Ehrlich, R. and Schierhout, G., 1997. Prevalence of occupational lung disease among Botswana men formerly employed in the South African mining industry. *Occupational and environmental medicine*, *54*(1), pp.19-26.

Stuckler, D., Steele, S., Lurie, M. and Basu, S., 2013. Introduction: 'Dying for gold': The effects of mineral miningon HIV, tuberculosis, silicosis, and occupational

diseases in southern Africa. *International Journal of Health Services*, *43*(4), pp.639-649.

Tráore, P. A. (1994). Constraints on small-scale mining in Africa. Natural Resources Forum, 18(3), 207-212.

Uitto, J.I.: 1992, Preface: Community Responses to Industrial Hazards, Report of the Conference held in Minamata, Japan, IV–V

van der Merwe, J. (2011). Presidential Address: Future of the South African mining industry and the roles of the SAIMM and the Universities. Journal of the Southern African Institute of Mining and Metallurgy, 582-592

Walsh, K. L. (1999). Earth science education in Zimbabwe. Journal of African Earth Sciences, 28(4), 861-866.

Warhurst, A. (1999), "Environmental Regulation, Innovation, and Sustainable Development," In A. Warhurst (ed.) Mining and the Environment: Case Studies from the Americas Ottawa, Canada

Shank, G.D., 2002. Analysing. *Qualitative research: A personal skills approach*, pp.126-145.

Bernard, H. R., 2011. Research methods in anthropology: Qualitative and quantitative approaches. s.l.:Rowman Altamira.

Bryman, A., 2016. *Social research methods*. Oxford university press.

Cohen, L., Manion, L. and Morrison, K., 2013. *Research methods in education*. Routledge.

Creswell, J.W. and Creswell, J.D., 2017. *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Creswell, J.W. and Poth, C.N., 2016. *Qualitative inquiry and research design: Choosing among five approaches*. Sage publications.

Denzin, N.K. and Lincoln, Y.S. eds., 2011. *The Sage handbook of qualitative research*. Sage.

De Vaus, D., 2001. *Research design in social research*. Sage.

Salkind, N.J. ed., 2010. *Encyclopedia of research design* (Vol. 1). Sage.

Yeboah-Fofie, M., 2017. Technology Integration and Transformation of Election in Africa: An Evolving Modality in Ghana. *Technology Integration and Transformation of Elections in Africa: An Evolving Modality*, p.13.

McNabb, C., 2012. Descriptive research methodologies. *Retrieved from*.

Creswell, J.W. and Clark, V.L.P., 2017. *Designing and conducting mixed methods research*. Sage publications.

Ariga, K., Hill, J.P. and Ji, Q., 2007. Layer-by-layer assembly as a versatile bottom-up nanofabrication technique for exploratory research and realistic application. *Physical Chemistry Chemical Physics*, *9*(19), pp.2319-2340.

Flick, U., 2015. *Introducing research methodology: A beginner's guide to doing a research project*. Sage.

Morgan, D.L., 2007. Paradigms lost and pragmatism regained: Methodological implications of combining qualitative and quantitative methods. *Journal of mixed methods research*, *1*(1), pp.48-76.

Chilisa, B. and Kawulich, B., 2012. Selecting a research approach: Paradigm, methodology and methods. *Doing social research: A global context*, *5*(1), pp.51-61.

Clarke, C., 2009. Paths between positivism and interpretivism: An appraisal of Hay's via media. *Politics*, *29*(1), pp.28-36.

Yanow, D. and Schwartz-Shea, P., 2015. *Interpretation and method: Empirical research methods and the interpretive turn*. Routledge.

Dammak, A., 2015. Research paradigms: Methodologies and compatible methods. *Veritas*, *6*(2), pp.1-5.

Denzin, N.K. and Lincoln, Y.S. eds., 2011. *The Sage handbook of qualitative research*. Sage.

Hennink, M., Hutter, I. and Bailey, A., 2010. Qualitative research methods. Sage.

Williams, C., 2007. Research methods. *Journal of Business & Economics Research (JBER)*, *5*(3).

Jackson, M.R., 2015. Resistance to qual/quant parity: Why the “paradigm” discussion cannot be avoided. *Qualitative Psychology*, *2*(2), p.181.

Richardson, L., 2003. Writing: A method of inquiry. *Turning points in qualitative research: Tying knots in a handkerchief*, *2*, p.379.

Lewis, S., 2015. Qualitative inquiry and research design: Choosing among five approaches. *Health promotion practice*, *16*(4), pp.473-475.

Lindlof, T.R. and Taylor, B.C., 2017. *Qualitative communication research methods*. Sage publications.

Mackey, A. and Gass, S.M., 2015. *Second language research: Methodology and design*. Routledge.

Maxwell, J.A., 2012. *Qualitative research design: An interactive approach* (Vol. 41). Sage publications.

Miller, T., Birch, M., Mauthner, M. and Jessop, J., 2012. Ethics in qualitative research. Sage.

Neuman, W. L. and Robson, K., 2012. Basics of social research: Qualitative and quantitative approaches. s.n.

Padgett, D.K., 2016. *Qualitative methods in social work research* (Vol. 36). Sage publications.

Mhlongo, S.E. and Amponsah-Dacosta, F., 2016. A review of problems and solutions of abandoned mines in South Africa. *International Journal of Mining, Reclamation and Environment*, *30*(4), pp.279-294.

Litosseliti, L., 2003. *Using focus groups in research*. A&C Black.

Yin, R., 2013. Case study research: Design and methods. Sage publications.

Zikmund, W.G., Carr, J.C. and Griffin, M., 2013. *Business Research Methods (Book Only)*. Cengage Learning.

Saunders, M., 2011. Research methods for business students. Pearson Education India.

Silverman, D., 2016. Qualitative research. Sage.

Panneerselvam, R., 2014. Research methodology. PHI Learning Pvt. Ltd.

Punch, K.F., 2013. *Introduction to social research: Quantitative and qualitative approaches*. Sage.

Ritchie, J., Lewis, J., Nicholls, C.M. and Ormston, R. eds., 2013. *Qualitative research practice: A guide for social science students and researchers*. Sage.

Denzin, N.K. and Lincoln, Y.S., 1995. Transforming qualitative research methods: Is it a revolution? *Journal of Contemporary Ethnography*, *24*(3), pp.349-358.

Tashakkori, A. and Teddlie, C. eds., 2010. *Sage handbook of mixed methods in social & behavioral research*. Sage.

Taylor, S.J., Bogdan, R. and DeVault, M., 2015. *Introduction to qualitative research methods: A guidebook and resource*. John Wiley & Sons.

Somekh, B. and Lewin, C. eds., 2005. *Research methods in the social sciences*. Sage.

Agyapong, E. (1998). Streamlining artisanal gold mining activities and the promotion of cleaner production in the mining sector in sub-Saharan Africa: Ghana as a case study.

Unpublished master's thesis, International Institute for Industrial Environmental Economics, Lund University, Sweden.

Amedofu, G.K., Brobby, G.W., and Ocansey, G.A.: 1996, Occupational hearing loss among workers at a large gold mining company in Ghana (West Africa), Australian Journal of Audiology 18, 47–48.

Boffetta, P., Kogevinas, M., Pearce, N. and Matos, E.: 1994, Cancer, in Occupational Cancer in Developing Countries, International Agency for Research on Cancer, IARC Scientific Publication 129, Oxford University Press, New York, pp. 111–126

Butchart, A.: 1996, The industrial panopticon: mining and the medical construction of migrant African labor in South Africa, 1900–1950, Social Science and Medicine 42, 185–197

Denzin, N.K. and Lincoln, Y.S., 1995. Transforming qualitative research methods: Is it a revolution? Journal of Contemporary Ethnography, 24(3), pp.349-358.

Down, C.G., & Stocks, J. (1977). Environmental Impact of Mining. London: Applied Science Publishers.

Green, J., & Plumb, S. (2011). Mobile Robotics Competition: a Challenging Application in mobile robotics. AFRICON&11 - Special Session on Robotics and Artificial Intelligence in Africa. Livingstone: IEE Xplore

Harada, M.: 1997, Neurotoxicity of Methylmercury: Minamata and the Amazon, in M. Yasui, M.J. Strong, K. Ota and M.A. Verity (eds), Mineral and Metal Neurotoxicology, CRC Press, Tokyo, pp. 177–188.

Harling G, Ehrlich R, Myer L. The social epidemiology of tuberculosis in South Africa: a multilevel analysis. Social Science & Medicine. 2008;66(2):492–505.

Madhavan, R 2001, Terrain aided localization of autonomous vehicles in unstructured environments, Ph.D. thesis, School of Aeronautical, Mechanical and Mechatronic Engineering, The University of Sydney

Matysek, A L and Fisher, BS, 2016. Productivity and innovation in the mining industry, BAE research report 2016.1 (BAEconomics: Kingston

Mhlongo, S.E. and Amponsah-Dacosta, F., 2016. A review of problems and solutions of abandoned mines in South Africa. International Journal of Mining, Reclamation, and Environment, 30(4), pp.279-294.

Mossman, B.T.: 1993, Cellular and Molecular Mechanisms of Disease, in D. George, Jr. Guthrie and B.T. Mossman (eds), Review in Mineralogy, Vol. 28, Mineralogical Society of America, pp513–553.

Murphy, M 2011 in 'Haulage goes autonomous', Net Resources International, 28 July, viewed 13 October 2011, http://www.mining-technology.com/features/feature125450/.

Uitto, J.I.: 1992, Preface: Community Responses to Industrial Hazards, Report of the Conference held in Minamata, Japan, IV–V

van der Merwe, J. (2011). Presidential Address: Future of the South African mining industry and the roles of the SAIMM and the Universities. Journal of the Southern African Institute of Mining and Metallurgy, 582-592